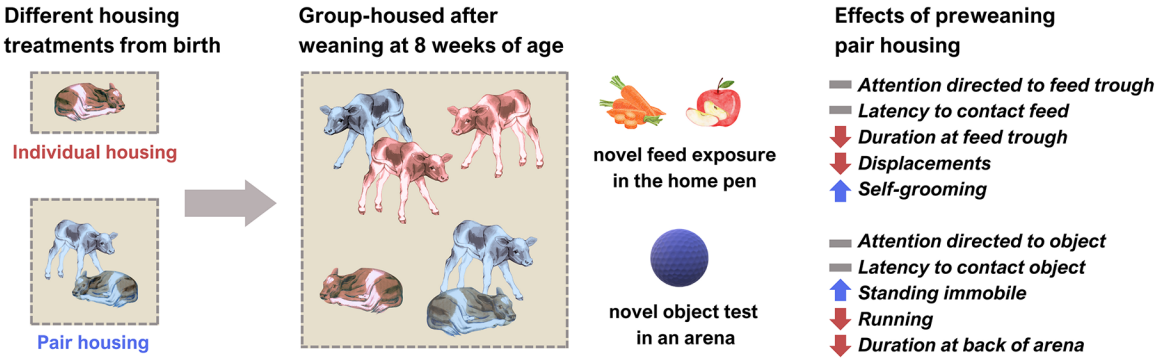
JDS Communications®
2024; 5:384–389

https://doi.org/10.3168/jdsc.2023-0446
Short Communication
Health, Welfare, and Behavior

Effects of social housing on dairy calf response to novelty shortly after weaning and grouping

E. E. Lindner, K. N. Gingerich, S. Utzig, and E. K. Miller-Cushon*

Graphical Abstract

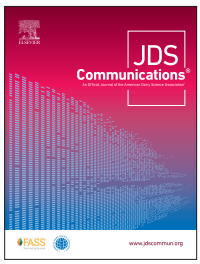


Summary

We examined the effects of preweaning social housing, with calves housed either individually or in pairs, on responses to novel feed and objects 3 days following postweaning grouping. Previous housing treatment did not affect latency to contact novel feed in a home pen test, but previously individually housed calves spent more time feeding and were displaced from the feed trough more. Previously individually housed calves were more active in a novel object test conducted individually in an arena, but latency to contact the object was not affected by previous housing.

Highlights

- We assessed how preweaning social contact affects how weaned calves react to novelty.
- Preweaning housing did not affect latency to consume novel feed in postweaning groups.
- Preweaning housing did not affect novel object contact during individual tests.
- Previous housing type influenced aspects of social feeding and activity.



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The list of standard abbreviations for JDSC is available at adsa.org/jdsc-abbreviations-24. Nonstandard abbreviations are available in the Notes.

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Effects of social housing on dairy calf response to novelty shortly after weaning and grouping

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Abstract: Dairy calf social development and responses to novelty are influenced by social contact, but longer-term implications of early life social housing for response to novelty in weaned calves are less clear. The objective of this study was to evaluate the effects of preweaning social housing on how dairy calves respond to novel feed and objects a few days following weaning and grouping. At birth, calves were alternately assigned to either individual (IH; n = 22 calves) or pair housing (PH; n = 18 pairs; 1 focal calf enrolled/pair). Following weaning (at 53.4 ± 2.0 d; mean ± standard deviation), calves were mingled between treatments and group-housed with calves born the same week (4 to 6 calves/pen; 12 total groups). Beginning at 56.4 ± 2 d of age, calves were exposed to 2 novel feed tests (sliced carrots and chopped red apples) conducted in the home pen on consecutive days. Following novel feed tests, a subset of calves (n = 11 IH and n = 9 PH calves, from separate paired pens) was exposed to a novel object test, conducted individually in a testing arena. During novel feed tests, the latency to contact the novel feed did not differ between treatments but previously IH calves spent more time at the feed trough (6.9 vs. 4.3 min/h, IH vs. PH, standard error = 0.25). In the novel object test, latency to contact the novel object and duration of contact did not differ between previous housing treatments but previously IH calves moved around the arena more. These results suggest that preweaning social housing had some carryover effects on behavioral responses during novel feed and novel object tests a few days following weaning and grouping, potentially reflecting differences in social feeding behavior and activity in a novel space, but avoidance of the novel object and feed were not affected.

As dairy cattle develop, they are exposed to novel stimuli including changing diets, housing, and social groups. The ability to cope with these transitions varies between individuals and may predict welfare (reviewed by Koolhaas and Van Reenen, 2016). In dairy calves, individual variability in response to novelty, as assessed in standardized behavioral tests, is associated with key performance outcomes, including feed intake and weight gain (Neave et al., 2018; Michalski et al., 2023).

Evidence across species suggests that fearfulness and response to novelty is shaped by early experiences, including social contact (rats: Lukkes et al., 2009; primates: Voelkl et al., 2006). This is also supported in dairy calves, where social housing during the preweaning period shapes response to novel situations, including reducing avoidance of novel feeds (Whalin et al., 2018) and novel objects and environments (De Paula Vieira et al., 2012; Meagher et al., 2015), although response to novelty may depend on degree of social contact (Jensen et al., 1999). Differences in response to novelty beyond the period of differential housing during the preweaning period have been less studied. More generally, previous social housing affects response to postweaning grouping, reducing latency to feed (De Paula Vieira et al., 2010) and increasing exploration and rest (Lyu et al., 2023), suggesting that early social housing may have longer-term effects on response to novel environments.

Given gaps in our knowledge surrounding the carryover effects of early life social contact on behavioral responses following postweaning grouping, the objective of this study was to evaluate the effect of dairy calf social housing on activity upon postweaning grouping and response to novel stimuli, utilizing novelty tests within and outside the home pen. We hypothesized that providing dairy calves with social contact during the preweaning period would decrease avoidance of novel stimuli and increase rest following postweaning grouping.

Holstein heifers (n = 40 focal calves; 58 total calves) were enrolled at the University of Florida Dairy Unit (Hague, FL) during the months of September 2020 through April 2021. Calves were managed under standard operating procedures for the facility, and all procedures were reviewed and approved by the University of Florida Institutional Animal Care and Use Committee (protocol #201910617). At birth, calves were alternately assigned to either individual housing (**IH**; n = 22 calves) or pair housing (**PH**; n = 18 pairs; 1 randomly selected focal calf/pair) for the first 8 wk of life. Pens were constructed of wire mesh with pens for PH calves twice the size of IH calf pens (1.8 × 1.8 m vs. 0.9 × 1.8 m). Pens were bedded with sand that was replaced when soiled, or otherwise on a weekly basis. Following colostrum feeding (approximately 4 L within 6 h of birth, and an additional 4 L within 24 h), calves were provided milk replacer (28% CP and 20% fat; Suwannee Valley Feeds) in 2 feedings via teat bucket (Peach Teat Limited, New Zealand) at 0630 and 1500 h. Calves were initially offered 6 L/d until they were consuming the entire allotment of milk (typically around 3–5 d of age), at which point they were offered 8 L/d. Calves also had ad libitum access to water and calf starter (22% CP and 2% fat; Ampli-Calf Starter Warm Weather, Purina Animal Nutrition LLC) from birth, offered via buckets hanging in the pen (ratio of 1/calf). All pens were located in an open-sided barn providing protection from weather.

At the beginning of wk 7 of life (42.4 ± 2.0 d of age; mean ± SD), calves were weaned over a 10-d step-down plan (see Lindner

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Table 1. Ethogram describing behaviors characterized during the novel feed exposure in the home pen, individual novel object test, or both

Behavior	Test	Description
Latency to contact	Both	Duration to contact the feed trough during the novel feed test or the object during the novel object test.
Feeding behavior	Feed	Head in the feed trough and lowered.
Displacement	Feed	Pushing or head butting another calf from feed (noted as initiated or received).
Attention-directed	Both	Facing in the direction of the feed trough during the novel feed test or object during the novel object test.
Licking or sniffing object	Object	Muzzle is within 5 cm of the stimulus.
Licking or sniffing ground or wall	Object	Muzzle is within 5 cm of the ground or wall.
Standing immobile	Both	Feet on the ground and remains stationary.
Walking	Both	Moving slowly around the arena with 2 hooves touching the ground at all times.
Running	Both	Moving at a faster pace with all hooves lifting off the ground.
Lying	Feed	Whole body on the ground. Noted as social lying (<1 body length of another calf) or alone.
Self-grooming	Both	Muzzle contacts any part of the calf's own body.
Social grooming	Feed	Muzzle in contact with another calf with mouth movement evident; excluding cross-sucking.
Location	Object	Recorded location in the front half of arena (entry end) or back half.

et al., 2022). At 53.4 ± 2.0 d (mean ± SD) of age (2 d after weaning was completed), calves were moved to group pens (7.4 × 16 m). Groups were formed of 4 to 6 calves born within the same week, from both previous housing treatments (including both focal calves from the pair pens and nonfocal pair-housed calves, at least 1 calf/previous housing treatment included). A total of 12 weaned groups were followed. Calves received starter and water ad libitum. Upon introduction to group housing, calves were placed with a HOBO data logger for 7 d (HOBO Pendant G Data Logger, Onset) on the outside of their rear legs to record lying time (Bonk et al., 2013) with data extracted into Microsoft Excel as lying duration and bout frequency (UBC AWP, 2013).

At the beginning of wk 8 of life (56.4 ± 2.0 d of age; mean ± SD), 3 d after introduction to group housing, calves were exposed to 2 different novel feeds, sliced carrots (average 5 × 2.5 cm) and chopped red apples (average 7.6 cm slice cut into 3 sections), on 2 consecutive days (test order was consistent for all calves). Response to novel feed was assessed in the home pen (10 groups tested) to examine individual differences in response to novelty presented within the social context, since we were interested in response to novel feed rather than a novel environment, and responses to individual tests may be confounded by effects of social isolation on fear (Forkman et al., 2007). At approximately 0600 h, after removal of any remaining starter, a preweighed quantity of the novel feed (0.68 kg or 1.5 lbs; weighed using a scale accurate to 0.01 kg) was spread along a shallow feed trough (1.8 m in length, 10 cm in depth) such that all calves (4 to 6/group) could feed simultaneously. The novel feed was left in the trough for 1 h (until approximately 0700 h), and in no pens had calves finished the allotted feed. Pens were video recorded (Axis M2026-LE Network Camera, Axis Communications, mounted 3 m from the ground). According to the ethogram in Table 1, behavior of all focal calves was recorded for 1 h using Behavioral Observation Research Interactive Software (**BORIS**; Friard and Gamba, 2016) with calves identified by their unique coat patterns. For a subset of calves (n = 30 calves; 13 PH and 17 IH, from 9 weaned groups; selected based on availability of video footage), duration of time spent consuming starter was recorded from video (defined as head lowered in feed trough) for 24 h before the onset of the novel feed tests, to assess whether starter feeding time was a predictor of response in the novel feed tests. We had no specific predictions about the relationship between time consuming starter and time consuming novel feed, but considered it valuable to assess: for example, a negative relationship may have suggested that novel feed intake was reduced due to present satiety, whereas a positive relationship may have indicated that novel feed intake was motivated by hunger.

Following 2 d of consecutive novel feed tests in the home pen, a subset of calves (n = 20 calves; 9 PH and 11 IH) were individually exposed to a novel object test in an arena, to evaluate individual response to a novel environment and social isolation. Calves were removed from their home pens and moved via a wire mesh pen (0.9 × 1.8 m; calves walked within the pen, which was lifted and carried by 2 study personnel walking slowly), to the entrance of the testing arena. The testing arena (13 × 7 m) was under cover and the walls of the arena were covered with an opaque tarp. A blue rubber kickball (20.3 cm) rested in the center of the arena. Calves were assisted into the arena and remained inside for 5 min. After the 5 min had elapsed, calves were removed from the arena, placed back into the wire mesh pens, and returned to their home pen. Calves had previously been placed in the same testing arena without the novel object during wk 4 of life for 10 min (see Lindner et al., 2022), such that the space itself was only partially novel. Tests were video recorded (GoPro Hero6, GoPro Inc.) and behaviors were recorded using BORIS according to the ethogram described in Table 1. A single observer recorded behavior for both behavioral tests. This observer was blind to previous housing treatment and intraobserver reliability was assessed (≥0.90 Cohen's kappa coefficient calculated in BORIS).

Activity logger data, describing daily lying time and lying bout frequency, were analyzed in a linear mixed model (Proc Mixed, SAS v. 9.4, SAS Institute Inc.), with day as a repeated measure. The model included the fixed effects of previous housing treatment, day, treatment by day interaction, calf as a subject for repeated measures, and group pen as a random effect. The autoregressive order 1 model was selected as the variance-covariance matrix structure for activity data on the basis of best fit according to Schwarz's Bayesian information criterion. Activity logger data were missing for one group (3 IH, 2 PH).

Data from the novel feed tests were analyzed in a linear mixed model (Proc Mixed), including the fixed effects of previous housing treatment, feed type, interaction between feed type and treatment, and the random effects of group and calf. For the subset of calves where starter feeding time during the 24 h preceding the novel feed tests was recorded from video, we tested whether baseline starter

Table 2. Effects of preweaning social housing (IH = previously individually housed, n = 22 calves; or PH = previously pair-housed, n = 18 calves, 1 focal calf/pair, during the first 7 wk of life) on behavior during a 1-h period of novel feed (NF; carrot and apple on subsequent days) exposure in the home pen, following postweaning grouping[1]

	Treatment (T)			*P*-value		
Behavior	IH	PH	SE	T	NF	NF × T
Latency to contact[2] (min)	1.9 (1.0, 4.0)	1.9 (0.95, 4.0)	—	0.99	0.11	0.97
Attention directed[3] (min)	6.3 (4.4, 8.6)	7.9 (5.7, 10.6)	—	0.24	0.38	0.50
Feeding time[3] (min)	6.9 (4.5, 8.6)	4.3 (2.5, 6.8)	—	0.05	0.73	0.39
Feeding frequency (no.)	21.0	15.5	0.36	0.10		0.42
Received displacements[3] (no.)	1.3 (0.50, 2.6)	0.69 (0.14, 1.6)	—	0.07	0.71	0.22
Initiated displacements[3] (no.)	0.98 (0.29, 2.1)	0.71 (0.14, 1.7)	—	0.56	0.27	0.87
Standing immobile (min)	42.4	39.9	2.5	0.44	0.61	0.55
Walking (min)	5.0	4.3	0.42	0.18	0.19	0.92
Running[3] (min)	0.04	0.03	—	0.44	0.49	0.92
Lying (min)	10.6	14.1	2.9	0.32	0.85	0.60
Self-grooming[3] (min)	0.40 (0.17, 0.72)	0.72 (0.39, 1.2)	—	0.08	0.08	0.72
Social grooming[3] (min)	0.88 (0.38, 1.6)	0.56 (0.16, 1.2)	—	0.41	0.41	0.48

[1]Denominator df = 3.

[2]Data were log-transformed to meet assumptions of normality. Back-transformed means and 95% CI are reported.

[3]Data were square-root transformed to meet assumptions of normality. Back-transformed means and 95% CI are reported.

feeding time was a significant predictor of time spent consuming the novel feed, in a similar model including starter feeding time as a covariate. Data for one group (6 calves) were missing for the carrot feed test. Novel object data were similarly analyzed in a model with the fixed effect of housing treatment and random effect of home pen group (Proc Mixed). Behaviors that occurred rarely were similarly analyzed in a generalized linear mixed model as binary outcomes (Proc Glimmix) with a negative binomial distribution and a log link function. Model residual plots were screened to assess for normality and homogeneity of variance. Some variables were transformed to meet model assumptions of normality (see footnotes for Tables 2 and 3).

For the week following postweaning grouping, there were no effects of previous housing treatment on duration of lying time (15.8 vs. 16.1 h/d, IH vs. PH, SE = 0.20, $F_{1,40} = 0.88$, $P = 0.35$) or frequency of lying bouts (19.1 vs. 18.4 bouts/d, IH vs. PH, SE = 1.4, $F_{1,40} = 0.19$, $P = 0.66$). Lying time increased over the week ($F_{5,160} = 5.72$, $P < 0.001$) and lying bouts decreased ($F_{5,160} = 2.48$, $P = 0.04$), with no interaction between previous housing treatment and day ($P > 0.83$).

During the periods of novel feed exposure in the home pen (Table 2), latency to contact and attention directed toward the feed trough did not differ between previous housing treatments. However, we found some evidence to suggest that previously IH calves spent more time at the trough ($P = 0.05$), had somewhat more frequent visits ($P = 0.10$), and received more displacements ($P = 0.07$), although they did not initiate more displacements. Duration of locomotor activities did not differ between treatments. Social lying during the test was only performed by 4 calves (1 IH, 3 PH) with an average duration of 15.2 min/h. There were no interactions between the feed type and previous housing treatment in behavioral outcomes. Starter feeding time during the day preceding novel feed testing was not a significant predictor of time spent consuming the novel feed ($F_{1,20} = 0.13$, $P = 0.72$). Starter feeding time did not differ between treatments (94.7 vs. 92.7 min/d; IH vs. PH; $F_{1,20} = 0.07$, $P = 0.79$).

During the novel object test (Table 3), there was no effect of previous housing treatment on latency to contact the novel object, duration of attention directed toward the novel object, or duration of contact with the novel object. Previously PH calves spent more time at the front of the testing arena, less time at the back, and moved between the front and back of the arena fewer times. We also found some evidence to suggest that previously IH calves spent more time running ($P = 0.09$) and less time standing immobile ($P = 0.07$).

The aim of this study was to assess the effects of preweaning social housing response to novelty following postweaning grouping. Contrary to our predictions, we found minimal effects of early social housing on interaction with novel feeds within the social context of the home pen or individual responses to a novel object in a testing arena. However, some behavioral differences during testing suggest differences in social feeding behavior during the novel feed test, and differences in reactivity when placed individually in a novel environment.

During the novel feed test, a limitation of the present study design was that individual intake of the novel feed could not be recorded, so it is not clear how rate of intake may have differed. The increase in time spent at the feed trough for the previously IH calves could be related to the degree of competition they experienced, as we found some evidence to suggest that IH calves received more displacements than PH calves. Previous findings suggest that socially reared calves have greater competitive success

Table 3. Effects of previous social housing (IH = individually housed, n = 11 calves; or PH = pair-housed, n = 9 calves, 1 focal calf/pair, during the first 7 wk of life) on response to an individual novel object test following postweaning grouping

	Treatment				
Behavior	IH	PH	SE	$F_{1,18}$	*P*-value
Latency to contact object (min)	2.8	4.1	0.60	2.42	0.14
Attention directed to object[1] (min)	0.36 (0.19, 0.58)	0.49 (0.27, 0.78)	—	0.80	0.38
Licking or sniffing the object[2]	0.45	0.67	0.15	0.88	0.36
Licking or sniffing the ground[1] (min)	0.57 (0.26, 1.0)	0.65 (0.28, 1.2)	—	0.09	0.77
Licking or sniffing the wall[1] (min)	0.76 (0.41, 1.2)	0.89 (0.48, 1.4)	—	0.19	0.67
Standing immobile[3] (min)	3.3 (2.8, 4.0)	4.0 (3.4, 4.8)	—	3.79	0.07
Walking (min)	1.2	1.1	0.13	0.40	0.53
Running[1] (min)	0.52 (0.21, 0.97)	0.15 (0.01, 0.46)	—	3.19	0.09
Self-grooming[2]	0.82	0.78	0.13	0.05	0.83
Back[1] (min)	0.72 (0.30, 1.3)	0.12 (0.0004, 0.46)	—	5.62	0.03
Front[1] (min)	4.2 (3.7, 4.7)	5.1 (4.5, 5.8)	—	5.83	0.02
Movement between front and back of the arena[1] (no.)	3.4 (1.5, 6.3)	0.70 (0.01, 2.4)	—	4.92	0.04

[1]Data were square-root transformed to meet assumptions of normality. Back-transformed means and 95% CI are reported.
[2]Licking and sniffing the object and self-grooming were modeled as binary outcomes (1 = any occurrence, 0 = no occurrence).
[3]Data were log-transformed to meet assumptions of normality. Back-transformed means and 95% CI are reported.

compared with calves housed individually following postweaning grouping (Duve et al., 2012). The novel feed was available for a limited time during which animals routinely fed together, such that response to the social feeding environment may have influenced individual outcomes.

There were no differences in previous housing treatment on the latency to contact the feed trough during the novel feed tests. The lack of difference could be attributed to the effects of social facilitation (Galef and Laland, 2005). Previous studies examining effects of social contact on response to novel feeds have used individual tests (Costa et al., 2014; Whalin et al., 2018) such that behavior was not subject to social facilitation. However, in a practical setting, response to novel feeds in group-housed heifers will be subject to interactions between previous social experience and present social context. Previously, Miller-Cushon and DeVries (2016) found that feeding synchrony in pairs of weaned calves was not affected by preweaning social housing. Our results suggest that social facilitation may have had a stronger influence on behavior in the present social environment than previous social experience.

We found that time spent consuming novel feed was not related to time spent consuming starter in the 24 h before the novel feed test, suggesting a lack of relationship between individual satiety or feeding motivation and interaction with the novel feed. We also observed no differences between previous housing treatments in time consuming starter. Previously, De Paula Vieira et al. (2010) found that previously pair-housed calves began consuming starter sooner after postweaning grouping and had greater feeding time, compared with previously individually housed calves. However, differences in feeding time were most apparent only on the day of mixing, suggesting that effects of preweaning housing treatment on feeding time may be short-lived in weaned calves, aligning with results from Miller-Cushon and DeVries (2016).

Contrary to our hypothesis, we found no effect of previous housing treatment on latency to contact the novel object. Avoidance of novel objects may depend on the degree of social contact, as Meagher et al. (2015) described reduced latencies to contact a novel object in calves with access to the dam, whereas pair-housed calves did not differ from individually housed calves. Similarly, Zhang et al. (2022) found no difference in latency to contact a novel object between calves housed in pairs and calves housed individually with physical contact. In contrast, Gingerich et al. (2023) found that group-housed calves approached a novel object more readily when housed in pairs for the first 2 wk of life before grouping, compared with individual pens. While we found no carryover effects of previous social contact on latency to contact the novel object in the present study, we did observe behavioral differences during the test.

We found that previously PH calves spent more time in the front area of the testing arena, whereas IH calves were more active, moving between sections of the arena more and spending somewhat more time running. There is similar evidence of greater reactivity to novel environments in individually housed calves in other studies, including more time spent running and more frequent defecation (De Paula Vieira et al., 2012). Similarly, individually housed calves had increased activity (Bučková et al., 2021) and play (Valníčková et al., 2015) in other studies, which was interpreted as a rebound effect due to movement restriction in the home pen. Although calves had been mingled between treatments and group-housed with access to more space at the time of this test, it is possible that previous movement restriction influenced their locomotor behavior. In addition, calves in this study were previously exposed to the testing arena during wk 4 of life (social preference test; Lindner et al., 2022), such that the previous memory or degree of habituation to the physical environment may have influenced responses in

the present study. Pair-housed calves have been reported to spend less time exploring a novel object with repeated testing, compared with individually housed calves (Gaillard et al., 2014), suggesting that social housing may facilitate faster habituation. Gingerich et al. (2023) found that calves housed in pairs for 2 wk before group housing were initially more active during exposure to a testing arena at 4 wk of life, compared with calves housed individually before grouping, but decreased activity compared with previously individually housed calves during repeated arena exposure.

Social grouping is a stressful event that can disrupt behavior. For example, Horvath and Miller-Cushon (2018) found that weaned calves spent more time standing on the day following introduction to a novel social group on pasture, and standing time decreased over the first week of introduction. Despite evidence that previous social housing may increase rest following introduction to group housing (Lyu et al., 2023) and generally increase adaptation to group housing (e.g., reducing latency to feed; De Paula Vieira et al., 2010), we found no effect of previous housing treatment on calf activity following postweaning grouping. However, lying time increased across the week, consistent with previous findings (Horvath and Miller-Cushon, 2018), which may be attributed to increased exploratory or reactive behaviors during initial grouping.

In summary, we assessed the effects of preweaning social housing on the responses to novelty in the home pen and testing arena following postweaning grouping. We found no evidence to support effects of previous social contact on avoidance of novel feeds or objects. However, behavioral differences during testing were evident, which may be explained in terms of differences in response to social feeding and activity in the testing arena. We encourage longer-term work to assess behavioral development in socially housed calves.

References

Bonk, S., O. Burfeind, V. S. Suthar, and W. Heuwieser. 2013. Evaluation of data loggers for measuring lying behavior in dairy calves. J. Dairy Sci. 96:3265–3271. https://doi.org/10.3168/jds.2012-6003.

Bučková, K., R. Šárová, Á. Moravcsíková, and M. Špinka. 2021. The effect of pair housing on dairy calf health, performance, and behavior. J. Dairy Sci. 104:10282–10290. https://doi.org/10.3168/jds.2020-19968.

Costa, J. H. C., R. R. Daros, M. A. G. von Keyserlingk, and D. M. Weary. 2014. Complex social housing reduces food neophobia in dairy calves. J. Dairy Sci. 97:7804–7810. https://doi.org/10.3168/jds.2014-8392.

De Paula Vieira, A., A. M. De Passillé, and D. M. Weary. 2012. Effects of the early social environment on behavioral responses of dairy calves to novel events. J. Dairy Sci. 95:5149–5155. https://doi.org/10.3168/jds.2011-5073.

De Paula Vieira, A., M. A. G. von Keyserlingk, and D. M. Weary. 2010. Effects of pair versus single housing on performance and behavior of dairy calves before and after weaning from milk. J. Dairy Sci. 93:3079–3085. https://doi.org/10.3168/jds.2009-2516.

Duve, L. R., D. M. Weary, U. Halekoh, and M. B. Jensen. 2012. The effects of social contact and milk allowance on responses to handling, play, and social behavior in young dairy calves. J. Dairy Sci. 95:6571–6581. https://doi.org/10.3168/jds.2011-5170.

Forkman, B., A. Boissy, M.-C. Meunier-Salaün, E. Canali, and R. B. Jones. 2007. A critical review of fear tests used on cattle, pigs, sheep, poultry and horses. Physiol. Behav. 92:340–374. https://doi.org/10.1016/j.physbeh.2007.03.016.

Friard, O., and M. Gamba. 2016. BORIS: A free, versatile open-source event-logging software for video/audio coding and live observations. Methods Ecol. Evol. 7:1325–1330. https://doi.org/10.1111/2041-210X.12584.

Gaillard, C., R. K. Meagher, M. A. von Keyserlingk, and D. M. Weary. 2014. Social housing improves dairy calves' performance in two cognitive tests. PLoS One 9:e90205. https://doi.org/10.1371/journal.pone.0090205.

Galef, B. G., and K. N. Laland. 2005. Social learning in animals: Empirical studies and theoretical models. Bioscience 55:489–499. https://doi.org/10.1641/0006-3568(2005)055[0489:SLIAES]2.0.CO;2.

Gingerich, K., E. Lindner, S. Kalman, and E. Miller-Cushon. 2023. Social contact from birth influences personality traits of group-housed dairy calves. JDS Commun. 4:484–488. https://doi.org/10.3168/jdsc.2023-0383.

Horvath, K. C., and E. K. Miller-Cushon. 2018. Characterizing social behavior, activity, and associations between cognition and behavior upon social grouping of weaned dairy calves. J. Dairy Sci. 101:7287–7296. https://doi.org/10.3168/jds.2018-14545.

Jensen, M. B., L. Munksgaard, L. Mogensen, and C. C. Krohn. 1999. Effects of housing in different social environments on open-field and social responses of female dairy calves. Acta Agric. Scand. A Anim. Sci. 49:113–120. https://doi.org/10.1080/090647099424178.

Koolhaas, J. M., and C. G. Van Reenen. 2016. Interaction between coping style/personality, stress, and welfare: Relevance for domestic farm animals. J. Anim. Sci. 94:2284–2296. https://doi.org/10.2527/jas.2015-0125.

Lindner, E. E., K. N. Gingerich, K. C. Burke, S. B. Doyle, and E. K. Miller-Cushon. 2022. Effects of social housing on dairy calf social bonding. Animals (Basel) 12:821. https://doi.org/10.3390/ani12070821.

Lukkes, J. L., M. V. Mokin, J. L. Scholl, and G. L. Forster. 2009. Adult rats exposed to early-life social isolation exhibit increased anxiety and conditioned fear behavior, and altered hormonal stress responses. Horm. Behav. 55:248–256. https://doi.org/10.1016/j.yhbeh.2008.10.014.

Lyu, J., C. Wang, X. Zhao, E. Miao, Z. Wang, Y. Xu, X. Bai, and J. Bao. 2023. Effect of group size and regrouping on physiological stress and behavior of dairy calves. J. Integr. Agric. 22:844–852. https://doi.org/10.1016/j.jia.2022.08.073.

Meagher, R. K., R. R. Daros, J. H. Costa, M. A. von Keyserlingk, M. J. Hötzel, and D. M. Weary. 2015. Effects of degree and timing of social housing on reversal learning and response to novel objects in dairy calves. PLoS One 10:e0132828. https://doi.org/10.1371/journal.pone.0132828.

Michalski, E., M. Woodrum Setser, G. Mazon, H. W. Neave, and J. H. Costa. 2023. Personality of individually housed dairy-beef crossbred calves is related to performance and behavior. Front. Anim. Sci. 3:1097503. https://doi.org/10.3389/fanim.2022.1097503.

Miller-Cushon, E. K., and T. J. DeVries. 2016. Effect of social housing on the development of feeding behavior and social feeding preferences of dairy calves. J. Dairy Sci. 99:1406–1417. https://doi.org/10.3168/jds.2015-9869.

Neave, H. W., J. H. C. Costa, D. M. Weary, and M. A. G. von Keyserlingk. 2018. Personality is associated with feeding behavior and performance in dairy calves. J. Dairy Sci. 101:7437–7449. https://doi.org/10.3168/jds.2017-14248.

UBC AWP. 2013. UBC Animal Welfare Program: SOP – HOBO Data Loggers. University of British Columbia, Vancouver, Canada.

Valníčková, B., I. Stěhulová, R. Šárová, and M. Špinka. 2015. The effect of age at separation from the dam and presence of social companions on play behavior and weight gain in dairy calves. J. Dairy Sci. 98:5545–5556. https://doi.org/10.3168/jds.2014-9109.

Voelkl, B., C. Schrauf, and L. Huber. 2006. Social contact influences the response of infant marmosets towards novel food. Anim. Behav. 72:365–372. https://doi.org/10.1016/j.anbehav.2005.10.013.

Whalin, L., D. M. Weary, and M. A. G. von Keyserlingk. 2018. Pair housing dairy calves in modified calf hutches. J. Dairy Sci. 101:5428–5433. https://doi.org/10.3168/jds.2017-14361.

Zhang, C., D. T. Juniper, and R. K. Meagher. 2022. Effects of physical enrichment and pair housing before weaning on growth, behaviour and cognitive ability of calves after weaning and regrouping. Appl. Anim. Behav. Sci. 249:105606. https://doi.org/10.1016/j.applanim.2022.105606.

Notes

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This work is supported by the USDA National Institute of Food and Agriculture (Washington, DC; grant no. 2019-67015-29571).

We thank the staff of the University of Florida Dairy Unit (Hague, FL), graduate research assistant Sam Doyle, and undergraduate research assistants for their assistance.

Calves were managed under standard operating procedures for the facility, and all procedures were reviewed and approved by the University of Florida Institutional Animal Care and Use Committee (protocol #201910617).

The authors have not stated any conflicts of interest.

Nonstandard abbreviations used: BORIS = behavioral Observation Research Interactive Software; IH = individual housing; NF = novel feed; PH = pair housing.