ABSTRACT
Although social contact between dairy calves has broad effects on their behavioral development, influences of calf social housing on human-animal relationships are less well understood, despite implications for longer-term calf management and welfare. We characterized human-animal interactions in 3 distinct testing contexts to examine effects of social housing on development of human-directed behavior. At birth, Holstein heifer calves were randomly assigned to individual housing (n = 17 calves) or pair housing (n = 17 calves; 1 focal calf/pair). A human approach test was performed twice in the home pen (wk 3 and 5 of life), within an open testing arena (13 × 7 m; wk 4 of life), and within group-housing pens 6 d after all calves were weaned, mingled between treatments, and moved to groups (4 calves/pen; wk 8 of life). For these tests, a human approached, and then extended their hand, over a 2 min period for home and group pen tests and a 5 min period for the arena test, and behavior was recorded from video. During preweaning human approach tests in the home pen, individually housed calves had shorter latencies to contact the human (22.4 vs. 45.1 s; individual vs. pair housing) and spent more time in contact with the human [80.5 vs. 41.1 s; standard error (SE) = 9.9; individual vs. pair housing], with similar responses between repeated tests. In the arena approach test, individually housed calves spent more time oriented toward the human (134.6 vs. 81.3 s; SE = 16.5; individual vs. pair housing), whereas pair-housed calves were more likely to perform pen-directed non-nutritive oral behavior (60 vs. 40% of calves; pair vs. individual housing), suggesting differences in interest directed toward the human compared with the novel environment. We also found that total duration of human contact was correlated between the first home pen approach test and the novel arena test, but that specific response to human approach varied between testing contexts.

Effects of treatment persisted during the postweaning group pen approach test, with previously individually housed calves tending to spend more time looking toward the human (53.0 vs. 30.0 s; SE = 9.4; individual vs. pair housing) and more likely to contact the human (47 vs. 12% of calves; individual vs. pair housing). Overall, these results show persistent effects of early life social housing on human-directed behavior which may have implications for longer-term management.

Key words: human-animal interaction, social housing, non-nutritive oral behavior

INTRODUCTION
Dairy cattle frequently experience human contact throughout their life, and maintaining positive human-animal relationships is critical for the improvement of animal welfare (Waiblinger et al., 2004). For example, behavioral indicators of fear are related to more forceful human handling (Lindahl et al., 2016). Decreases in fear responses additionally allow for better safety conditions and less risk of injury to stockpersons and animals (Waiblinger et al., 2004; Bertenshaw et al., 2008; Lindahl et al., 2016). Improved human-animal relationships have additional benefits for producers, as positive human-animal interactions may improve productivity (Hanna et al., 2009) and conception rates (Rueda et al., 2015). Human-animal relationships have important implications for management, potentially influencing fearfulness in handling scenarios and ease of handling.

The development of human-directed behavior in dairy calves may depend on aspects of the early environment. Social housing is becoming increasingly common in the dairy industry and is widely considered to improve welfare for dairy calves, having broad benefits on aspects of calf performance and behavioral development. Dairy calves are motivated to obtain social contact (Ede et al., 2022; Holm et al., 2002), suggesting that social housing accommodates an important behavioral need. Social housing is particularly important in the development of social behavior in dairy calves. Calves housed in pairs or groups exhibit preference for a penmate, compared...
with unfamiliar calves, in social preference tests (Farevik et al., 2006; Duve and Jensen, 2011; Lindner et al., 2022), showing that social contact facilitates the development of social bonds. Effects of social housing may translate to differences in social ability following eventual group housing. For example, Lindner et al. (2021) found that calves housed in pairs during only the first 2 wk of life spent more time lying near other calves when moved into group housing, compared with calves housed individually before grouping. Although calf social housing is understood to affect social development, the effects of conspecific social contact on human-directed behavior are less clear. However, some previous work suggests that social housing may be an important factor in the development of human-animal relationship. Duve et al. (2012) found that individually housed dairy calves were more likely to initiate contact when a human stands stationary within the pen, compared with pair- or group-housed calves; this effect could be driven by a lack of social contact with conspecifics for individually housed calves. Mogensen et al. (1999) found that individually housed calves without visual contact with other calves had a shorter latency to approach a stationary human, compared with calves housed with visual contact or in groups. In addition to stationary human tests, where calves are allowed to voluntarily approach a human, human approach tests (or involuntary approach tests) can be used to directly measure behavior toward humans and demonstrate reactivity to people (Waiblinger et al., 2003; de Pasillé and Rushen, 2005). Mogensen et al. (1999) found evidence to suggest that social housing during the first months of life may increase flight distances during human approach tests on pasture.

Although it has been established that dairy calf social behavior toward conspecifics changes over time (Veisssier et al., 1997; Bertelsen and Jensen, 2019), there are gaps in our knowledge surrounding the development of human-directed behavior in dairy calves reared in different housing environments. Therefore, the objective of this study was to assess the effects of social housing, with calves reared individually or in pairs, on human-directed behavior during the preweaning and postweaning period in different testing contexts. We hypothesized that individually housed calves would exhibit increased human-directed behavior during human approach tests compared with pair-housed calves, and these behaviors may increase over time. Further, we predicted that early life social housing would have carry-over effects on human-directed behavior, once calves were mingled between treatments and grouped after weaning, given previous evidence that social housing may have long-term effects on various aspects of human-directed and conspecific social behavior, including flight distances (Mogensen et al., 1999) and response to social competition (Duve et al., 2012). Finally, a secondary objective of this research was to examine whether human-directed behavior in different testing contexts were correlated, considering various approaches to conducting human approach tests both in the home pen and arena tests (Jago et al., 1999) in previous work.

MATERIALS AND METHODS

Animals, Management, and Experimental Design

Holstein heifer calves (n = 34 focal animals; 51 animals total) were enrolled at the University of Florida Dairy Unit (Hague, FL) within 24 h of age. This study was conducted during January through May 2021. Calves were managed according to facility standard operating procedures and study procedures were approved by the University of Florida Institutional Animal Care and Use Committee (#201910617). Calves received 4 L of quality-controlled colostrum (checked using a digital refractometer, TS >25%) by bottle within 4 h of birth and calves were additionally uniquely identified with radiofrequency identification ear tags. A subset of calves (1 individually housed and 2 pair-housed calves) were additionally provided a second 4-L allotment of quality-controlled colostrum 12 h following the first feeding, due to a change in farm standard operating procedures toward the end of the enrollment period.

According to a completely randomized design, calves were assigned to either individual (n = 17 calves) or pair housing (n = 17 pairs of calves with 34 pair-housed calves total; one focal calf was randomly selected from each pair pen) at birth for the first 7 wk of life. Housing treatments alternated between every calf or pair of calves born. An online random number generator was used to determine which calf of the pair would be used as the focal animal for this study.

Pens were constructed of wire mesh with dimensions of 0.9 by 1.8 m (width × depth) for individual pens and double-sized pens (1.8 by 1.8 m; width × depth) for pair-housed calves. Individual and paired pens were interspersed in the barn, typically alternating between pair and individual housing pens. Pens were spaced such that physical contact between adjacent pens was prevented; however, all calves had visual and auditory contact with adjacent calves. Calves were bedded on sand, which was replaced weekly. All calves were provided 8 L of milk replacer (28% CP and 20% fat; Suwannee Valley Feeds) over 2 feedings each day via teat bucket (delivered by farm personnel at 0630 and 1430 h). Calf starter (22% CP and 2% fat; Ampli-Calf Starter Warm Weather, Purina Animal Nutrition LLC) and water were provided to calves ad libitum. All pens were constructed of wire mesh with dimensions of 0.9 by 1.8 m (width × depth) for individual pens and double-sized pens (1.8 by 1.8 m; width × depth) for pair-housed calves. Individual and paired pens were interspersed in the barn, typically alternating between pair and individual housing pens. Pens were spaced such that physical contact between adjacent pens was prevented; however, all calves had visual and auditory contact with adjacent calves. Calves were bedded on sand, which was replaced weekly. All calves were provided 8 L of milk replacer (28% CP and 20% fat; Suwannee Valley Feeds) over 2 feedings each day via teat bucket (delivered by farm personnel at 0630 and 1430 h). Calf starter (22% CP and 2% fat; Ampli-Calf Starter Warm Weather, Purina Animal Nutrition LLC) and water were provided to calves ad libitum. All pens were constructed of wire mesh with dimensions of 0.9 by 1.8 m (width × depth) for individual pens and double-sized pens (1.8 by 1.8 m; width × depth) for pair-housed calves. Individual and paired pens were interspersed in the barn, typically alternating between pair and individual housing pens. Pens were spaced such that physical contact between adjacent pens was prevented; however, all calves had visual and auditory contact with adjacent calves. Calves were bedded on sand, which was replaced weekly. All calves were provided 8 L of milk replacer (28% CP and 20% fat; Suwannee Valley Feeds) over 2 feedings each day via teat bucket (delivered by farm personnel at 0630 and 1430 h). Calf starter (22% CP and 2% fat; Ampli-Calf Starter Warm Weather, Purina Animal Nutrition LLC) and water were provided to calves ad libitum. All pens were constructed of wire mesh with dimensions of 0.9 by 1.8 m (width × depth) for individual pens and double-sized pens (1.8 by 1.8 m; width × depth) for pair-housed calves. Individual and paired pens were interspersed in the barn, typically alternating between pair and individual housing pens. Pens were spaced such that physical contact between adjacent pens was prevented; however, all calves had visual and auditory contact with adjacent calves. Calves were bedded on sand, which was replaced weekly. All calves were provided 8 L of milk replacer (28% CP and 20% fat; Suwannee Valley Feeds) over 2 feedings each day via teat bucket (delivered by farm personnel at 0630 and 1430 h). Calf starter (22% CP and 2% fat; Ampli-Calf Starter Warm Weather, Purina Animal Nutrition LLC) and water were provided to calves ad libitum. All pens were constructed of wire mesh with dimensions of 0.9 by 1.8 m (width × depth) for individual pens and double-sized pens (1.8 by 1.8 m; width × depth) for pair-housed calves. Individual and paired pens were interspersed in the barn, typically alternating between pair and individual housing pens. Pens were spaced such that physical contact between adjacent pens was prevented; however, all calves had visual and auditory contact with adjacent calves. Calves were bedded on sand, which was replaced weekly. All calves were provided 8 L of milk replacer (28% CP and 20% fat; Suwannee Valley Feeds) over 2 feedings each day via teat bucket (delivered by farm personnel at 0630 and 1430 h). Calf starter (22% CP and 2% fat; Ampli-Calf Starter Warm Weather, Purina Animal Nutrition LLC) and water were provided to calves ad libitum. All pens were constructed of wire mesh with dimensions of 0.9 by 1.8 m (width × depth) for individual pens and double-sized pens (1.8 by 1.8 m; width × depth) for pair-housed calves. Individual and paired pens were interspersed in the barn, typically alternating between pair and individual housing pens. Pens were spaced such that physical contact between adjacent pens was prevented; however, all calves had visual and auditory contact with adjacent calves. Calves were bedded on sand, which was replaced weekly. All calves were provided 8 L of milk replacer (28% CP and 20% fat; Suwannee Valley Feeds) over 2 feedings each day via teat bucket (delivered by farm personnel at 0630 and 1430 h).
were located within an open-sided barn where they were protected from downward rain, wind, and sun. The barn was equipped with overhead fans to improve air circulation. Farm staff and research personnel monitored the calves daily. Health assessments were conducted by veterinarians weekly, and research personnel recorded occurrences of diarrhea daily. It was common for calves to experience scouring in the first 2 wk of life, which was treated with the provision of free-access electrolytes mixed in water. No major health events necessitated removal of calves from this study. Animals were not to be handled or interacted with unless it was necessary for data collection, feeding (hand delivering milk twice daily), or the health and well-being of the animal (e.g., weekly veterinary exams, weighing calves). Human contact during this routine husbandry did not differ between housing treatments. Calf care personnel were not aware of the hypotheses of the present study.

Calves were disbudded at approximately 4 wk of age (30.3 ± 3.2 d of age; mean ± SD). Calves were disbudded by hot iron (Rhinehart X-50A, Rhinehart Development Corporation) by a veterinarian. Calves received a nonsteroidal anti-inflammatory drug for analgesia 3 to 4 h before disbudding (meloxicam provided orally; 0.5 mg/kg; Unichem Pharmaceuticals USA Inc.) and a local cornual nerve block 10 to 15 min before disbudding (5 mL of 2% lidocaine hydrochloride; Bimeda-MTC; injected on each side over the cornual nerve). Disbudding occurred after the arena approach test and approximately one week before the second home pen approach test (methods described below), with the timing intended to minimize effects of pain on behavioral responses to testing.

Calves began weaning at 6 wk of age, with milk allotment gradually decreased over the course of 10 d. For the first 4 d of weaning, calves were provided 6 L/d of milk total rather than 8 L/d over the course of 2 milk meals per day. For the following 4 d, this reduced to 4 L/d of milk in 2 meals. Calves received 2 L/d in 2 meals for the final 2 d. Following weaning (at 53 ± 1.8 d of age; mean ± SD; with calves born within the same week managed on the same weekly schedule), calves were mingled between previous housing treatments and moved into group pens (4.4 ± 0.6 calves/group pen; mean ± SD, 3.7 × 8.0 m²/pen; with some variability in group size due to fluctuations in weekly birth rate). Calves that were pair housed were always grouped together. Study calves were distributed across a total of 14 postweaning group pens (2.4 ± 0.8 study calves/pen; mean ± SD), with each group additionally housing some nonstudy calves born within the same week (2.0 ± 1.3 additional calves/group, mean ± SD, which included the 17 nonfocal pair calves as well as a total of 5 individually housed and 6 pair-housed calves that were managed identically but not used for data collection in this study). Groups were always composed of at least one calf from each treatment [1.6 ± 0.7 (mean ± SD) previously individually housed calves/group, min 1 and max 3; and 2.8 ± 1.0 (mean ± SD) previously pair-housed calves/group, minimum 2 and maximum 4]. Groups were stable for the remainder of the study. Group pens were deep-bedded with sand and were located at the opposite end of the open-sided barn where they were housed before weaning. Group-housed calves were provided with ad libitum access to water and the same calf starter as before weaning.

Calves were exposed to repeated human approach tests in different contexts, as described in detail below. We conducted (1) human approach tests in the home pen at wk 3 and 5 of age; (2) an approach test in a novel testing arena at wk 4 of age; and (3) postweaning approach test in the home group pen at wk 8 of age, 6 d after group housing. We conducted tests in multiple contexts (home pen and novel arena) to assess how housing affected responses to human approach in different environments, considering that these different approaches to assessing human-directed behavior have been used previous across the literature (e.g., Jago et al., 1999). We used human approach tests, where a human approaches the animal during the test, as opposed to stationary tests, where the animal voluntarily approaches the human. Approach tests were used rather than stationary tests, as it has been suggested that responses during stationary tests reflect not only reactivity to people, but also other motivations that may vary depending on the context or environment of the stationary human test (Waiblinger et al., 2003; de Passillé and Rushen, 2005). These approach tests are sometimes described as involuntary (or forced approach), in comparison to testing where the human remains stationary and voluntary approach is assessed. However, any contact with the test person was voluntary, in comparison to tests that may involve animal handling or forced contact.

Multiple humans were used for approach testing, as described in more detail below. Approaching humans were research assistants, all of whom assisted with data collection or health checks occasionally (approximately 2 mornings per week), such that they had some limited contact with the study calves but were not primarily involved in calf husbandry. These humans were not aware of the study hypotheses. They were trained to follow the same testing protocol, as outlined below, and prior practice tests were administered to nonstudy animals to familiarize personnel with the protocol. There was a single observer who recorded data and was present to provide oversight at all tests.
Two home pen approach tests were conducted during the preweaning period at 3 and 5 wk of age while the calves were in either their individual or pair-housed pens (see Figure 1). These 2 time points were chosen to avoid the influence of early life health events on behavior (scouring affected some calves in the first 2 wk of life) and to avoid the period of weaning during wk 6 and 7 of life. Testing occurred between the hours of 0900 and 1130 h, a time point that coincided with no additional activity in the barn. The procedure for the home pen approach test was adapted from that described by Jago et al. (1999).

First, the human stood across the barn aisle (approximately 2.5 m away) from the calf and remained there for 5 s. Then, at a rate of approximately 1 step/s, the human moved toward the front and center of the calf pen. They remained standing motionless just outside of the calf pen with their arms at their sides for 90 s. Calves were able to initiate contact with the human over or through the openings in the wire mesh side of the pen. After 90 s had passed, the human then offered their hand out, reaching over the side of the pen for 30 s. Finally, the human retreated, and the test was concluded.

The number of calves tested per day varied (minimum 2 and maximum 8 animals were tested per day). During testing, the research team moved from one end of the barn to the other, to avoid passing by animals who were still under observation, so as not to disturb their behavior. It was possible that a calf may visually observe testing procedures for other calves undergoing testing, as no modifications to the calf barn were made during testing. However, there was no reason to suppose this testing process would specifically attract attention as calves were habituated to human presence (e.g., neighboring calves receiving routine health exams) and, anecdotally, were not reactive to humans interacting with calves in adjacent pens. Testing procedures were the same for pair and individually housed calves, with the human approaching at the center of the front of the home pen. For pair-housed calves, only the behavior of the focal animal was recorded. If the nonfocal animal approached the human in addition to the focal animal, the test human did not interfere. For this test, 6 different research assistants performed the human approach. The observing human was present during all testing, visible to the calf but standing stationary at a greater distance, to direct the test and to record live observations. Individuals were not to make direct eye contact with calves during testing, nor did they speak apart from a soft, one-word cue to the test individual to proceed with the next phase of the test.

**Preweaning Human Approach Test in a Novel Test Arena**

To assess human-directed behavior in different testing contexts, calves experienced a human approach test in a novel testing arena (13 × 7 m) at 4 wk of age (see Figure 1). Examples of the preweaning approach tests in the home pen for (A) individually housed calves and (B) pair-housed calves. For this test, the human stood about 2.5 m from the pen for 5 s and then approached the pen at a rate of 1 step/s. The human then remained motionless just outside the pen with their arms at their sides for 90 s, as shown here. The human then offered their hand out, reaching over the side of the pen for 30 s. Finally, the human retreated, and the test was concluded.
Figure 2, adapted from a procedure described by Jago et al. (1999). This test was similar to the approach test in the home pen, with a human walking toward the calf but not implementing involuntary contact, with the methods adapted in consideration of the open testing arena. Arena testing occurred between 0800 and 1100 h. Calves were tested individually and were transported from their home pen to the testing arena (approximately 25–35 m, depending on pen location within the barn) within a wire mesh pen (which was slowly carried while the calf walked within it, a procedure to which calves were previously habituated during routine husbandry). Calves did not have visual contact with the testing procedures from outside of the testing arena, and were not exposed to the arena before their test day.

First, calves were placed in the testing arena for 10 min before the human approach test. Following this 10 min exposure, the calf was removed from the testing arena, and then reintroduced for the human approach test. When the calf entered the arena, a human stood in the center of a testing arena facing the direction where the calf would be released into the arena. The test began when the calf entered the arena. The human remained stationary with their hands at their sides for 1 min, to avoid startling the calf and to allow the calf to briefly acclimate to their presence. The human then moved toward the calf at a speed of approximately 1 step/s, as in the home pen approach test. The human remained standing in the spot where the calf had been, even if the calf had moved away, for a duration of 90 s. The human then attempted to approach the calf again in the same manner, stopping where the calf was initially standing and remaining stationary in that location, even if the calf moved away from the human, for 90 s. For the final 60 s of the test, the human would reach their hand out in front of them. If a calf was already contacting the human at any point of transition between portions of the test, the human would still attempt an approach by shifting their body and turning toward the calf, or by taking one or 2 small steps even closer to them. This test took a total of 5 min. Calves were away from their home pen for the minimum amount of time required for movement and testing (<20 min).

Eye contact was not made with the calf during testing, and the human was to look out toward the horizon, not only to avoid intimidating the calf, but also to receive time cues from the observing human outside of the testing arena. The human was not to talk to or prompt interaction with the calf other than what is specified within the testing protocol. The same human was used for all arena human approach tests. As for the other approach tests, this was someone that the calves had occasional exposure to during routine husbandry throughout the week.

Postweaning Human Approach Test in the Group Home Pen

An additional home pen test was conducted at 8 wk of age following the calves’ transition to group housing.
(see Figure 3), to examine potential carry-over effects of preweaning social housing on human-directed behavior. All calves within each group pen were tested once at 6 d following grouping. This time point coincided with the last day that calves were housed in their postweaning social group, before movement to pasture according to standard farm operating procedure. Testing was performed between 0930 and 1100 h. This home pen human approach test followed the same procedure as the home pen human approach tests conducted during wk 3 and 5 when calves were housed in individual and pair-housing pens.

First, the human stood across from the fence line of the group pen, approximately 2.5 m away, for 5 s. Following this, at a rate of approximately 1 step/s, the human stepped forward until they reached the fence line of the group pen. For 90 s, the human remained standing at the fence wall of the calf pen, motionless, with their arms at their sides. Calves were able to initiate contact with the human through the bars of the pen. Then, for 30 s, the human extended their hand out toward the calves. After 30 s, the test concluded, and the human turned around and walked to where they began the test.

Nine different research assistants were used as the approaching human. These research assistants were blind to previous housing treatment and not informed of the study hypotheses. The same primary observer was present at the time of testing to direct testing and to record live observations, as for other tests. Neither individual made eye contact with calves during testing and were not to speak with the exception of soft, one-word cues to prompt the test human to proceed with the next portion of testing.

**Behavioral Data Collection**

Tests were recorded using a video camera (GoPro Hero6, GoPro Inc.) mounted on a tripod and positioned at an angle from where the human was approaching or mounted to the corner of the testing arena. Behaviors recorded during testing are defined according to the ethogram in Table 1. According to methods described by Jago et al. (1999), we recorded the calf’s latency to contact the human and frequency of urination and defecation. We additionally measured duration of human contact, occurrences of pen-directed non-nutritive oral behaviors, self-grooming, and latency to lie down following the human approach test. We recorded pen-directed non-nutritive oral behaviors in this study to assess how calves spent their time during testing, in addition to human-directed behavior, considering that young dairy calves often perform these behaviors extensively (e.g., Horvath et al., 2020). During arena and group pen testing, we additionally recorded duration of time looking toward (oriented) toward the test human. During the arena test, we recorded locomotor activity (standing, walking, running). These
behaviors were recorded continuously from video using Behavioral Observation Research Interactive Software, v. 7.9.8 (Friard and Gamba, 2016), by one observer (intra-observer reliability ≥0.93, calculated within the software).

Calves were additionally assigned a score during the human approach tests, based on their proximity to a human, whether they made contact with the human, and the duration of contact (1 = complete avoidance of the human; 2 = close proximity to the human with minimal contact or minimally oriented toward human; 3 = close proximity to the human test subject with some contact and most time oriented toward the human; and 4 = nearly constant contact while oriented toward the human test subject). This score was recorded through live observation by the single observer who was present at all testing. For the human approach test in the home pen, this score was recorded during the human approach and the human reaching a hand out. For the novel arena approach test, this score was recorded at each stage of testing: response score to the stationary human, response score to the initial and secondary human approach, and response score to the human reaching a hand out. These scores were checked by reviewing video footage if needed and to confirm intra-observer reliability.

**Statistical Analysis**

The number of calves available for enrollment was determined by a larger ongoing study examining effects of social housing on a range of other behavioral and performance outcomes. Based on previously reported variation in response variables similar to the primary outcomes in this study (latency to contact and duration of contact during various human approach tests; Jago et al., 1999), we estimated that, with 17 calves enrolled per treatment, we would be able to detect medium to large effect sizes (Cohen’s d = 0.7).

Data were analyzed separately for each approach test (preweaning home pen approach tests, arena approach test, and postweaning home pen approach test) in general linear mixed models (using SAS v. 9.4; SAS Institute; with Proc MIXED, for normally distributed data, and Proc GLIMMIX, for negative binomial and binary distributions). Score data (with values assigned 1–4) were modeled with a negative binomial distribution. Behaviors that were not observed in a fraction of calves (duration of pen-directed non-nutritive oral behaviors in the preweaning home pen test, duration of self-grooming in the arena and the postweaning group pen test, and duration of human contact during the postweaning group pen test) were converted to binary outcomes (1 = any occurrence of the behavior during the test; 0 = no occurrence) and modeled with a binary distribution.

For the preweaning home pen approach tests, the model included the fixed effects of treatment, week, and treatment by week interaction, with week of testing (wk 3 or 5) as a repeated measure modeled with the compound symmetry covariance structure, selected according to the Bayesian information criterion. Test person (6 different people used across all tests) was included as a random effect. For the arena approach test, the model included fixed effects of treatment. For the postweaning group pen approach test, the model

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home pen tests</td>
<td>All tests</td>
</tr>
<tr>
<td>Arena</td>
<td>All tests</td>
</tr>
<tr>
<td>All tests</td>
<td>All tests</td>
</tr>
<tr>
<td>All tests</td>
<td>All tests</td>
</tr>
<tr>
<td>All tests</td>
<td>All tests</td>
</tr>
</tbody>
</table>
included the fixed effect of previous housing treatment, random effect of group, and random effect of test person (9 different people used across all tests). Due to video recording failure, latency to lie down was not able to be recorded for 2 individually housed calves during the postweaning group pen approach test.

Model conditional residuals were screened for normality and some duration data were transformed to meet model assumptions of normality; these are noted with footnotes in results tables, with back-transformed means and 95% confidence intervals reported. All data are reported as least squares means. Significance was declared at \( P < 0.05 \), and trends were reported if \( 0.05 \leq P \leq 0.10 \).

To assess consistency of individual responses in different testing contexts, we examined the correlation between human response scores measured at corresponding time points (human approach, and human reaching out) in the first preweaning home pen approach test and the arena approach test, as well as the correlation between durations of human contact in both testing contexts. For this comparison between testing contexts, we included responses only from the first home pen approach test, to assess the correlation between data obtained from a single time point in both tests, and from the first exposure to both testing contexts. Correlation was analyzed by calculating Spearman’s rank correlation coefficient (CORR procedure in SAS), a nonparametric measure of rank correlation which is robust to outliers.

**RESULTS**

**Preweaning Human Approach Test in the Home Pen**

Responses during the home pen approach tests differed between individually housed and pair-housed calves, as reported in Table 2. There was no effect of week, or interaction between housing treatment and week, in any of the responses recorded during the repeated preweaning home pen approach tests.

Across both tests, individually housed calves spent more time in contact with a human and more time engaged in human-directed non-nutritive oral behaviors compared with pair-housed calves. Pair-housed calves had greater latency to initiate contact with a human compared with calves housed individually. Pair-housed calves also tended to lie down more quickly following human approach test. Significant effects of treatment were also found for score data, for both response to the approaching human and to the human reaching out a hand; individually housed calves were exhibited more human-directed behavior at both stages.

<table>
<thead>
<tr>
<th>Table 2. Behavioral responses to a human approach test conducted in the home pen during wk 3 and 5 of life for calves on different housing treatments (T): individually housed calves (IH; ( n = 17 )) and pair-housed calves (PH; ( n = 17 ))</th>
<th>Wk 3</th>
<th>PH</th>
<th>IH</th>
<th>Wk 5</th>
<th>PH</th>
<th>IH</th>
<th>T</th>
<th>T × Wk</th>
<th>( P )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency to contact human (s)</td>
<td>25.5</td>
<td>36.2</td>
<td>19.2</td>
<td>54.0</td>
<td>—</td>
<td>0.0010</td>
<td>0.81</td>
<td>0.18</td>
<td></td>
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<tr>
<td>(14.8, 43.4)</td>
<td>(21.3, 61.0)</td>
<td>(11.0, 33.0)</td>
<td>(31.5, 92.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human contact (s)</td>
<td>82.0</td>
<td>44.8</td>
<td>79.0</td>
<td>37.4</td>
<td>9.9</td>
<td>&lt;0.001</td>
<td>0.63</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>(58.0, 106.0)</td>
<td>(28.6, 61.0)</td>
<td>(52.0, 106.0)</td>
<td>(24.0, 54.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human-directed non-nutritive oral behaviors (s)</td>
<td>72.9</td>
<td>40.8</td>
<td>65.2</td>
<td>33.7</td>
<td>9.1</td>
<td>0.005</td>
<td>0.83</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>(51.9, 93.9)</td>
<td>(24.6, 55.0)</td>
<td>(46.2, 84.2)</td>
<td>(22.5, 45.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latency to lie down following testing (s)</td>
<td>9.0</td>
<td>5.5</td>
<td>7.9</td>
<td>5.6</td>
<td>—</td>
<td>0.0324</td>
<td>0.18</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>(5.4, 14.4)</td>
<td>(3.2, 9.0)</td>
<td>(4.5, 11.8)</td>
<td>(3.3, 9.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response score for approaching human</td>
<td>3.0</td>
<td>2.5</td>
<td>3.1</td>
<td>1.6</td>
<td>0.3</td>
<td>0.012</td>
<td>0.18</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>(2.3, 3.8)</td>
<td>(1.9, 3.2)</td>
<td>(2.6, 3.6)</td>
<td>(1.2, 2.3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response score for human reaching out</td>
<td>3.6</td>
<td>2.5</td>
<td>1.2</td>
<td>0.6</td>
<td>0.3</td>
<td>0.0024</td>
<td>0.18</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>(2.4, 4.8)</td>
<td>(1.9, 3.2)</td>
<td>(1.0, 2.2)</td>
<td>(0.4, 1.2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pen-directed non-nutritive oral behavior</td>
<td>0.37</td>
<td>0.56</td>
<td>0.39</td>
<td>0.44</td>
<td>0.14</td>
<td>0.0051</td>
<td>0.18</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>(0.20, 0.54)</td>
<td>(0.30, 0.72)</td>
<td>(0.22, 0.52)</td>
<td>(0.08, 0.56)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 These variables were transformed to meet model assumptions of normality (Log10+1), and back-transformed means and confidence intervals are reported. Significance was declared at \( P < 0.05 \), and trends were reported if \( 0.05 \leq P \leq 0.10 \).

2 Score data were collected using a scale of 1 to 4, with 1 indicating avoidance of the human during testing and 4 indicating proximity near the human for the entire duration of testing. Human-directed behavior was not observed in a fraction of calves and so was analyzed as a binary outcome (1 = any occurrence of the behavior, 0 = no occurrence of the behavior) and is reported as a ratio.
The occurrence of pen-directed non-nutritive oral behaviors did not differ between treatments. Additionally, self-grooming, urination, and defecation occurred so rarely that these data were not analyzed. Across both home pen tests, 10 calves engaged in self-grooming and 3 calves urinated. No calves defecated during either week of home pen approach testing.

**Preweaning Human Approach Test in a Novel Test Arena**

There were significant effects of housing treatment on the duration of time calves spent looking toward a human and pen-directed non-nutritive oral behavior during the human approach test in a novel testing arena (Table 3). Pair-housed calves spent less time looking toward the human inside of the arena, and more time performing pen-directed non-nutritive oral behaviors. We found no effects of housing treatment on latency to contact the human, duration of human-directed non-nutritive oral behavior, human contact, standing, walking, or running. There was no significant effect on any score data collected. Occurrence of self-grooming did not differ between treatments. The frequency of urination and defecation was not able to be analyzed, as these behaviors rarely occurred.

**Postweaning Human Approach Test in the Group Home Pen**

In the postweaning home pen approach test, there was an effect of previous housing treatment on duration of time looking toward the human and occurrence of human contact (Table 4). Previously individually housed calves spent more time looking toward the human and were more likely to contact the human. Latency to lie down following the approach test did not differ between treatments. Score during the human approach stage did not differ, but score during the stage where the human reached out their hand did; previously individually housed calves were more likely to initiate contact with the human at this point of the approach test. There were no significant effects of previous housing treatment on pen-directed non-nutritive oral behavior, or self-grooming. Urination, and defecation were not able to be analyzed as these behaviors seldom occurred within the group pen test observation window.

**Correlation Between Individual Responses to the Home Pen and Novel Arena Approach Tests**

We found no correlation between the human response score recorded in the arena approach test and the first

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**Table 3. Behavioral responses to a human approach test conducted in a novel testing arena for calves housed individually (IH; n = 17) or in pairs (PH; n = 17) during wk 4 of life**

<table>
<thead>
<tr>
<th>Response</th>
<th>IH</th>
<th>PH</th>
<th>SE</th>
<th>$F_{1,32}$</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looking toward human (s)</td>
<td>134.6</td>
<td>81.3</td>
<td>16.5</td>
<td>5.20</td>
<td>0.029</td>
</tr>
<tr>
<td>Latency to contact human (s)</td>
<td>65.2</td>
<td>100.7</td>
<td>—</td>
<td>1.64</td>
<td>0.21</td>
</tr>
<tr>
<td>Human contact (s)</td>
<td>(39.9, 106.4)</td>
<td>(61.7, 164.3)</td>
<td>—</td>
<td>0.49</td>
<td>0.49</td>
</tr>
<tr>
<td>Human-directed non-nutritive oral behavior (s)</td>
<td>22.6</td>
<td>13.3</td>
<td>—</td>
<td>0.41</td>
<td>0.53</td>
</tr>
<tr>
<td>Pen-directed non-nutritive oral behavior (s)</td>
<td>14.9</td>
<td>8.6</td>
<td>—</td>
<td>0.12</td>
<td>0.93</td>
</tr>
<tr>
<td>Standing (s)</td>
<td>233.3</td>
<td>222.0</td>
<td>10.9</td>
<td>0.74</td>
<td>0.39</td>
</tr>
<tr>
<td>Walking (s)</td>
<td>40.4</td>
<td>60.0</td>
<td>—</td>
<td>2.58</td>
<td>0.12</td>
</tr>
<tr>
<td>Running (s)</td>
<td>(28.3, 57.6)</td>
<td>(42.1, 85.6)</td>
<td>—</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Self-grooming (2)</td>
<td>22.2</td>
<td>21.4</td>
<td>5.8</td>
<td>0.01</td>
<td>0.93</td>
</tr>
<tr>
<td>Response score for a stationary human (3)</td>
<td>0.5</td>
<td>0.4</td>
<td>0.1</td>
<td>0.12</td>
<td>0.73</td>
</tr>
<tr>
<td>Response score for initial human approach (3)</td>
<td>1.4</td>
<td>0.7</td>
<td>0.3</td>
<td>1.54</td>
<td>0.28</td>
</tr>
<tr>
<td>Response score for secondary human approach (3)</td>
<td>(0.8, 2.3)</td>
<td>(0.4, 1.4)</td>
<td>—</td>
<td>0.03</td>
<td>0.99</td>
</tr>
<tr>
<td>Response score for human reaching out (3)</td>
<td>2.2</td>
<td>1.5</td>
<td>0.4</td>
<td>1.51</td>
<td>0.23</td>
</tr>
<tr>
<td>Response score for secondary human approach (3)</td>
<td>(1.5, 3.2)</td>
<td>(1.0, 2.4)</td>
<td>—</td>
<td>0.3</td>
<td>0.92</td>
</tr>
<tr>
<td>Response score for human reaching out (3)</td>
<td>1.7</td>
<td>1.3</td>
<td>0.3</td>
<td>0.28</td>
<td>0.99</td>
</tr>
</tbody>
</table>

1These variables were transformed to meet model assumptions of normality (square root transformed: human-directed non-nutritive oral behavior, human contact, and walking; or log-transformed: latency to contact the human). Back-transformed means and confidence intervals are reported.

2This behavior was not observed in a fraction of calves and so was analyzed as a binary outcome (1 = any occurrence of the behavior; 0 = no occurrence of the behavior) and is reported as a ratio.

3Score data were collected using a scale of 1 to 4, with 1 indicating avoidance of the human during testing and 4 indicating proximity near the human for the entire duration of testing.
home pen approach test, either during the stage where the human approached (Spearman correlation coefficient = −0.03; \( P = 0.88 \)) or reached out their hand (Spearman correlation coefficient = 0.25; \( P = 0.15 \)). However, the total duration of human contact during testing (which included potential contact following approach during the home pen test, and any contact within the novel test arena) was positively correlated between the arena approach test and the first home pen approach test (Spearman correlation coefficient = 0.35; \( P = 0.047 \)).

**DISCUSSION**

Our results suggest that early life social housing has effects on human-directed behaviors of dairy calves, which persist for at least a short time postweaning, with calves housed individually appearing more motivated to engage in several human-directed behaviors compared with calves housed in pairs. It has been speculated that animals who are housed individually have stronger responses to human-animal interactions and increased possibility of developing a human-animal relationship due to a solitary environment (Ward and Melfi, 2015). Similar to our findings, Duve et al. (2012) found that individually housed calves tended to make more human contact and were quicker to approach a human during stationary tests within the home pen compared with calves housed in pairs, and calves reared with their dam were the least likely to approach a human in the home pen. This could suggest that calves housed with conspecifics bonded more with either the dam or their peers (Krohn et al., 2003; Raussi et al., 2003; Duve and Jensen, 2011), whereas calves housed individually may have bonded with humans. Lensink et al. (2001) also found that pair-housed calves were generally less likely to accept contact from humans. However, they found that calves who received additional human contact were less latent to make or accept contact with humans (Lensink et al., 2001), suggesting an effect of human contact on subsequent human-animal relationships.

Contrary to our hypothesis that human-directed behavior may increase over time, we found relatively similar responses across repeated home pen approach tests during the preweaning period. In contrast, Jago et al. (1999) found that, as calves age (62 vs. 17 d of age), latency to contact humans increased and duration of time spent near humans when another calf was present decreased. This coincides with previously noted increases in social behavior between conspecifics as calves age. For example, calves perform more frontal pushing, a component of social play, at wk 7 compared with wk 6 of life (Bertelsen and Jensen, 2019). We had predicted that an increased motivation to socialize as calves age may translate to increased human-directed behavior over time in individually housed calves. However, our results suggested that responses in the preweaning home pen approach test were relatively consistent over time. A limitation of the present study was the inability to assess development of human-directed behavior over longer time intervals, as preweaning testing was constrained to only 2 time points at wk 3 and 5 of age. It is possible that repeated testing over longer intervals or at a later period in life may shed more light on the development of human-directed behavior.

For all home pen testing in the present study, it is important to note that multiple humans were used for the approach. In avoidance distance testing done by Napolitano et al. (2011), only one observer was used to avoid nuisance effects of multiple observers. We suggest that our use of multiple test humans could be viewed as either a limitation, as it introduced a nuisance variable to be accounted for in the analysis, or a strength, as it may improve the external validity of this study. There

**Table 4.** Behavioral responses to a human approach test conducted in the home pen for group-housed calves (\( n = 4/\text{pen} \)) during wk 8 of life, with mingled groups formed of calves previously housed individually (IH; \( n = 17 \)) or in pairs (PH; \( n = 17 \)) prior to weaning

<table>
<thead>
<tr>
<th>Response</th>
<th>IH</th>
<th>PH</th>
<th>SE</th>
<th>( F_{1,19} )</th>
<th>( P )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looking toward human (s)</td>
<td>53.0</td>
<td>30.0</td>
<td>9.4</td>
<td>5.64</td>
<td>0.08</td>
</tr>
<tr>
<td>Human contact(^1)</td>
<td>0.47</td>
<td>0.12</td>
<td>0.12</td>
<td>4.48</td>
<td>0.048</td>
</tr>
<tr>
<td>Self-grooming(^1)</td>
<td>0.44</td>
<td>0.31</td>
<td>0.15</td>
<td>0.52</td>
<td>0.48</td>
</tr>
<tr>
<td>Response score for approaching human(^2)</td>
<td>1.2</td>
<td>0.7</td>
<td>0.3</td>
<td>1.57</td>
<td>0.23</td>
</tr>
<tr>
<td>Response score for human reaching out(^2)</td>
<td>1.8</td>
<td>0.6</td>
<td>0.5</td>
<td>4.69</td>
<td>0.043</td>
</tr>
<tr>
<td>Latency to lie down after testing (min)</td>
<td>18.5</td>
<td>18.1</td>
<td>3.6</td>
<td>0.01</td>
<td>0.91</td>
</tr>
</tbody>
</table>

\(^1\)This behavior was not performed by a fraction of calves and so was analyzed as a binary outcome (1 = any occurrence of the behavior; 0 = no occurrence of the behavior), and results are reported as ratios.

\(^2\)Score data were collected using a scale of 1 to 4, with 1 indicating avoidance of the human during testing and 4 indicating proximity near the human for the entire duration of testing.
is evidence to suggest that calves can discriminate between individuals based on how they are treated by said individual (de Passillé et al., 1996). Although all test humans in our study had a similar role and level of contact with study animals, it is possible that some animals may have developed a preference for some individuals over others.

Some effects of housing treatment were also evident in the novel arena approach test, with individually housed calves spending more time looking toward the human. However, latency to contact the human and total duration of human contact during the novel arena approach test did not differ between treatments. The duration of human contact was also numerically lower in the novel arena approach test, compared with the home pen approach test. Napolitano et al. (2011) found that sheep avoidance distances were significantly lower when a human approached from the feed bunk, likely because animals are highly motivated to feed. Additionally, some animals may have become accustomed to human presence surrounding feeding and feeding times, and they may perceive humans near the feeding bunk as less threatening or frightening than in other contexts (Napolitano et al., 2011). Although testing occurred several hours after feeding time, familiarity with humans approaching to deliver feed may increase comfort with humans during our home pen approach test. de Passillé et al. (1996) suggest that fear of humans may not be generalizable across contexts and environments for some animals, which could explain the differences in behavior observed between testing contexts in our study. Similarly, interest in humans (or indifference toward human presence) may not be consistent across testing contexts, if behavioral motivations in the novel testing arena competed with fear of the novel environment or motivation to explore.

Importantly, previous work suggests that individually housed calves are more fearful in an open field test, spending more time in the center of the arena and having higher heart rates (Jensen et al., 1997), and it is possible that differences in fearfulness may explain some behavioral differences between treatments in the arena test in the present study. In contrast to individually housed calves, we found that pair-housed calves performed more pen-directed non-nutritive oral behaviors during the arena test despite the human approaching the calves at 2 separate instances during the 5 min testing period. It is possible that the novel environment stimulated curiosity and an increased motivation to explore in pair-housed calves, whereas individually housed calves may have been more fearful as well as more human-directed. It is important to note that pair-housed calves were in the presence of their penmate for the home pen approach test, whereas all calves were tested individually in the arena approach test. Stress buffering effects of social contact are well documented across species, with social contact resulting in reduced behavioral and physiological indicators of stress associated with novel object tests (in horses; Ricci-Bonot et al., 2021) as well as social stressors, such as maternal separation (in piglets; Kanitz et al., 2014).

Individual differences in response to social separation, from pen-mates as well as adjacent calves, as well as differences in reactivity to the testing arena may affect correlation between response scores recorded during the first home pen and arena approach tests. We found no correlation between testing contexts of the human response scores recorded during human approach and when the human reached out their hand. However, we did find that the total duration of human contact during the novel arena test and the first home pen approach test were positively correlated. Other studies have found that novel testing environments influence animal behavior, suggesting that the external validity of these findings may be limited in some cases. For example, calves reared with their dams exhibited an increased avoidance distance compared with calves reared artificially without the dam present in the home pen, but no significant differences were detected in avoidance distance when calves were tested in a novel testing area (Waiblinger et al., 2020). There is also evidence that calves can discriminate between humans who provide either positive or aversive handling in the home pen but lose the ability to do so when tested in a novel pen (de Passillé et al., 1996). In contrast, some evidence suggests that calves receiving some type of additional human contact exhibit increased human-directed behavior consistently across multiple testing contexts. Jago et al. (1999) found that dairy calves who were not fed by humans but received handling from humans were more likely to approach and interact with a person in both a test arena and their home pen. Similarly, across tests in both the home pen and a novel arena test, Lensink et al. (2000) found that individually housed dairy calves receiving additional human contact exhibited generally increased behavior directed toward familiar and unfamiliar humans, compared with calves that had received minimal human contact. The present findings suggest some individual consistency in duration of human contact across both home pen and novel arena approach tests. However, the lack of correlation between response scores during specific stages of testing, including the human approach and human reaching out a hand, suggests some individual variability in human-directed behavior when tested in the home pen, in the presence of other calves, and when tested alone in a relatively novel environment.
We found that pair-housed calves tended to lie down more quickly following the human approach tests in the home pen. This may be indicative of a reduction in arousal following testing. More generally, previous findings suggest that socially reared calves are less reactive to novel social contexts. For example, Lindner et al. (2021) found that there was a tendency for calves who had been housed in pairs to have an increase in lying time upon grouping, compared with previously individually housed calves. Rest of pair-housed calves may therefore be less disrupted by external events, and particularly social changes. Interestingly, Veissier et al. (1997) postulate that due to social deprivation, individually housed calves must spend more time active to seek out stimulation, implying that lying time may also be related to the amount of environmental stimulation an animal receives. Provision of stationary brushes to individually housed calves was previously found to increase the duration of rest and decrease non-nutritive oral behaviors surrounding milk-feeding (Horvath et al., 2020). Coupled with level of activity is underlying motivation to engage in natural behaviors; if animals are permitted to engage in highly motivated behaviors, their needs will be better met, and they may dedicate more time to resting behaviors. For example, provision of an automatic concentrate feeder that feeds out small portions of grain at a time throughout the day caused stabled horses to exhibit significantly more lying behavior (Hoffman et al., 2012). Therefore, increased activity in the time period around the human approach test may have been motivated in part by stimulus seeking related to human contact.

We noted short-term carry-over effects of previous social housing treatment on human approach behavior in home pen testing once calves were mingled between treatments and group-housed. Our findings contribute to an understanding of how early social housing, and particularly pair housing of calves, may potentially influence the development of human-directed behavior and result in differences that persist after weaning. Specifically, we found that previously individually housed calves tended to look toward the human for longer and were more likely to contact the human than calves reared in pairs, during postweaning human approach tests in the group home pen. During this short-term test, we found that not all calves approached the test human, but that orientation toward the human additionally reflected differences between treatments. It is possible that other differences may have been apparent with a longer period of human presence or handling. Mogensen et al. (1999) found effects of housing during the first 12 wk of life on response to repeated human approach tests on pasture once heifers were 14 to 16 mo of age; flight distances were greatest in calves reared in cow-calf pairs, following by calves reared in groups, calves reared individually with visual contact, and calves individually without visual contact. Boissy and Bouissou (1988) also described longer-term effects of varying human contact on human-directed behavior, with prolonged, early life human contact reducing fear responses observed at 15 mo of age during reactivity tests that involved a human. Effects of early life housing can be seen on other dairy calf behaviors outside of human-directed behaviors. It is well established that social housing before weaning affects social development and response to novel events (Costa et al., 2016). For example, previous social contact results in increased social lying, particularly with familiar calves, following subsequent grouping (Færvik et al., 2007; Lindner et al., 2021). Early life social contact has also been found to increase preference for a conspecific rather than a human, when tested in a Y-maze (Raussi et al., 2003).

The present findings contribute to a growing body of work suggesting that early life social contact may have implications for development of social behavior, both between conspecifics and human-animal relationships. It is important to consider how this may affect handling and management. Although positive human-animal relationships and reducing fear around humans are beneficial for animal welfare (Waiblinger et al., 2004), a high motivation for human contact, and a low reactivity to humans entering the flight zone, may create challenges for animal handling. For example, survey-based data indicates that humans with a more positive attitude foster more positive relationships with their animals, suggesting that frustration arising when working with animals that are difficult to handle may lead to more negative tactile interactions between producer and animal (Breuer et al., 2000). Mogensen et al. (1999) found that prolonged early life isolated housing reduced later flight distance during human approach tests but did not affect behavior during milking, suggesting a possibility that social housing may affect preference for human contact without affecting ease of handling. In the present study, our observations were conducted during a short time frame postweaning. Further work is encouraged to better understand how typical approaches to rearing dairy calves with social contact may have longer-term effects on human-directed behavior and ease of handling.

CONCLUSIONS

We assessed human-directed behaviors of dairy calves housed individually and in pairs over time and across testing contexts. Individually housed calves engaged in more human contact and human-directed non-nutritive oral behaviors in their home pens com-
pared with pair-housed calves and directed more attention toward humans in an arena approach test. We also found evidence of short-term carry-over effects of previous housing treatment once calves were mingled between treatments and group-housed following weaning, with calves previously housed individually more likely to contact a human. These results suggest that social housing of dairy calves affects development of human-directed behavior, which may have longer-term implications for heifer management and welfare.

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