Relative motivations of dairy cows to be milked or fed in a Y-maze and an automatic milking system

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Abstract

The relative motivations of cows to be milked or fed were examined in four experiments. In experiments I and II, six high (HY, 33.9 l/day, s.d. 5.4 l) and six low (LY, 13.8 l/day, s.d. 1.6 l) yielding dairy cows were given the choice to be milked or not in a Y-maze five times/day every 3.5 h. The mean number of milkings chosen/cow-day during the last 3 days of each part of each experiment was 3.3 (max 5, min 0) for the HYs and 2.1 (max 4, min 0) for the LYs, but this difference was not significant (P > 0.05). In experiment III, six HYs (35.2 l/day s.d. 3.1 l) were given the choice between being milked or fed 0.33 kg of pelleted concentrate food. At every opportunity the cows chose to be fed. In experiment IV, 12 cows (6 HY and 6 LY, yielding 27.5 l/day (s.d. 3.36 l) and 13.6 l/day (s.d. 3.55 l) respectively) were allowed voluntary attendance to an automatic milking system (AMS) for 15 h/day. The mean number of milkings chosen/cow-day over the 8 days was 1.2 (max 4.1, min 0) for the HYs and 0.8 (max 3.6, min 0) for the LYs, but this difference was not significant (P > 0.05). When fed concentrate (HYs: 4 kg/day, LYs: 2 kg/day) in the AMS, the HYs' milking choices rose significantly to a mean of 4.0 (max 6.6, min 0.3) (P < 0.025), and the LYs' rose non-significantly to 1.6 (max 5.6, min 0) (P > 0.05). Individual cows may find milking either positively or negatively reinforcing, but overall, the motivation to be milked is weak. Food is significantly more rewarding than milking and likely to be a necessary incentive to attract cows to an AMS. © 1998 Elsevier Science B.V.

Keywords: Cattle-milking; Milking systems; Choice tests

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1. Introduction

Whether cows gain some reinforcement from being milked is important for a number of reasons. Firstly, the commercial success of any automatic milking system (AMS) initiated by voluntary visits from the cows will depend, in part, on their motivation to enter the system. If they choose to attend more frequently than twice daily, we would expect an increase of 10 to 15% in milk yield (Hillerton and Winter, 1992; Knight and Wilde, 1993) provided that their nutrition is satisfactory and they have appropriate space and time for eating and rest (Webster, 1995). Attendance less than twice per day would reduce milk yield due to autocrine feedback inhibition of alveolar milk secretion (Wilde and Peaker, 1990). Reduced milking frequency may also increase the incidence of mastitis (Hillerton and Winter, 1992). Too frequent a level of attendance may lead to the system wastefully processing cows for whom there is no economic advantage to milk.

To date there have been no automatic milking trials which separate the motivation of the cow to be milked from that to be fed (e.g., Rossing et al., 1985; Winter and Hillerton, 1995). However, the relative motivations of cows to attend the system may influence how it is designed. For example, if cows are strongly motivated to be milked per se, then there will be little need to provide additional rewards in the system, e.g., food, to encourage further attendance up to a predetermined level. Alternatively milking may generate a weaker incentive than food for cows to enter the system and could lead to a more optimal level of attendance.

Secondly, if cows gain some reward from being milked, then systems that allow free access to a milking station will have advantages to cows over systems that do not, principally by allowing them greater control over their environment, which has been associated with improved welfare (e.g., Wathes, 1997; Wiepkema and Koolhaas, 1993). Thirdly, and allied to the second reason, is public perception of conventional and novel milking systems will be enhanced if cows are shown to find milking positively reinforcing.

There are at least three theories why a dairy cow may gain some reward from being milked. First is the discomfort of a large and distended udder (Rathore, 1982). This may be true in the early stages of lactation when the udder's cell number, size and differentiation increase as milk yield increases up to a peak (Knight and Wilde, 1993), the discomfort of which may be relieved by milking. Rathore (1982) found that cows yielding more milk volunteered to enter a conventional parlour earlier than cows yielding less. However, Hidar et al. (1973) and Winter (1993) found no such effect.

An alternative theory is that cows may enjoy being milked for psychological reasons in that it satisfies some motivation to suckle a calf, a motivation which may wane through lactation mirroring the natural weaning process. Both Trivers (1974) and Bateson (1994) suggest that with time there is a decline in the parental investment in their young. Here parental investment may be the provision of milk, although the potential for this to be expressed in the "unnatural" circumstances of a milking parlour will depend on how the decline is facilitated.

A declining motivation to be milked through lactation, for physical or psychological reasons, has some support in natural cow–calf interactions, although the relative contributions of dam and calf to the observed suckling frequency is unknown. Early in
lactation a calf sucks between five and eight times per day. As the calf grows older however, this declines to between three and five times per day (Phillip, 1993). Day et al. (1987) found that calves 52 days old sucked more often than calves 167 days old (8.6 vs. 4.5 suckles/day) and that the older calves sucked for less time per day than the younger calves (64 vs. 44 min./day). Odde et al. (1985), however, showed that calves sucked on average five times per day (range 1–11) but there was no effect of calf age on this frequency.

The third potential reason for a dairy cow to choose to be milked is that the process of letting down or milking is positively reinforcing. Let down may be positively reinforcing due to the involvement of the hormone oxytocin, which is implicated in sexual arousal and orgasm in some animals (for a review see Anderson and Dennerstein, 1995). Milking may be positively reinforcing due to tactile stimulation of the cow’s teats by the milking system.

Two studies are described here. In the first (experiments I, II and III), the effects on motivation to be milked of stage of lactation, udder fill and a competitive motivation to receive a food reward were studied in a Y-maze. In the second study (experiment IV), the effects of stage of lactation and the provision of food reward were studied in relation to voluntary attendance at an automatic milking system.

2. Materials and Methods

2.1. Experiment I, II and III

2.1.1. The Y-maze

The maze (see Fig. 1) was 8.5 m long, had solid sides 1.8–2.0 m high and passageways 1 m wide. The floor was concrete, sloping gently upwards towards the end of the maze.

The maze consisted of a holding stall, a decision area and two spurs, each separated by doors. The entrance to the holding stall had a strong, side-hinged gate designed to hold cows and prevent them reversing. The exit of the holding stall was via one-way full-length double doors. The doors opened into the decision area when a latch was
operated remotely. The opposite end of the decision area had two exits, one into each of
the left and right spurs. At the end of each spur were wooden doors. Once the cows had
been through the maze they could return to the living area via a return race down one
side of the maze.

A milking machine was located either side of the maze at the end of each spur, this
gave similar milking conditions to that received by the cows in the farm’s main parlour
(vacuum level of 45 kpa and pulsation rate of 56 per min). To reach the cow’s udder, a
lower portion of each side of the maze was cut away and hinged, providing a flap which
could be opened or closed. Holes were also cut into the side of the maze so a bar could
be positioned behind the cow to prevent her reversing out of the spur while being
milked.

Full details of the Y-maze and the milking equipment can be found in the work of

2.1.2. General method

During the experiments the cows were herded into a collecting ring at specified times
and allowed through the maze individually. If they did not choose the milking spur, they
were allowed to return to the living area. If they did choose the milking spur, the exit
door at the end of the spur was locked shut and a bar positioned behind the cow,
preventing her leaving the spur either forwards or backwards. When the cow had been
restrained, the flap in the side of the maze was opened and the cow’s teats cleaned.
Immediately following this, the teat cups were attached and the cow milked. When the
cow had finished milking, the teat cups were removed, her teats dipped in disinfectant,
and she was let out and was free to return to the living area via the return race. The next
cow was then allowed into the decision area and given the same choice. The cows were
free to enter the holding stall in any order. During trials the floor of the maze was kept
wet but not cleaned between trials, except in the rare event of defecation or urination
when it was hosed clean.

2.1.3. General Experimental design

In each of the three experiments detailed below the cows were trailed through the
maze every 3.5 h five times per day. For the first experiment the times at which each
trial started were 0700, 1030, 1400, 1730 and 2100. For the remaining two experiments,
each trial started 1 h earlier. The cows were milked a minimum of twice per day. If any
cow failed to choose to be milked at the first trial of the day she was made to be milked,
after being allowed an initial voluntary choice, at the second trial. If she had not chosen
to be milked at the third or fourth trial she was made to be milked, after an initial
voluntary choice, at the fifth trial. Equally if a cow had chosen to be milked at the first,
second and third trial, she was made to use the non-milking spur at the fourth trial, after
an initial voluntary choice (this was to help prevent the generation of a preference for
one side of the maze). Therefore, a cow who never chose to be milked would have had
an ‘enforced’ milking interval of approximately 13.5 h overnight and 10.5 h during the
day.

Each experiment followed a similar design. Six cows were divided into two groups or
three. Group I were trained to associate one side of the maze with one treatment and the
other with the other treatment. Group 2 were similarly trained but with the treatments reversed between the spurs. The cows were then allowed to choose between the treatments five times per day for 9 days. The treatments were then transferred between the spurs for each group; the cows retrained and the experiment continued for a further 9 days with five trials per day. This design was adopted to identify any cows who chose a particular spur despite the treatment it contained.

Each experiment involved two similar training periods, each 3 days long, the first at the beginning, and the next midway through the experiment after the transfer. A training day consisted of the cows being milked three times per day in the appropriate spur at the first, third and fifth trial session. At the second and fourth trial sessions, the cows were made to use the non-milking spur. Each cow experienced milking nine times and non-milking six times in the appropriate spur during each trial period.

2.1.3.1. Experiment I (Milk vs. nothing, high yielders). Six high yielding, early lactation (HY) cows (mean yield of 33.9 l/day, s.d.5.4), and 129 days in milk (s.d.29.3) were given the choice between being milked or not. The first half of the experiment consisted of 8 days and the second continued for 9 days.

Two cows (3 and 5, see later) contracted mastitis in the second half of the experiment. They were treated in the recommended manner with intramammary antibiotic infusions administered in the cubicles not in the maze to prevent the cows from associating the maze with negative consequences. Neither cow appeared alarmed by the procedure.

2.1.3.2. Experiment II (Milk vs. nothing, low yielders). This experiment was the same as the previous experiment. However, the cows were later in lactation (264 days, s.d.11.3) and yielding less than half the amount of milk (13.8 l/day, s.d.1.6). It was intended to use the same cows in this experiment as were used in the previous experiment, but at a later stage of lactation. By the time the former cows were in late lactation, however, one was chronically lame, one dried off and another had mastitis. These were replaced by cows of similar yields. Three cows however, 1, 2 and 4 (see later), were used in both experiments.

2.1.3.3. Experiment III (Milk vs. food, high yielders). This experiment gave six cows the choice of being milked or receiving 0.33 kg of food in a large (10 l) grey plastic bucket. The food was a commercial dairy cow ration (BOCM/Pauls 1592 dairy nuts). The cows had a mean milk yield of 35.2 l/day, (s.d.3.1) and were 129 days in milk (s.d.21.4).

2.2. Experiment IV: materials and methods

2.2.1. The automatic milking system (AMS)

A detailed description of the AMS are given by Street et al. (1992) and Mottram et al. (1995). The AMS was located adjacent to a bedded area. If a cow visited the AMS and had not been milked within the last 4 h, she was milked. The cow’s teats were cleaned in the milking stall and the teat cups attached. The teat cups were removed from each teat manually when each quarter had milked-out, and her teats disinfected. The milking stall exit door was then opened, allowing the cow to walk from the milking stall into the
exit area. If the cow had been milked in the last 4 h, she was let straight through the milking stall into the exit area without being stopped. The cows were not fed in the milking stall.

The system was available to the cows between 0400 and 2230, but between 1330 and 1400 the system was closed for cleaning.

Any cow that failed to attend the AMS during the day was milked after the system had been closed to voluntary traffic (2230). Between 2230 and 0400 all the gates between the bedded area and the exit area (via the milking stall) were opened allowing the cows free access to the exit area.

2.2.2. Experimental design and data recording

Six HYs (mean yield of 27.5 l/day (s.d. 3.36); 151 days in milk (s.d. 20.6)) and six LYs (mean yield 13.673 l/day (s.d. 1.35); 276 days in milk (s.d. 7.9)) were used in this experiment. The experiment comprised two 8-day periods, the first involved giving the cows no food reward in the AMS. In the second period, the cows were fed concentrate in the exit area of the milking stall via two automatic concentrate feeders (ALPRO, Alfa-Laval). Cows in early lactation received 4 kg of concentrate per day, while cows in late lactation received only 2 kg per day. The concentrate was rationed on a variable interval schedule where the cow could receive as much concentrate as had accrued since her last visit, as a proportion of her 24 h ration. This schedule ensured that a cow was always rewarded for a visit provided she did not return within 30 min of the last visit. The cows were also fed a complete ration available ad lib in the bedded area. This diet contained (as a proportion of fresh weight) 46% maize silage, 36% grass silage, 16% whole crop cereal and 20% straw. The resulting mix, as dry matter, provided 11.5 MJ/kg metabolisable energy and was 18.3% crude protein. This was calculated to meet the requirements for maintenance plus 20 l of milk.

The time at which each cow entered, whether she was milked or not, and the time taken to enter and exit the milking stall were recorded manually.

For 10 days before the start of the experiment the cows were trained. The first 3 days involved running the cows through the system without milking them. For the remaining 7 days the cows were batch milked twice per day to accustom them to the milking process.

2.3. Data analysis

In all experiments comparisons between different animals were made using the Mann–Whitney U test (U). Comparisons between treatments for the same animals were made using the Wilcoxon Matched Pairs test (W). Trends in data over the course of an experiment were analysed using the Spearman’s Rank test (S).

3. Results

3.1. Experiment I, II and III

The number of milkings for each cow in experiments I, II and III are shown in Table 1. The data represent the total number of milkings over the last 3 days of each part of
Table 1
Mean number of choices to be milked (maximum of 5) made by individual cows per day, derived from the last 3 days of each half of each experiments I (high yielders; milking vs. nothing), II (low yielders; milking vs. nothing) and III (high yielders; milking vs. 0.33 kg of concentrate). The six data columns show the choices made by each of the six cows used for each experiment.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Cow numbers</th>
<th>Individuals' choices</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1–6</td>
<td>4.8</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2</td>
<td>4.0</td>
</tr>
<tr>
<td>II</td>
<td>7–12</td>
<td>0.7</td>
<td>3.8</td>
</tr>
<tr>
<td>III</td>
<td>13–18</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Each experiment for each cow, therefore the number of choices available was 30. Some cows appeared motivated to be milked. In experiment I, cows 1, 4 and 5 all chose to be milked frequently, and followed the milking treatment as it was transferred between the spurs of the maze. Other cows appeared indifferent. For example, cow 6 in experiment I initially chose to be milked but when the treatment was transferred between the spurs she continued to choose the same spur and, consequently, was not milked. Some cows appeared averse to being milked. In experiment II, cows 7, 11 and 12 largely avoided the milking spur. There was no significant difference in the number of milkings chosen by the high and low yielders in experiments I and II ($U = 45.0, P > 0.05$, $n_1 = 6, n_2 = 6$). Fig. 2 however, plots the total number of milkings chosen by the cows for each day of the experiment. In experiment I, the cows (as a group) increasingly chose to be milked, and this trend was significant for both halves of the experiment ($S = 0.98$ and 0.68;
Table 2
Mean number of visits made by individual cows per day to the AMS (experiment IV) derived from eight days when they were fed and when they were not, for both high and low yielders. The six data columns show the choices made by each of the six cows used for each experiment.

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment</th>
<th>Cow numbers</th>
<th>Individuals’ choices</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>High yielders</td>
<td>Not Fed</td>
<td>19–24</td>
<td>1.1 1.0 0 0.5 4.1 0.5</td>
<td>1.2^*</td>
</tr>
<tr>
<td>Low yielders</td>
<td>Not Fed</td>
<td>25–30</td>
<td>0 0 0 1.3 0.4 3.6 0.8</td>
<td></td>
</tr>
<tr>
<td>High yielders</td>
<td>Fed</td>
<td>19–24</td>
<td>3.4 5.5 0.3 2.5 6.0 6.6 4.1^b</td>
<td></td>
</tr>
<tr>
<td>Low yielders</td>
<td>Fed</td>
<td>25–30</td>
<td>0.1 0.1 0 1.6 1.9 5.6 1.6^b</td>
<td></td>
</tr>
</tbody>
</table>

^Rows with the same superscript differ by P < 0.05.
^Rows with the same superscript differ by P < 0.01.

P < 0.01 and P < 0.05: n = 8 and n = 9 for the first and second halves of the experiment, respectively. In experiment II, the cows showed a significant but reversed trend to this in the first half of the experiment (S = -0.73; P < 0.05; n = 9) but not in the second half (S = 0.13; P > 0.05; n = 9). These data suggest that for the HYs as a group, voluntary milking may have been significantly reinforcing but this was not true for the LYs.

When the cows were given the choice between being milked or fed (experiment III) they all chose to be fed at every opportunity.

3.2. Experiment IV

The data are shown in Table 2. When the cows were not fed, attendance was low for both the HYs and LYs alike, with a mean of 1.1 visit/cow-day. The variation was relatively high however (s.d. = 1.63), some cows did not volunteer to visit at all while two cows, one in the HY and one in the LY group, accounted for 62% of all visits. There was no significant difference in the number of milkings between the HYs and LYs (U = 44.5; P > 0.05; n_1 = 6, n_2 = 6) when the cows were not fed when they visited the AMS. When the cows were fed in the AMS the HYs attended significantly more often than they had when not fed (W = 0; P < 0.025; n = 6), and more often than the LYs (U = 51.0; P < 0.01; n_1 = 6, n_2 = 6). The LYs did not attend more often when fed than when not (W = 21; P > 0.05; n = 6).

4. Discussion

The results suggest that motivation to be milked is weak, variable and may be independent of stage of lactation. The high yielders did increasingly choose to be milked as experiment I progressed, while the low yielders did not, implying that milking may have been positively reinforcing in early lactation only. However, in contradiction, a Mann-Whitney U test found no significant difference in the number of milkings chosen by the high and low yielders. Udder fill seems unimportant, because most of the high yielders and some low yielders chose to be milked at the minimum milking interval of
3.5 h in the Y-maze, at which interval there will have been little milk in the udder. This was not recorded but presuming milk synthesis rates of 1.06 l/h (s.e. = 0.08) and 0.46 l/h (s.e. = 0.03) for high and low yielding cows, respectively (Knight et al., 1994), would give yields of 3.7 l and 1.6 l for each group after a 3.5 h milking interval. The cows may, therefore, either be deriving some physical reward from being milked (e.g., tactile stimulation of the teats or the oxytocin release during let down), or some psychological reward, for example, they may associate the milking process with feeding a calf. The variability in the motivation to be milked suggests that some cows may find being milked negatively-reinforcing, whereas, for other cows milking may be positively-reinforcing.

There are three reasons for concluding that motivation to be milked was weak. First, the cows took a comparatively long time to show evidence of learning an apparently simple response even after a training period (see Fig. 2). Secondly, the cows exhibited a high degree of variability in their response, implying a generally weak motivation. Finally, in experiment III the cows chose a food reward over being milked. On the presumption that strength of motivation is related to the speed and uniformity within a group, of learning a task, experiment III showed that motivation to eat a concentrate reward was significantly more rewarding, in comparison with the data from experiment I, than being milked.

In the AMS, the high yielding cows made significantly more visits when fed 4 kg of concentrate than when not fed. This confirms that the motivation to visit a milking parlour was higher when the cows were fed than when they were not. The low yielders did not significantly increase their level of attendance when fed which suggests that the 2 kg of concentrate was insufficient to increase their motivation to visit the system.

The cows did still make some visits to the system even when not fed, but there was little difference in the frequency of attendance between the high and low yielding cows. The low level of attendance does indicate some motivation to be milked (or at least visit the system) but in agreement with the Y-maze experiments, this motivation seems weak and variable between cows.

Two cows attended the AMS frequently even when not fed. In the case of cow 30, this may have been to escape the agonistic attentions of higher ranking cows. Cow 23 was not a low ranking cow and there is no obvious reason why she attended as often as she did. She was however, an extremely 'friendly' cow who often solicited attention from the farm staff and the AMS operators, therefore she may have been entering the system in an attempt to solicit attention.

This experiment suggested that the value of the reward could affect how often the cows attend the system, because the low yielders, fed only 2 kg/day, attended significantly less often than the high yielders, fed 4 kg/day, and no difference was detected when neither group was fed. The level of the food reward may have affected this as well as the difference in hunger that the high and low yielders may have felt. the high yielders probably being hungrier than the low yielders because they are producing more milk. Three cows in the low yielding group largely failed to visit the system voluntarily even when fed. This may be because the complete, forage-based diet available in the bedded area exceeded their nutritional requirements and they may not have been hungry (the diet was calculated to supply the needs of maintenance plus 20 l
of milk. One cow from the high yielding group often failed to attend the system even when fed (cow 21). When she was forced into the system, she often yielded more than 25 l, but always appeared nervous. She was an old cow, with a large udder, that took a long time to milk out and had a history of mastitis; for her, milking may have been a process to endure rather than enjoy.

In conclusion, motivation to be milked appeared weak, variable and not strongly related to stage of lactation, and is, therefore, unlikely to be a significantly important incentive for attracting cows to an AMS. Motivation to access a concentrate food reward was more robust and could be used reliably to attract cows into the AMS, provided the animals were not able to satisfy their motivation elsewhere. For some cows the provision of an automatic milking system may improve their welfare by providing them with more control over their environment but for others there may be no advantage.

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References


