WATER, FEED, AND MILK PRODUCTION RESPONSE OF DAIRY CATTLE EXPOSED TO TRANSIENT CURRENTS

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ABSTRACT. *A study was conducted to determine the level of 60 Hz transient current, relative to the short−term response threshold, required to affect feed and water intake, milk production, and cow behavior. Long−term exposure levels were set relative to the sensitivity of individual animals to short−duration exposure to take into account the wide range of sensitivities among cows. The groups were monitored for a 14−day pretreatment period, a 21−day treatment during which one cycle of 60 Hz transient current was applied to water bowls once every second, and a 14−day post−treatment period. Water intake, feed consumption, and milk production were monitored during the experiment. No changes in the 21−day average treatment period water intake or milk production were attributable to current exposure for any exposure level. A slight reduction in the 21−day average feed intake was observed at the highest exposure level. Reductions in water intake, feed consumption, and milk production were apparent in the first several days of the exposure period but only at the highest exposure levels. Animals showed an acclimation to the transient current exposure, with avoidance behaviors most prominent immediately after exposure and reduced avoidance response with increasing exposure time. The current level required to cause a short−term reduction in water and feed intake and milk production was higher than that required to produce a behavioral response.*

Keywords. *Animal health, Cattle, Dairy farming, Electric current, Stray voltage.*

Many studies have documented behavioral responses of cows to brief exposures to both steady and transient 60 Hz electrical current (Whittlestone et al., 1975; Norell et al., 1982; Henke−Drenkard et al., 1982; Lefcourt, 1982; Lefcourt et al., 1983; Gorewit et al., 1984; Gustafson et al., 1984; Appleman and Gustafson, 1985; Gorewit et al., 1985; Henke−Drenkard et al., 1985; Lefcourt et al., 1985; Lefcourt et al., 1986; Brennan and Gustafson, 1986; Aneshansley et al., 1987; Gustafson et al., 1988; Currence et al., 1990; Aneshansley et al., 1992; Reinemann et al., 1995a; Reinemann et al., 1996; Gorewit and Aneshansley, 1997; Aneshansley et al., 1997; Aneshansley and Gorewit, 1999; Reinemann et al., 1999; Reinemann et al., 2003; Reinemann et al., 2004). Reducing the phase duration (or increasing the frequency) of stimuli has been shown to dramatically increase the level of current required to elicit behavioral responses for both humans and cows (Gustafson et al., 1988; Reilly, 1994, 1995, 1998; Aneshansley et al., 1997; Aneshansley and Gorewit, 1999; Reinemann et al., 1999). The sensitivity to the same waveform stimuli has also been shown to vary considerably within the population of both humans and cows (Currence et al., 1990; Reilly, 1998; Reinemann et al., 1999). Studies with large samples have shown that the level of current required to elicit a behavioral response is approximately normally distributed within the population of humans and cows. The least−sensitive cows show behavioral responses at applied currents 2 to 4 times higher than the most−sensitive cows, for the same stimulus waveforms (Currence et al., 1990; Reilly, 1998; Reinemann et al., 1999).

The effect of longer−term exposure to steady 60 Hz voltages on aversion and reduced water intake and milk production of cows has also been examined. In the study reported by Gorewit et al. (1989), water intake, milk yield, and feed consumption were monitored before, during, and after 21−day exposure to 0.0, 0.5, 1.0, 2.0, or 4.0 V RMS of continuous 60 Hz AC voltage between water bowls and metal floor mats. Initial application of voltage caused group average delays in drinking, with increasing delay at the higher exposure levels. Of the 30 cows in this experiment, all resumed drinking quickly, except for two of the six cows in the 4.0 V exposure group who did not drink for 36 h. In a second experiment, all 84 cows exposed to 3.0, 4.0, 5.0, or 6.0 V RMS of continuous 60 Hz AC voltages between water bowls and metal floor mats for two days resumed drinking within the first day of exposure, except for two of the 21st parity cows in the 5.0 V treatment group and two of the 21st parity cows in the 6.0 V exposure group. Group average delays in drinking increased with exposure level, but the authors reported no significant difference in daily average water intake in any treatment group for those cows that resumed drinking. The voltage treatments also did not significantly reduce milk production and feed consumption. The application of a constant voltage between the muzzle immersed in a waterer and two hooves on a low−impedance

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floor contact (metal mat) resulted in variation in current applied to cows of about 2:1.

Aneshansley et al. (1988) investigated the effects 5 to 8 V RMS of discontinuous 60 Hz voltages applied to water bowls on water intake, milk production, milk quality, and SCC. Steady voltages and 1 s voltage pulses with fixed daily cycles and random events were examined. No significant changes in average water intake, milk yield, milk fat, milk protein, or SCC were reported for any treatment. However, some behavioral changes were noted. Although total daily water consumption did not change, cows drank more water than when the voltage was not present. Cows also appeared to adapt to fixed magnitude voltages applied for relatively long periods of time (2 to 6 h) more rapidly than to short (1 s) pulses applied repeatedly over the same periods of time.

Gorewit et al. (1992) exposed four groups of ten cows each to 0.0, 1.0, 2.0, or 4.0 V RMS of 60 Hz voltage for an entire lactation and reported no significant difference in group average 305−day mature equivalent milk weights, milk composition, feed or water intake due to voltage exposure. The contact pathway was from a waterer to a metal grid on the floor. The range of currents applied during this constant−voltage exposure experiment also varied by about 2:1. All cows resumed drinking within the first day, except for one first−lactation cow at the 4 V RMS treatment that refused to drink for 36 h and was removed from the study.

Gumprich (1992) and Gumprich and Giesen (1993) exposed 30 cows to uniform voltage levels from 0.3 to 5.0 V RMS of 60 Hz voltage applied between water bowls and expanded metal grids placed on the rear of the cow platform. Voltages were varied during the day with a low−level background voltage applied continuously except for two periods of higher−voltage exposure simulating increased neutral voltage during times of heavy electrical use on the farm (milking time). The level of current passing through the animals was not reported. No significant differences in milk production, SCC, feed, or behavior (urinating, defecating, and drinking) were reported between treatment and control groups at the 1.0 and 2.5 V (RMS, 60 Hz) exposure levels. At the 5.0 V RMS exposure level, no immediate or residual differences were found in milk production, SCC, milking time, or animal behavior, while a 2.6% reduction in water intake was reported.

The aversion studies by Gorewit et al. (1989), Aneshansley et al. (1988), and Gumprich and Giesen (1993) used a constant voltage applied to cows as the criterion for treatment levels. Current levels were shown to vary by about 2:1 with this method of exposure (Gorewit et al., 1989; Gorewit et al., 1992). Current level is considered a more reliable indicator of nerve stimulation and the accompanying sensation than voltage (Reilly, 1994, 1995, 1998). The application of fixed voltage (rather than fixed current) levels, although more representative of field conditions, introduces a source of considerable variability in the level of nerve stimulation and potential behavioral responses of cows. Another source of variability that has not been considered in previous studies is the range of sensitivity to voltage and current among dairy cows. The wide range of current sensitivity of individual cows, up to 4:1, (Currence et al., 1990; Reilly, 1998; Reinemann et al., 1999), introduces another large source of variability in expected responses. The objectives of this study were to:

- Investigate aversive responses to 60 Hz transient currents.
- Determine if using fixed−current exposures and taking individual animal sensitivity into account could improve predictability of aversive response to voltage/current exposures.

MATERIALS AND METHODS

Eight experimental stalls were constructed so that treatments could be administered to six stalls individually, with two stalls serving as controls with no current exposure, as described by Reinemann et al. (1999). Transient currents were applied between the water bowl and the concrete floor of the test stalls. A sinusoidal, biphasic voltage was produced by a frequency generator and fed into a zero−crossing switching device. The switching device was set to pass one full sinusoid and then block the following 59 waves. The output of the switching device was thus one cycle of 60 Hz voltage every second. The output from the switching device was fed into a power amplifier, a transformer, and then to a common 300 V bus. The signal from the high−voltage bus was then passed through an individual decade resistance box, and this signal was applied to the water bowl in each respective stall. The resistance value of the decade box thus controlled the current applied to its corresponding stall.

The combined resistance of the water bowl, cow, and concrete pad typically ranged from 500 to 1500 Ω when cows were standing on clean concrete. Most of the variability in the circuit resistance was accounted for by the changes in the contact resistance at the hoof/pad interface. The nominal bowl/cow/pad resistance was assumed to be 1000 Ω for purposes of calculating circuit resistances (e.g., to apply 1 mA of current, the resistance was set at 299 kΩ, for a total circuit resistance of 300 kΩ, across which a source voltage of 300 V was applied). Sawdust bedding was applied to the rear of the stalls. The front half of the stalls were kept clear of bedding to facilitate good electrical contact and reduce variation in contact resistance. The applied current was tested periodically to ensure compliance with this specification. This method kept the applied current to within 4% of the desired value for peak currents up to 20 mA.

The transient current was administered to the water bowl every 1 s, as described above, so that the cows were exposed whenever they attempted to drink. Note that this article follows the convention used previously by the authors by expressing all current and voltage levels of transient events as the peak voltage or current. This differs from much of the stray voltage literature, which uses RMS voltages and current when describing steady exposure. The peak voltage and current values expressed here are, therefore, approximately 1.4 times higher than the same events expressed as RMS values.

Water meters were installed on the water bowl at each stall. These meters recorded the running total water consumption and the number of times the cow pushed the paddle in the water bowl to obtain water. These data were recorded several times per day. Feed intake was measured by the difference between the pounds of feed supplied and that not consumed during each day. Cows were moved from the test stalls to a milking parlor, where they were milked twice a day. Milk production was measured by milk meters and computerized milk records system in the UW Dairy Cattle Research Center.

Table 1. Summary of characteristics and sensitivity of cows.

Trial No.	Block No.	Stall No.	Cow No.	DIM at start	Lactation No.	ME 305 Prod. Level (lb)	Behavioral Response Level (Peak mA)		Treatment Type and Level	
							Pre	Post	Type	Peak mA
1	A	1	2068	44	6	17,390	6	7	R^{++}	9
1	A	2	3575	42	5	17,570	7	9	R^{+}	8.5
1	A	3	894	47	4	22,070	9	13	R	9
1	A	4	859	37	5	18,180	8	9	Control	0
1	B	5	3739	71	3	19,070	7	11	R	7
1	B	6	3740	56	3	19,710	9	13	R^{++}	12
1	B	7	3750	60	3	22,230	12	12	R^{+}	13.5
1	B	8	905	72	3	19,640	6	6	Control	0
2	C	1	3703	135	3	24,950	12	21	R^{+}	13.5
2	C	2	849	135	6	18,810	9	8	R	9
2	C	3	3808	155	2	20,292	7.5	8	Control	0
2	C	4	3594	154	4	19,970	9	7	R^{++}	12
2	D	5	3919	73	1	18,410	7.5	7	R^{++}	10.5
2	D	6	3910	74	1	16,580	8.5	8	R	8.5
2	D	7	3940	72	1	14,850	7.5	9.5	R^{+}	9
2	D	8	3932	72	1	18,670	13	12.5	Control	0
3	E	1	3868	46	2	17,870	11	12	R	11
3	E	2	923	54	3	15,720	11.5	8	R^{+}	13
3	E	3	3796	51	3	19,120	6.5	8.5	Control	0
3	E	4	3881	53	2	16,740	14	19	R^{++}	17
3	F	5	3566	46	5	19,850	13.5	18.5	R	13.5
3	F	6	3466	65	7	21,990	9.5	8	R^{+}	11
3	F	7	3767	58	3	19,880	12	13	Control	0
3	F	8	3771	64	3	22,270	11.5	12.5	R^{++}	14.5
4	G	1	3736	200	3	21,800	10	9	Control	0
4	G	2	3840	203	2	19,050	10.5	10.5	R*	15.5
4	G	3	839	205	2	19,120	10	15	R*	15
4	G	4	911	202	3	19,840	9	12	R*	13.5
4	H	5	3757	188	3	21,820	8	7	R*	12
4	H	6	3744	188	3	19,900	11	14	Control	0
4	H	7	3847	185	2	20,260	13.5	16	R*	20
4	H	8	3659	185	4	23,380	7.5	11	R*	11

Cows were blocked in groups of four based on lactation number, stage of lactation (±20 days in milk, DIM), and production level (±2000 lb. expected ME 305). The characteristics of the cows used in these experiments are shown in table 1. All cows were moved from other freestall or stanchion housing at the UW Dairy Cattle Research Center into the test stalls at least 14 days before the start of the treatment period (pre−treatment period). The transient current was applied to the water bowls once a second for 24 h per day for 21 consecutive days (treatment period). Cows were then observed for a period of 14 days after removal of the current exposure (post−treatment period). Two blocks of four animals were tested simultaneously.

In each block of four cows, one cow had no exposure and three cows were exposed to current levels specific to each cow's individual behavioral response threshold. The behavioral response threshold (R) of each animal was determined during the first 3 or 4 days of the pretreatment period. Animals were exposed through the nose−to−four−hooves pathway using methods previously developed (Reinemann et al., 1999) to determine a behavioral response threshold. Currents were applied in an ascending series until trained observers noted a repeated behavioral response (e.g., a blink, a jerk, a head lift) corresponding to the repeated application of a pulsed stimulus. Response threshold tests were repeated on consecutive days until two tests agreed to within 1 mA. The average of the lowest levels repeated within this specification was taken as the response threshold. This usually required no more than 3 days of testing per animal. The procedure to determine a response threshold required less than 20 min, with less than 5 min of current exposure per cow per day. At least 10 days transpired between these initial response threshold tests and the beginning of the treatment period. Response threshold tests were repeated in the post−treatment period, at least 7 days after exposure was stopped, to determine if the 21−day exposure period changed the behavioral response threshold.

For the first six blocks (A through F), one cow was exposed at her behavioral response current (R), one cow exposed at her response threshold plus 1.5 mA (R^{+}), and one cow exposed at her response threshold plus 3 mA (R^{++}). Within blocks, cows were randomly assigned to stalls and randomly assigned to exposure levels. The 1.5 peak mA increment was chosen because it was the standard deviation of the day−to−day variation in cow sensitivity in a previous study (Reinemann et al., 1999). One (R^{+}) or two (R^{++}) standard deviations above the response level was considered high enough to be clearly perceptible but not high enough to cause severe distress.

The results of the first six blocks, as described below, indicated that long−term response might be better predicted by a multiplicative rather than additive relationship to the behavioral reaction threshold. The types of responses exhibited in blocks A through F also indicated that increased levels relative to individual animal response thresholds would not cause cows distress. In the next two blocks (G and H), exposed cows received current in a multiplicative relationship to their response threshold. Each block of four cows had one control cow receiving no exposure and three cows exposed at their individual response threshold current times 1.5 (R × 1.5 = R*). The average additive increment above the response level was 4.7 mA with a range of 3.5 to 6.5 mA.

STATISTICAL ANALYSIS

Blocks A through F were structured as a completely randomized mixed−block experimental design. A mixed model with repeated measures analysis was performed to analyze treatment by period interactions for these blocks. The model used for this analysis was:

$$\begin{gathered} \mathit{response} = \\ \mathit{block} + \mathit{period} + \mathit{treatment} + (\mathit{treatment} \times \mathit{period}) \end{gathered} \tag{1}$$

where

response = daily water intake (L), daily feed consumption (kg), or daily milk production (kg)
block = blocks A through F, as indicated in table 1
period = pretreatment, treatment, and post−treatment
treatment = control, R, R^+, or R^{++}.

Cow, nested in block, was declared as the repeated, random variable, and an autoregressive correlation structure was assumed. The test of significance was $p < 0.05$.

Blocks G and H, which were used to test the multiplicative exposure method, were analyzed separately using the same mixed−model analysis but with treatments of control and R*. Two separate analyses were done because the experiment was repeated three times with blocks A through F with one control cow matched in time with the cows receiving tree different treatment levels within block and within period. The experimental design for blocks G and H differed in that one control cow was matched with three cows receiving the same treatment, and the experiment was not replicated at a different time.

RESULTS AND DISCUSSION

The results of the mixed−model analysis for blocks A through F (additive current method) are listed in table 2.

As expected, the block effect was significant for all response variables, indicating the differing production levels of the different blocks. The period effect was not significant for any response variable. The treatment effect was significant for water and feed, indicating that the cows in the different treatment groups had differing feed and water intake when averaged over the entire experimental period. The average daily water intake of the groups was: control = 106 L, R = 104 L, R^+ = 110 L, and R^{++} = 105 L, with the R^+ group having significantly more water intake than the R and R^{++} groups. The average daily feed consumption for the groups was: control = 39.8 kg, R = 37.0 kg, R^+ = 42.1 kg, and R^{++} = 39.9 kg, with the R^+ group having significantly more feed consumption than the R group. The average daily milk production for the groups was: control = 39.0 kg, R = 37.0 kg, R^+ = 39.5 kg, and R^{++} = 39.5 kg. The treatment × period interaction was not significant for any of the response variables, indicating that differences between treatment groups over time were not significantly different from the control groups or from each other (fig. 1). The detectable difference can be estimated from the standard error of the means indicated in figure 1.

The results of the mixed−model analysis for blocks G and H (multiplicative current method) are listed in table 3.

Table 2. Results of mixed−model analysis for blocks A through F.

Effect	P Value		
	Water	Feed	Milk
Block	**<0.0001**	**<0.0001**	**<0.0001**
Period	0.82	0.10	0.24
Treatment	**0.04**	**0.02**	0.18
Treatment × period	0.40	0.21	0.72

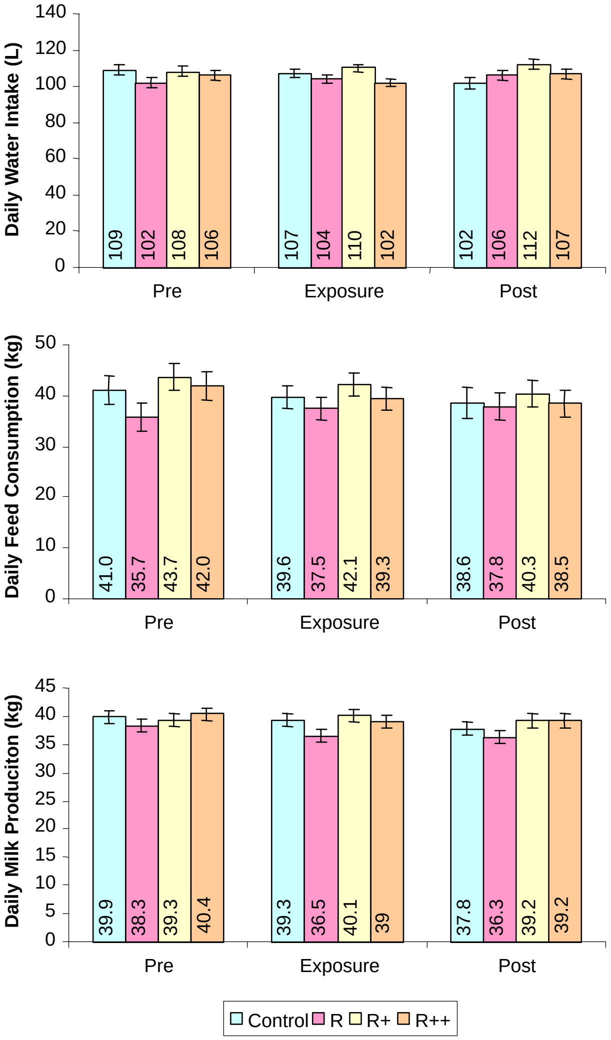

Figure 1. Treatment × period least squared means (LSM) for the additive current experiment. LSMs are indicated in each bar. Error bars indicate standard error of the estimate of the least squared mean (SEM). The treatment × period interaction was not significant. Detectable differences can be estimated from the SEM.

Table 3. Results of mixed−model analysis for blocks G through H.

	P Value		
Effect	Water	Feed	Milk
Block	**0.001**	**0.05**	**0.01**
Period	0.12	0.57	0.18
Treatment	0.07	0.44	0.68
Treatment × period	0.68	**0.006**	0.68

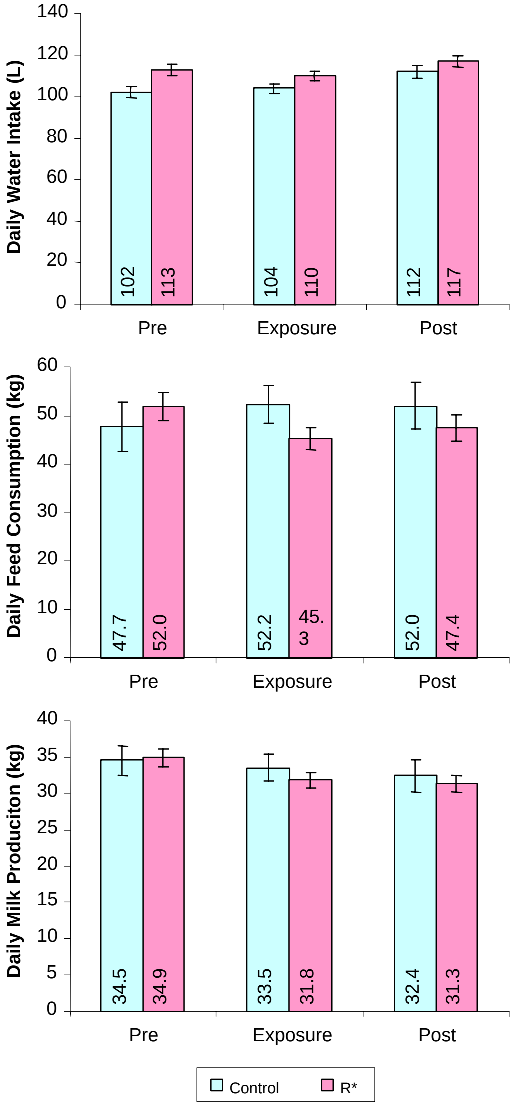

Figure 2. Treatment × period least squared means (LSM) for the multiplicative current experiment. LSMs are indicated in each bar. Error bars indicate standard error of the estimate of the least squared mean (SEM). The treatment × period interaction was not significant. Detectable differences can be estimated from the SEM.

The block effect was significant for all response variables, while the period and treatment effects were not significant. The treatment × period interaction was significant for daily feed consumption but not for daily water consumption or milk production (fig. 2). While the control group consumed somewhat more feed than the R* group in the pretreatment period, the R* group consumed somewhat less feed than the control group during the treatment period. The detectable difference can be estimated from the standard error of the means indicated in figure 2.

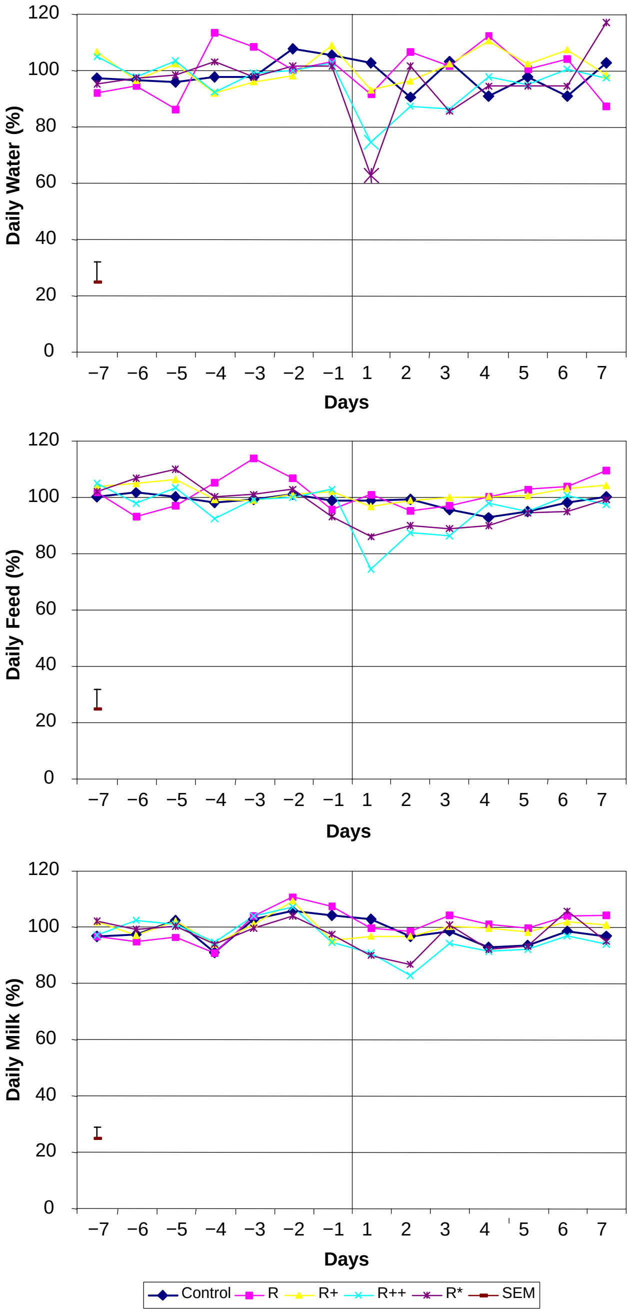

Figure 3. Treatment × day least squared means (LSM) for daily average water intake, feed consumption, and milk production normalized for individual cows. Days −7 to −1 are the first week before the exposure period; days 1 to 7 are the first week of the exposure period. The error bar in the lower left corner of each figure indicates the maximum standard error of the estimate of the LSMs. Detectable differences can be estimated from the SEM.

A clearer picture of animal response emerges when examining daily patterns. Daily water consumption for the control and for all treatment groups is presented in figure 3 for the 7 days immediately preceding the treatment period and for the first 7 days of the treatment period. The response variables are normalized to the percentage of each individual animal’s pretreatment average. The data for the first 7 days of current exposure were analyzed using a mixed model:

$$\mathit{response} = \mathit{day} + \mathit{treatment} + (\mathit{treatment} \times \mathit{day}) \quad (2)$$

Table 4. Significance of difference in daily least squared means for first week of current exposure.

	Control (*n* = 8)	R* Group (*n* = 6)	R^{++} Group (*n* = 6)	R^{+} Group (*n* = 6)	R group (*n* = 6)
Control (*n* = 8)	First Day → Days 2 −7 ↓	W_1 −39% ** F_1 −21% *** M_1 −11% *	W_1 −33% ** F_1 −14% * M_1 −12% *	W_1 ns F_1 ns M_1 ns	W_1 ns F_1 ns M_1 ns
R* Group (*n* = 6)	$W_{2–7}$ ns F_2 −19% * F_3 −15% * M_2 −11% *				
R^{++} Group (*n* = 6)	$W_{2–7}$ ns $F_{2–7}$ ns M_2 −14% *		First Day → Days 2 −7 ↓	W_1 ns F_1 ns M_1 ns	W_1 ns F_1 −15% * M_1 ns
R^{+} Group (*n* = 6)	$W_{2–7}$ ns $F_{2–7}$ ns $M_{2–7}$ ns		$W_{2–7}$ ns $F_{2–7}$ ns M_2 −12% *	First Day → Days 2 −7 ↓	W_1 ns F_1 ns M_1 ns
R group (*n* = 6)	$W_{2–7}$ ns $F_{2–7}$ ns $M_{2–7}$ ns		$W_{2–7}$ ns $F_{2–7}$ ns M_2 −16% **	$W_{2–7}$ ns $F_{2–7}$ ns $M_{2–7}$ ns	

W = water intake, F = feed consumption, and M = milk production. Subscripts indicate day of exposure (e.g., "F_2 = −19%" indicates that the feed response of the R* group was 19% lower than the control group on the second day of exposure).

Significance levels: ns = $p > 0.05$; * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.005$, and **** = $p < 0.001$.

Cow, nested in block, was declared as the repeated, random variable, and an autoregressive correlation structure was assumed. Blocks A through F (exposures R, R^{+}, and R^{++}) were again analyzed separately from blocks G and H (exposure 1.5R).

The significance of the differences in least squared means is presented in table 4. Suppression of water intake, feed consumption, and milk production were significant on the first day of exposure for both the R* and R++ groups, while the difference between the control and either the R or R+ groups was not significant. Suppression of feed consumption and milk production was also significant on the second day of exposure for the R* group, while only milk production was significantly reduced for the R++ group on the second day of exposure. Feed suppression continued into the third day for the R* group. By the fourth day of exposure, all response variables for all treatment groups returned to within the normal variation around the control group. Detectable differences can be estimated from the maximum standard error of the mean for each response variable indicated in figure 3.

CHANGE IN SENSITIVITY

The behavioral response thresholds measured during the pretreatment and post−treatment periods were compared using a paired, two−tailed t−test. The pre− and post−treatment behavioral response thresholds are shown in table 1. The mean pretreatment response thresholds were 9.3 and 9.7 mA peak 60 Hz current for the control and treatment cows, respectively. The mean post−treatment response thresholds were 10.0 and 11.4 mA peak 60 Hz current for the control and treatment cows, respectively. The mean difference between the pretreatment and post−treatment response thresholds was significant for cows exposed to transient current during the treatment period. The difference between the pretreatment and post−treatment response thresholds for the control cows was not significant.

DISCUSSION

The results of these experiments shed light on the current levels and the way that cows respond to forced voltage/current exposures. It is instructive to note the levels at which responses became significant as well as the exposure levels at which there was no significant response.

Cows exposed to current levels that were just sufficient to produce a behavioral response showed no reduction in daily water intake, feed consumption, or milk production measured either over the entire 21−day exposure period or the first day or week of the treatment period. The current exposures for this "R" group ranged from 7.0 to 13.5 mA (measured from zero to peak). As mentioned previously, these peak currents can be multiplied by 0.707 to approximate an RMS metric. Additionally, the equivalent behavior response threshold for a multiple−cycle stimulus is about 80% of the single−cycle (transient) stimuli used here (Currence et al., 1990; Reilly, 1998; Reinemann et al., 1999). The exposure levels at which no adverse effects were noted thus correspond to approximately 4.9 to 9.5 mA RMS for the single−cycle pulse and 3.9 to 7.6 mA for a multiple−cycle stimuli, or steady 60 Hz current. Assuming worst case and typical cow−plus−contact resistances of 500 and 1000 Ω, respectively (Lefcourt, 1991), this corresponds to a voltage exposures ranging from 2 to 7.6 V RMS.

As the current dose was increased above an individual cow's behavior reaction threshold, the short−term behavioral and aversive responses became apparent and more severe. However, even when the aversive responses were quite severe (cessation of drinking for up to 24 h), these cows resumed their normal daily water consumption within 4 days of exposure. The group with the highest current dose (the R* group) was exposed to currents ranging from 11 to 20 mA (zero to peak, corresponding to approximately 6.2 to 11 mA RMS and 3.1 to 11 V RMS for steady 60 Hz stimuli).

One of the objectives of this study was to determine if the exposure methods used here (constant current versus constant voltage, and exposure relative to an individual cow's sensitivity) would improve the predictability of aversive responses. Gorewit et al. (1992) reported that two cows from a randomly selected group of ten cows refused to drink for a period of 36 h when 8.0 V RMS of 60 Hz voltage was applied to their water bowl. While all of the cows in our study resumed drinking within 24 h using the R* exposure method, the 8 V RMS treatment used by Gorewit et al. (1992) falls in a range that could be a more severe exposure, if current application and individual animal sensitivities were taken into account.

Previous analysis of these data showed that, while total daily water consumption was not significantly different for the groups at the lower exposure levels, there was a significant delay to drink (Reinemann et al., 1995b). Cows at the higher exposure levels showed reduced total daily water intake on the first day of exposure to constant current. The percentages of animals in each treatment that reduced their water intake by 20% or more from their pre−exposure levels are shown in figure 4. One animal each in the control (one of eight cows), R (one of six cows), and R^+ (one of six cows) groups, 50% of cows in the R^{++} group (three of six cows), and 67% of cows in the R* group (four of six cows) had a 20% or more reduction in water consumption on the first day of exposure. The application of a constant current equal to 1.5 times each individual animal's behavioral response threshold thus appeared to produce a more consistent aversive response than constant voltage or additive current exposure methods.

The adaptation behavior seen in our study has been observed in several other studies. This suggests that, while the stimulus is clearly perceptible, and probably annoying, at the higher current exposure levels used in this study, it is not devastating. Behavioral adaptation may be due to the removal of the "surprise" element of a new stimulus and/or a cow's ability to mediate the effects of exposure. For example, the behavioral response thresholds were determined using a small contact area in the cow's nose. This results in a higher localized current density in the tissue in contact with the stimulus. A number of cows were observed to modify their drinking behavior by submerging their entire muzzle in the drinking bowl when current was present. This would provide a larger contact surface and reduce the maximum local current density in the muzzle tissue.

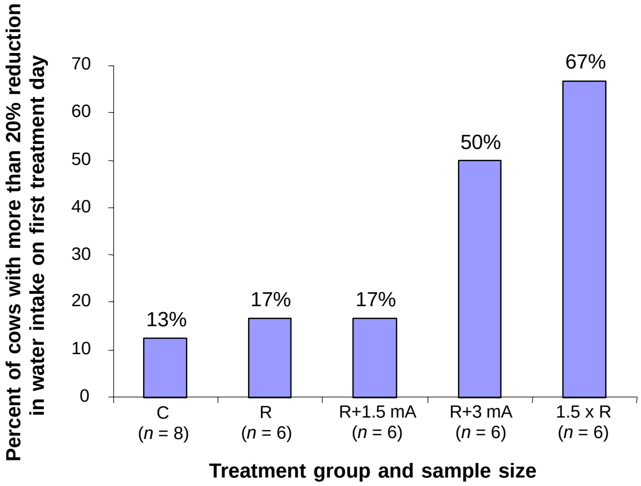

Figure 4. Percentage of animals with more than 20% reduction in water and feed intake on the first day of exposure.

CONCLUSIONS

This study did not find a significant reduction in water intake, feed consumption, or milk production in cows exposed to transient current on water bowls over a 21−day period at either the behavioral reaction threshold of cows (R) or at 1.5 mA (R^+) or 3.0 mA (R^{++}) above an individual cow's behavioral reaction threshold. Additionally, there was no significant reduction in water intake or milk production in cows exposed to transient current on water bowls over a 21−day period at 150% of an individual cow's behavioral reaction threshold (R*). However, a reduction in feed consumption over the 21−day exposure period was noted for these cows. An increase in the behavioral response threshold was observed between pretreatment and post−treatment periods, indicating that cows became less sensitive to current application after 21 days of exposure.

Cow behavior was more sensitive than water intake, feed consumption, or milk production to transient current exposure in that adverse effects on cow behavior were apparent at current levels below those for which a reduction in water and feed intake and milk production were observed. Behavioral effects, as indicated by delay to drink and gross observation, were apparent during the first day of exposure at levels lower than those required to cause measurable changes in daily total water intake, feed consumption, or milk production. Reductions in daily average water intake, feed consumption, and milk production were noted in the first 1 to 3 days of current exposure for the R^{++} and R* treatment groups. These aversive effects were not noted for the R or R^+ groups. This confirms results of previous studies and field observations noting changes in animal behaviors with no measurable decline in water or feed intake or milk production. In this experiment, cows were exposed to the transient current (1 cycle, 60 Hz) whenever they attempted to drink. In practice, transient events are typically not always present.

Predictability of response was improved over previous studies by taking into account the individual cow's level of sensitivity. This result clarifies previous experiments in which animals had to be removed from experimental trials because of dramatic responses. More consistency in behaviors was observed and greater response was obtained when using a multiplicative current exposure method (1.5 times the short−term mA response level; R*) than with an additive method (short−term response level plus 1.5 or 3 mA; R^+ or R^{++}). The responses were all explainable by avoidance of water bowls associated with the presence of an annoying stimulus rather than direct physiological effects.

These results help to explain the results of previous studies in which constant voltage exposure methods were used and individual animal sensitivities were not taken in to account. This study has extended the knowledge of cows' reactions to "transient" voltage/current exposures and has validated the conclusions of the USDA group of experts in that, while behavioral modification may occur for a small percentage of animals at exposures of 1 to 2 mA (steady RMS), changes in health and production would not be expected.

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