Martin Luther University Halle-Wittenberg
Institute of Agricultural and Nutritional Sciences (IANS)
Animal Breeding

Learning behavior of dairy cows in automatic milking systems

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Introduction

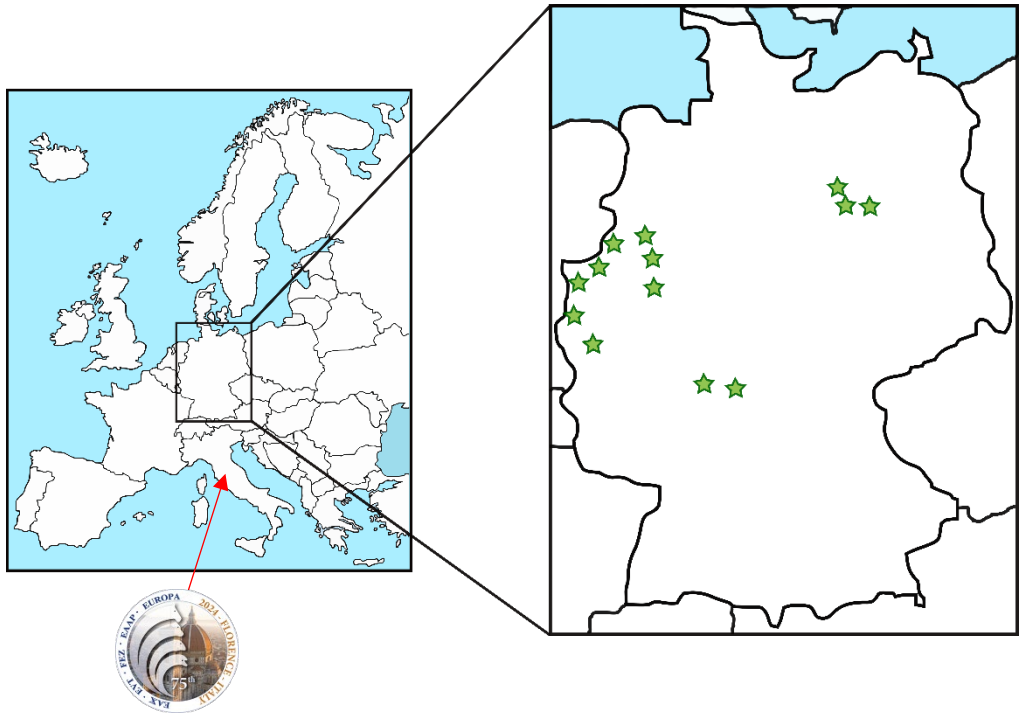
- Behavior has several components: agonistic behavior, estrus behavior, feeding behavior, maternal behavior, learning behavior etc.
- Learning consists of memorizing, storing and processing of individually acquired information
- automatic milking systems (AMS) function as a test system

How quickly do dairy cows learn to adapt to an AMS?

Material & Data

13 German dairy farms with AMS

- 7,803 milking Holstein cows



- Lely Astronaut robots (A3 next, A4, A5)
- observation period: 02/2009 – 08/2023

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Material & Data

13 German dairy farms with AMS

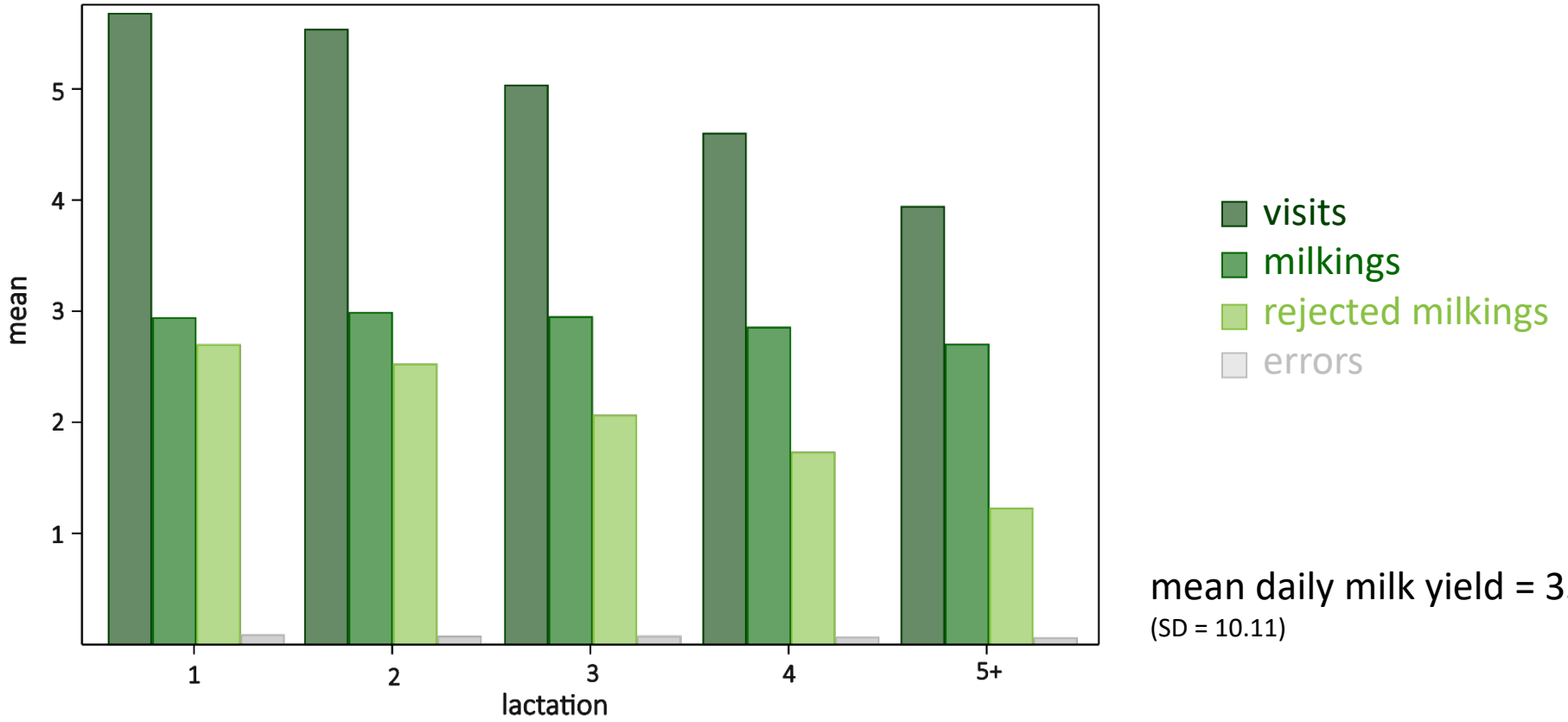
- 26.4 mill. records
- 18,684 lactations (1 – 14)
- 5 mill. daily animal-AMS-observational units

- Daily milk yields (calculated according to ICAR, 2014)
- All AMS traits aggregated as trait value per day
- **Traits: visits, milkings, rejected milkings and errors**

Lactation	N
1	6,074
2	4,365
3	3,278
4	2,268
5+	2,699

AMS traits

Average of daily cow-AMS observational units



mean daily milk yield = 35.01 kg
(SD = 10.11)

Model 1

Linear mixed model (SAS) for learning behavior

$$Y_{ijklmn} = \mu + dmy + season_i + parity_j(DIM_k * fam_l) + animal_m + residual_{ijklmn}$$

traits as daily records (response): visits, milkings, rejected milkings

fixed effects:

- average daily milk yield (according to ICAR rules)
- season (4 seasons/year at each farm)
- learning: days in milk (DIM) per lactation*familiarity with AMS

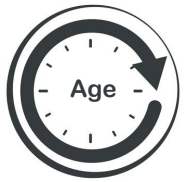
  DIM: 2-99, 100-199, >200

  familiarity with AMS: ≤25, 25-49, 50-74, 75-99, 100-149, >150

random effect: animal

Results 1

LSMeans for daily rejected milkings



Lactation	DIM	1st lactation at AMS						2nd lactation at AMS	3rd lactation at AMS	4th+ lactation at AMS
		1-25 days	26-50 days	51-75 days	76-100 days	101-150 days	151+ days			
1	1-99 days	2.59	2.82	2.92	2.89	2.90	.			
	100-199 days	3.88	2.91	3.18	2.86	2.93	2.98			
	200+ days	4.49	3.55	3.45	2.80	2.52	2.99			
2	1-99 days	3.36	2.93	2.31	1.94	.	.	2.75		
	100-199 days	2.97	2.36	2.42	2.08	2.40	2.47	2.51		
	200+ days	3.41	2.58	2.38	2.14	1.94	2.27	2.58		
3	1-99 days	2.65	2.85	2.40	2.28	.	.	2.71	2.30	
	100-199 days	2.36	2.34	2.33	1.95	2.15	2.36	2.01	2.20	
	200+ days	2.58	2.28	1.90	1.98	2.13	2.24	1.76	2.31	
4	1-99 days	2.20	2.46	1.99	1.63	.	.	2.84	2.25	1.99
	100-199 days	2.57	1.83	1.40	1.55	1.67	1.98	2.05	1.81	1.95
	200+ days	2.63	1.98	1.93	1.92	1.81	1.97	1.70	2.01	2.10
5+	1-99 days	1.81	1.50	1.45	1.41	.	.	2.17	2.29	1.87
	100-199 days	2.45	1.86	1.51	1.40	1.47	1.51	1.78	1.91	1.82
	200+ days	2.22	2.22	2.28	2.14	1.77	1.80	1.83	2.09	2.05

SD 0.03 – 0.13

mean = 2.21 rejections

Number of rejected milkings decrease with age and experience

Model 2

Linear mixed model (blupf90)

1 selected dairy farm

- 1,424 cows (1,273 genotyped)
- 2,226 lactations
- 551,137 daily animal-AMS-observational units

traits as daily records (response): visits, milkings, rejected milkings

fixed effects:

- season (4 seasons/year; 12 classes)
- learning: days in milk (DIM) per lactation*familiarity with AMS (22 classes)

covariate: average daily milk yield (ICAR)

random effect: animal (pedigree based relationship matrix/including SNPs), permanent environment

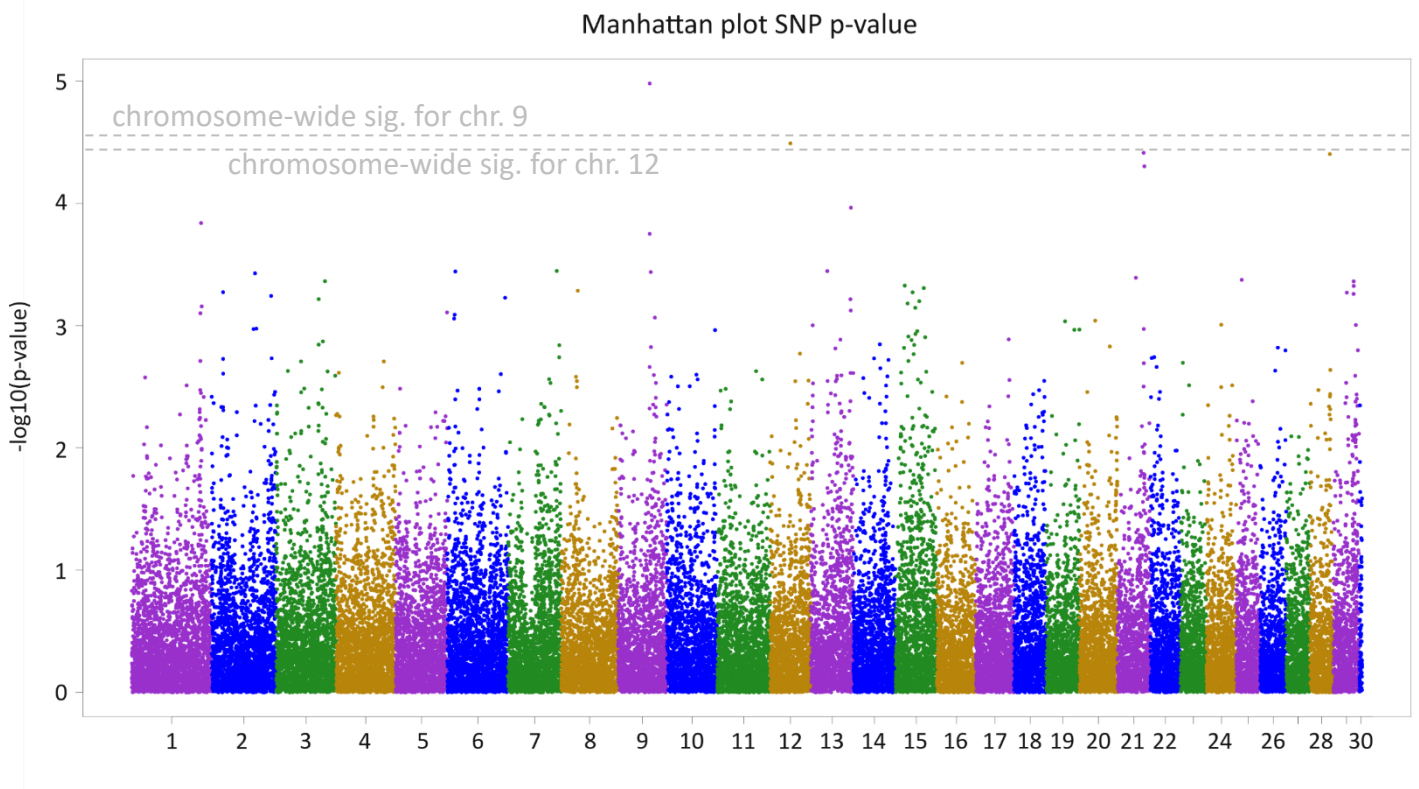
Results 2

Estimates of heritabilities (animal model)

Behavioral traits	h^2	σ^2_a (SE)	σ^2_{pe} (SE)	σ^2_e (SE)
visits	0.175	5.359 (0.62)	4.359 (0.37)	20.972 (0.04)
milkings	0.369	0.362 (0.03)	0.099 (0.01)	0.520 (0.99E-03)
rejected milkings	0.187	3.549 (0.46)	3.651 (0.29)	19.007 (0.04)

h^2 = heritability, σ^2_a = additive genetic variance; σ^2_{pe} = permanent environmental variance; σ^2_e = residual variance

GWAS for rejected milkings



Potential regions on chromosome 12 were also found by Schafberg et al., WCGALP (2022)

Conclusion

- Clear evidence for learning behavior of cows in AMS
  - Learning mainly occurs during the first 100 at AMS

- Rejected milkings appear to be suitable as a proxy for learning performance
  - Rejected milkings as unsuccessful visits are always undesirable
  - Heritability of 0.19 (0.13 (Schafberg et al., WCGALP, 2022))

- Clear evidence for a partially genetic background of learning behavior; could be exploited by genetic selection
- Genetic selection for decreased rejected milkings could improve adaptation to the technical environment (beneficial for cow welfare), and cow traffic

Work will continue → Aim: 1 big data set with 27 herds → more reliable heritability values and identification of candidate genes

Acknowledgements

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Additional information - modelling

<u>familiarity with AMS</u>

if „lactation AMS“ = 1

- visiting days (vd) < 26
- vd > 25
- vd > 50
- vd > 75
- vd > 100
- vd > 150

for lac. >2 → only one class per lactation

<u>days in milk</u>

- < 100 days
- > 99 days
- > 199 days

<u>season (example)</u>

1: dec 2013, jan – feb 2014

2: mar – may 2014

3: jun – aug 2014

4: sep – nov 2014

Additional information - modelling

- **SAS** → AMS data set
- **RENUMF90**
  - prepares data and virtually writes the job for other programs
  - Renumbering and data quality control
- **PREGSF90**
  - control of genome data-> SNP cleaning
- **Blupf90+**
  - Variance component and breeding value estimation for quantitative traits (e.g. milk yield)
- **POSTGSF90**
  - Estimation of SNP effects and GWAS (genome-wide association studies)
- **R**
  - creates the Manhattan plot using a file from POSTGSF90

Additional information - Results 1

LSMeans for daily visits

Lactation	DIM	1st lactation at AMS						2nd lactation at AMS	3rd lactation at AMS	4th+ lactation at AMS
		1-25 days	26-50 days	51-75 days	76-100 days	101-150 days	151+ days			
1	1-99 days	5.76	6.05	6.14	6.08	6.17	4.69			
	100-199 days	7.17	6.18	6.42	6.06	6.13	6.20			
	200+ days	7.56	6.69	6.59	5.91	5.59	6.13			
2	1-99 days	6.39	5.96	5.40	5.06	.	.	5.81		
	100-199 days	6.13	5.47	5.55	5.20	5.57	5.65	5.51		
	200+ days	6.41	5.66	5.43	5.16	4.95	5.36	5.60		
3	1-99 days	5.61	5.86	5.47	5.33	.	.	5.82	5.24	
	100-199 days	5.36	5.42	5.49	5.02	5.28	5.59	5.07	5.12	
	200+ days	5.61	5.30	4.89	5.03	5.22	5.35	4.69	5.30	
4	1-99 days	5.06	5.42	5.03	4.62	.	.	5.94	5.24	4.86
	100-199 days	5.47	4.74	4.30	4.51	4.70	5.04	5.05	4.71	4.81
	200+ days	5.63	4.90	4.87	4.87	4.82	4.98	4.61	4.89	5.05
5+	1-99 days	4.65	4.38	4.38	4.45	.	.	5.13	5.26	4.74
	100-199 days	5.30	4.83	4.60	4.41	4.48	4.51	4.65	4.77	4.68
	200+ days	5.14	5.17	5.25	5.16	4.75	4.79	4.69	5.03	5.00

SD 0.04. – 0.15

mean = 5.15 visits

Number of visits decrease with age and experience

Additional information - Results 1

LSMeans for daily milkings

Lactation	DIM	1st lactation at AMS						2nd lactation at AMS	3rd lactation at AMS	4th+ lactation at AMS
		1-25 days	26-50 days	51-75 days	76-100 days	101-150 days	151+ days			
1	1-99 days	3.13	3.19	3.19	3.17	3.25	3.66			
	100-199 days	3.26	3.23	3.22	3.18	3.19	3.21			
	200+ days	3.05	3.12	3.12	3.10	3.05	3.13			
2	1-99 days	2.98	2.99	3.06	3.09	3.09	2.88	3.03		
	100-199 days	3.10	3.08	3.09	3.08	3.14	3.16	2.98		
	200+ days	2.97	3.06	3.02	2.99	2.98	3.07	2.99		
3	1-99 days	2.91	2.96	3.02	3.00	.	.	3.07	2.90	
	100-199 days	2.95	3.03	3.12	3.03	3.08	3.19	3.02	2.89	
	200+ days	2.98	2.98	2.95	3.01	3.04	3.07	2.90	2.95	
4	1-99 days	2.82	2.90	2.99	2.94	.	.	3.04	2.93	2.82
	100-199 days	2.87	2.87	2.87	2.91	2.98	3.02	2.95	2.85	2.82
	200+ days	2.96	2.89	2.90	2.91	2.95	2.97	2.87	2.83	2.91
5+	1-99 days	2.78	2.83	2.88	2.97	.	.	2.91	2.91	2.80
	100-199 days	2.79	2.92	3.03	2.95	2.96	2.95	2.82	2.80	2.80
	200+ days	2.88	2.91	2.92	2.97	2.94	2.94	2.82	2.89	2.90

SD 0.006 – 0.01

mean = 2.91 milkings (SD = 0.93)

Number of milkings is rather consistent.

Additional information - Results 2

Estimates of heritabilities (animal model)

Behavioral traits	**h^2**	σ^2_a (SE)	σ^2_{pe} (SE)	σ^2_e (SE)
visits	0.175	5.359 (0.62)	4.359 (0.37)	20.972 (0.04)
milkings	0.369	0.362 (0.03)	0.099 (0.01)	0.520 (0.99E-03)
rejected milkings	0.187	3.549 (0.46)	3.651 (0.29)	19.007 (0.04)
errors	0.931E-17	0.1E-17 (0.0)	0.397E-01 (0.44E-03)	0.677E-01 (0.13E-03)

h^2 = heritability, σ^2_a = additive genetic variance; σ^2_{pe} = permanent environmental variance; σ^2_e = residual variance;

Additional information

GWAS for rejected milkings (Schafberg et al., WCGALP, 2022))