

EAAP Annual Meeting 2015, Session 38

Genetic and molecular background of cattle behaviour and its effects on milk production and welfare

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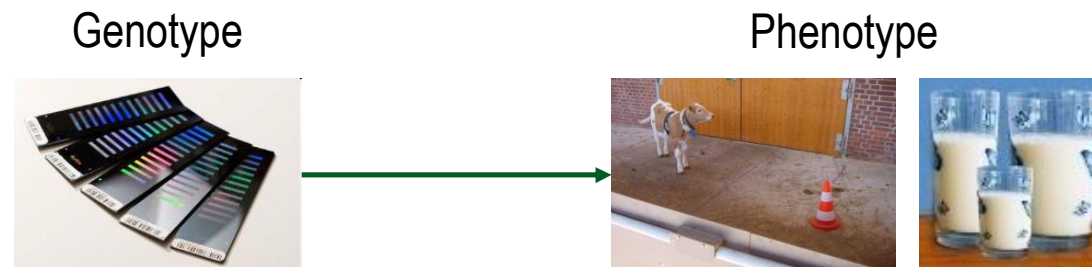
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Response to environmental stimuli can be described as behaviour characteristics

- ▶ Effects on animal welfare
- ▶ Effects on production traits:
 - “ Average daily weight gain (ADG) [1]
 - “ Meat quality [2]
 - “ Milk yield [3]
 - “ ...
- ▶ Insights into the genetic and molecular mechanisms affecting behaviour are still limited

Goal: Exploring underlying genetic and molecular mechanisms of cattle behaviour especially in regard to milk performance

1) SNPs affecting behaviour and milk performance



2) Differential gene expression between temperament types



1) SNPs affecting behaviour and milk performance

Genotype



Phenotype

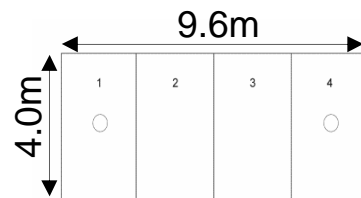


Material & methods

Animals: 147 F₂ Segfam cows (Charolais x German Holstein)

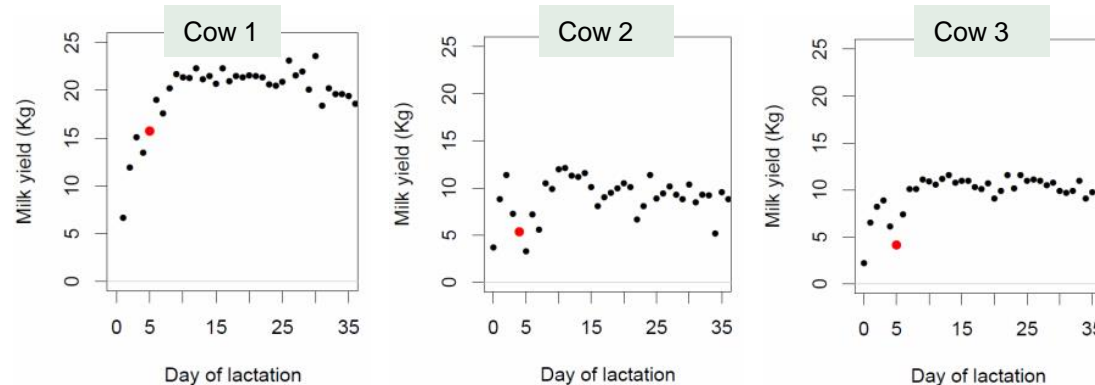
Behaviour phenotype:

- Activity, inactivity and exploration in open-field (OF) and novel-object (NO) test^[4]



Milk performance phenotype:

- Milk yield d1-d5, milk yield d6-d30, average daily yield
- Ratio for drop in milk yield after rehousing



[4] Graunke et al. (2014)

Genotype:

“ 37,201 SNPs (Illumina Bovine SNP50 Bead Chip®)

Statistical analysis:

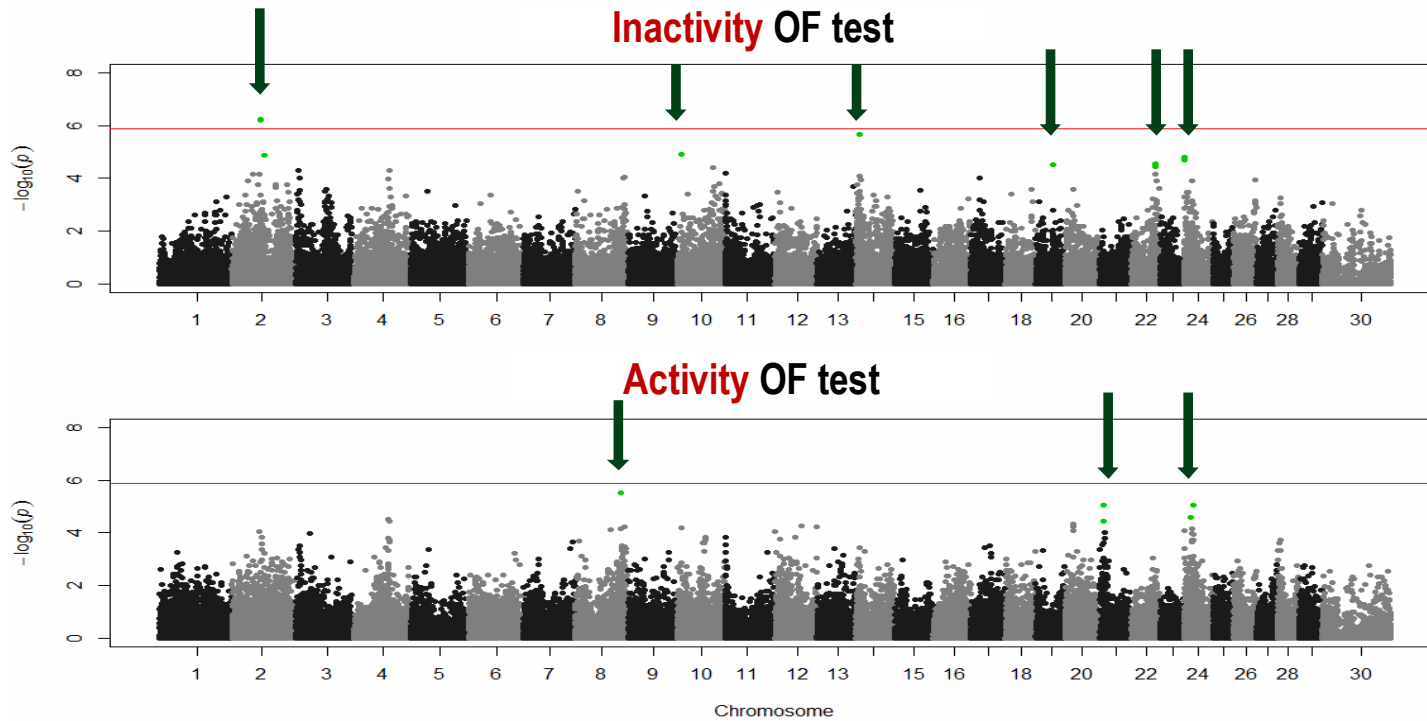
- “ Additive SNP effect in Qxpak 5.05 [5]
- “ Bonferroni correction ($p < 0.05$)

$$y_{ijk} = \mu + s_j + a_i + u_k + e_{ijk}$$

- y_{ijk} = the behaviour phenotype of animal i ($i = 1, \dots, 147$)
- μ = overall mean
- s_j = fixed effect of the interaction year x season ($j = 1, \dots, 22$)
- a_j = fixed additive-genetic effect of SNP i ($i = 1, \dots, 37201$)
- u_k = random infinitesimal polygenic effect of animal i
- e_{ijk} = residual random effect.

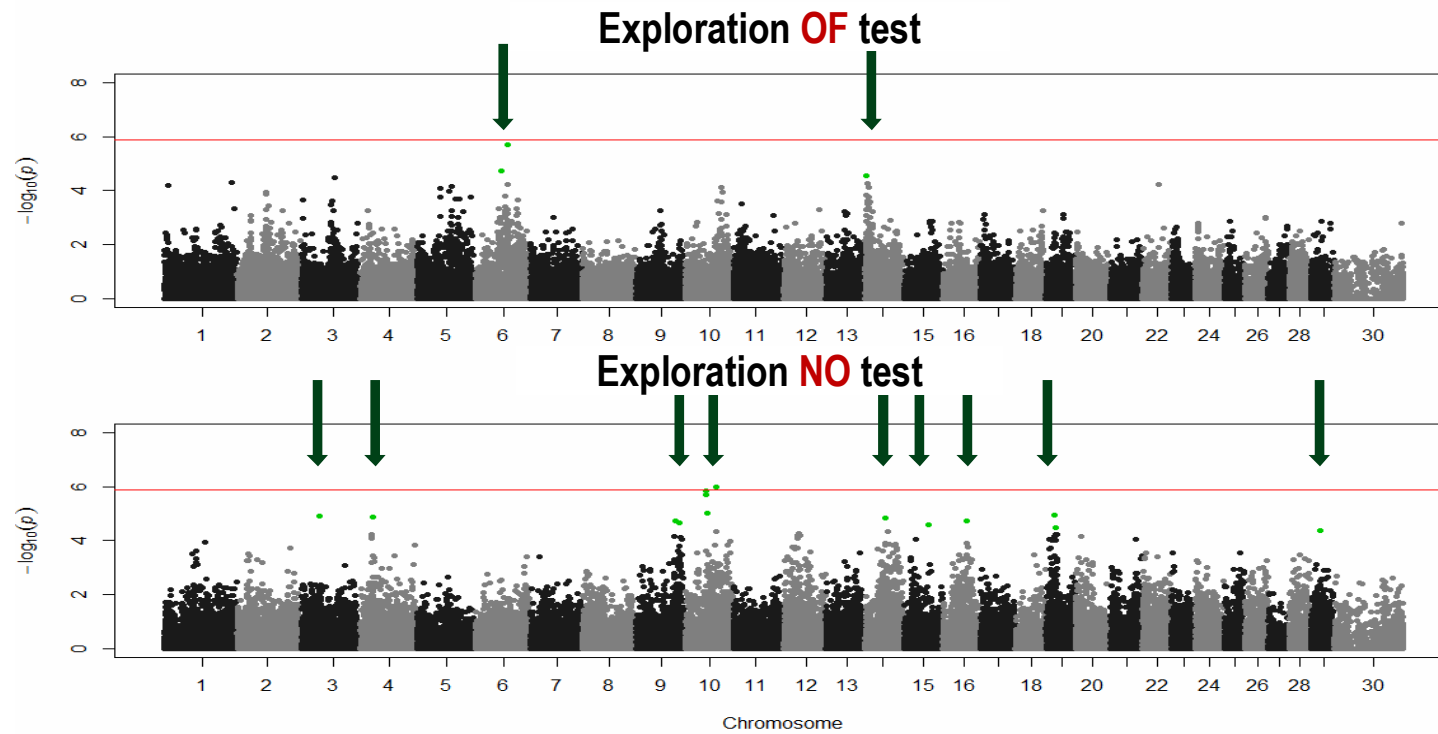
Results & discussion

- ▶ 41 SNPs were significantly associated with at least one of the behaviours in OF and NO test
- 1. Genetic loci affecting behaviour were specific for **trait** and test situation



Results & discussion

- ▶ 41 SNPs were significantly associated with at least one of the behaviours in OF and NO test
- 2. Genetic loci affecting behaviour were specific for trait and **test situation**





Results & discussion

- ▶ Of the 41 SNPs, 9 were significant for exploration in NO test and milk performance traits

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- ▶ Of the 41 SNPs, 9 were significant for exploration in NO test and milk performance traits
 - ~ Linkage block on BTA29: genomic region of known QTL for behaviour and milk performance [6,7,8]

SNP name	Chr	Trait	Genotype			
			n	1 LSM ± S.E.	n	2 LSM ± S.E.
rs108965864,	29	MY	90	6.5 ± 0.8	57	3.9 ± 0.8**
rs42169108,		R		1.2 ± 0.1		1.6 ± 0.2**
rs43099931		DE		51.0 ± 14.2		87.0 ± 14.6**

MY, average daily milk yield; R, milk drop rehousing; DE, exploration behaviour; ** p < 0.001

 exploration
  milk yield
  milk drop rehousing

2) Differential gene expression between temperament types

Transcriptome



Phenotype



Material & methods

Animals: 60 F₂ Segfam cows (Charolais x German Holstein)

Temperament phenotype:

- Temperament types assessed in novel-human (NH) test [4,9]

- 1 “fearful/neophobic-alert”
- 2 “interested-stressed”
- 3 “outgoing/neophilic-alert”
- 4 “subdued/uninterested-calm”
- 5 “indistinct group”

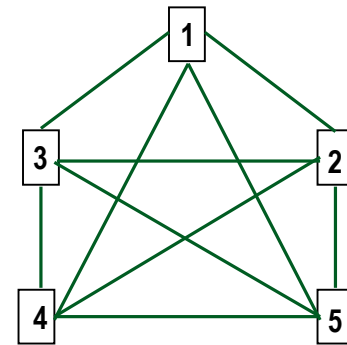


Transcriptome:

- Adrenal cortex tissue
- 10,986 transcripts (Affymetrix® GeneChip® Bovine Gene v1 Array)

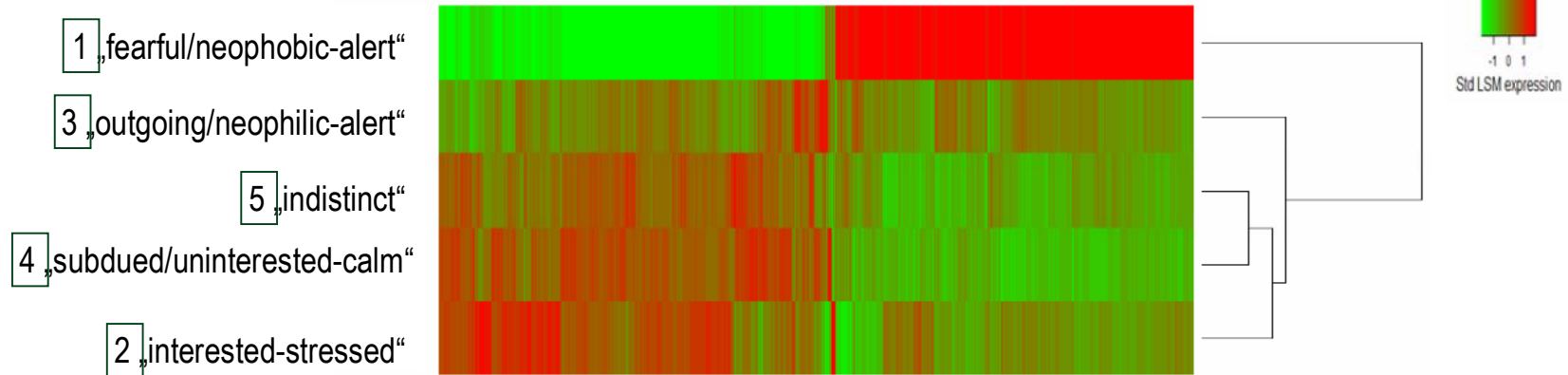
Statistical analysis:

- Analysis of variance
- FDR correction ($p < 0.05$)



Results & discussion

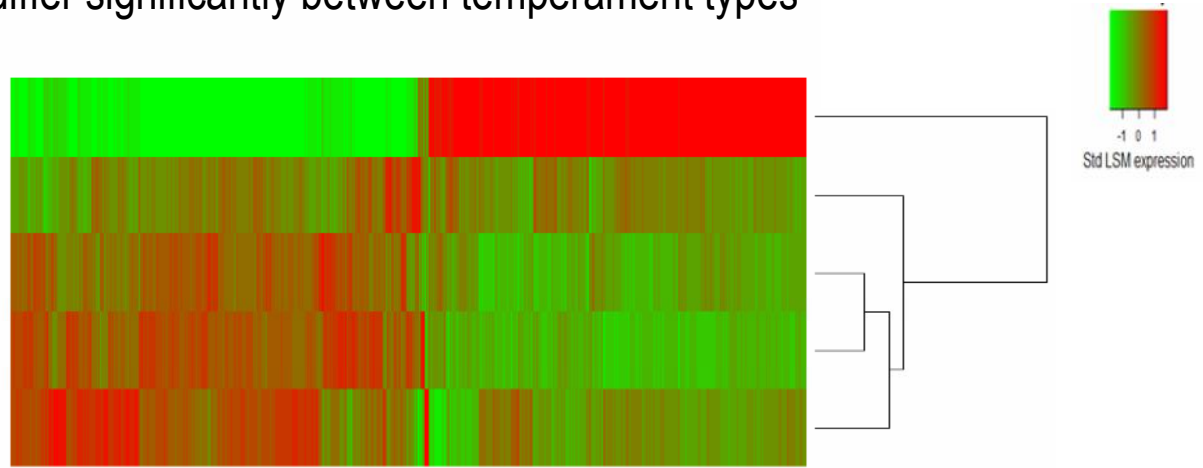
- ▶ 2,944 transcripts that differ significantly between temperament types



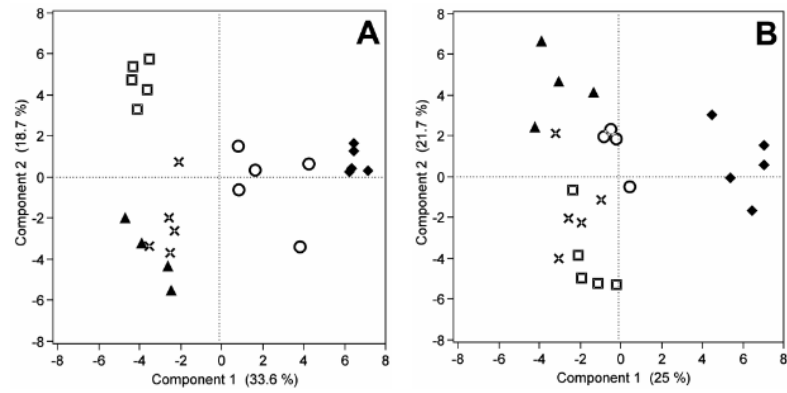
Results & discussion

▶ 2,944 transcripts that differ significantly between temperament types

- ◆ 1 „fearful/neophobic-alert“
- ▲ 3 „outgoing/neophilic-alert“
- ✕ 5 „indistinct“
- 4 „subdued/uninterested-calm“
- 2 „interested-stressed“

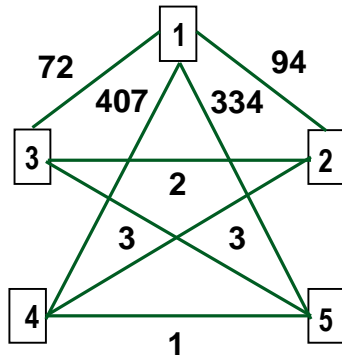


Principal component score plot of the first two principal components for metabolite features with high relevance in the classification of temperament types in the prefrontal cortex (A) and serum (B). [9]



Results & discussion

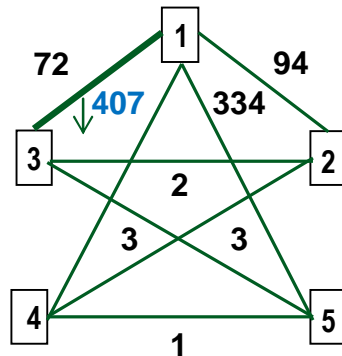
► Ingenuity Pathway Analyses (FC > 1.5)



- 1 “fearful/neophobic-alert”
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- ~ Cellular processes: growth, proliferation, signalling
- ~ Stress response: Glucocorticoid receptor signalling, NRF2-mediated oxidative stress response

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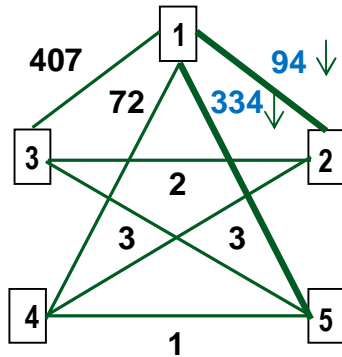


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Results & discussion

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- ~ Cellular processes: growth, proliferation, signalling
- ~ Stress response: Glucocorticoid receptor signalling, **NRF2-mediated oxidative stress response**

1) SNPs affecting behaviour and milk performance

Genotype



Phenotype



- ▶ **Genetic regions affect behaviour traits in cattle**
 - “ Specific in regard to trait and test situation
- ▶ **Association between behaviour traits and milk performance**
 - “ Variability in responsiveness towards rehousing visible in milk yield
 - “ Genetic variations associated with behaviour traits and milk performance indicate contrary genotype effects for agitated behaviour and milk yield

2) Differential gene expression between temperament types

Transcriptome



Phenotype



- ▶ **Expression profiling of the adrenal cortex identified transcripts differentially expressed between temperament types**
 - “ Clear discrimination of „fearful/neophobic-alert“ cows from the others indicates prominent role of fearfulness in behaviour manifestation
 - “ Highlighted pathways of adrenal development and stress response

Thank you for your attention!



Kontakt

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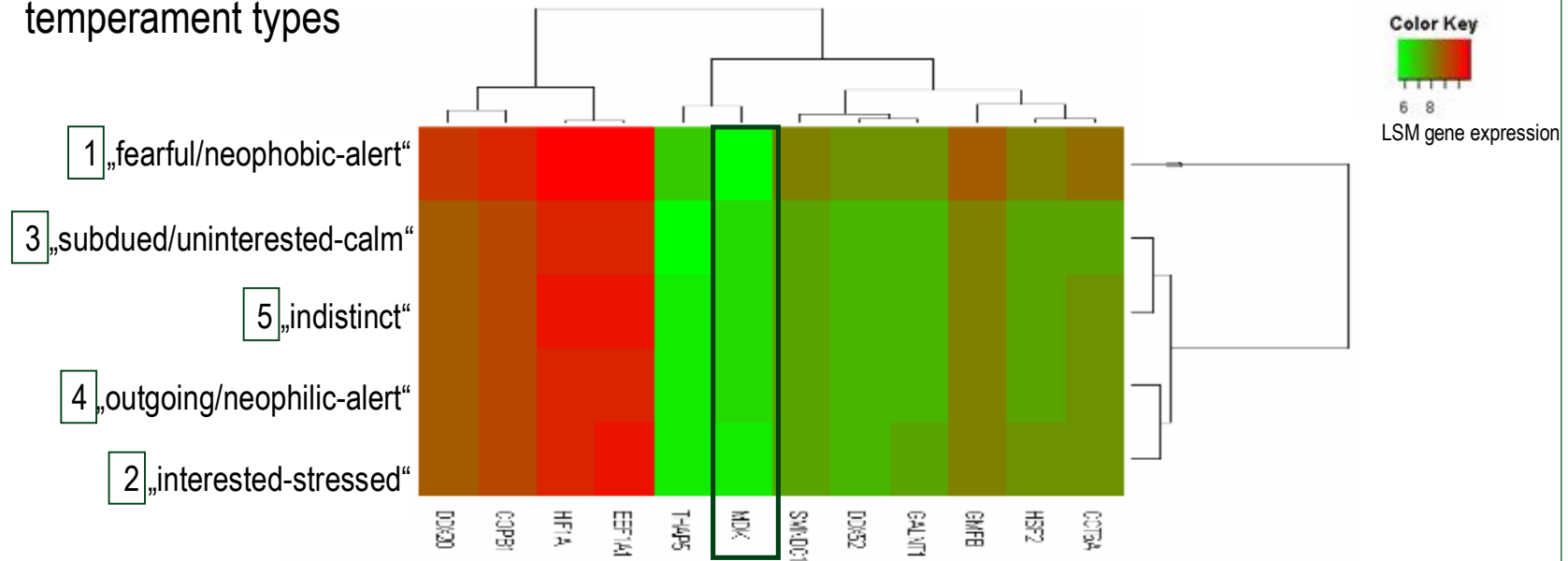
“PHENOMICS German Federal Ministry of Education and Research (BMBF), 0315536A and 0315536G

European Federation of Animal Science

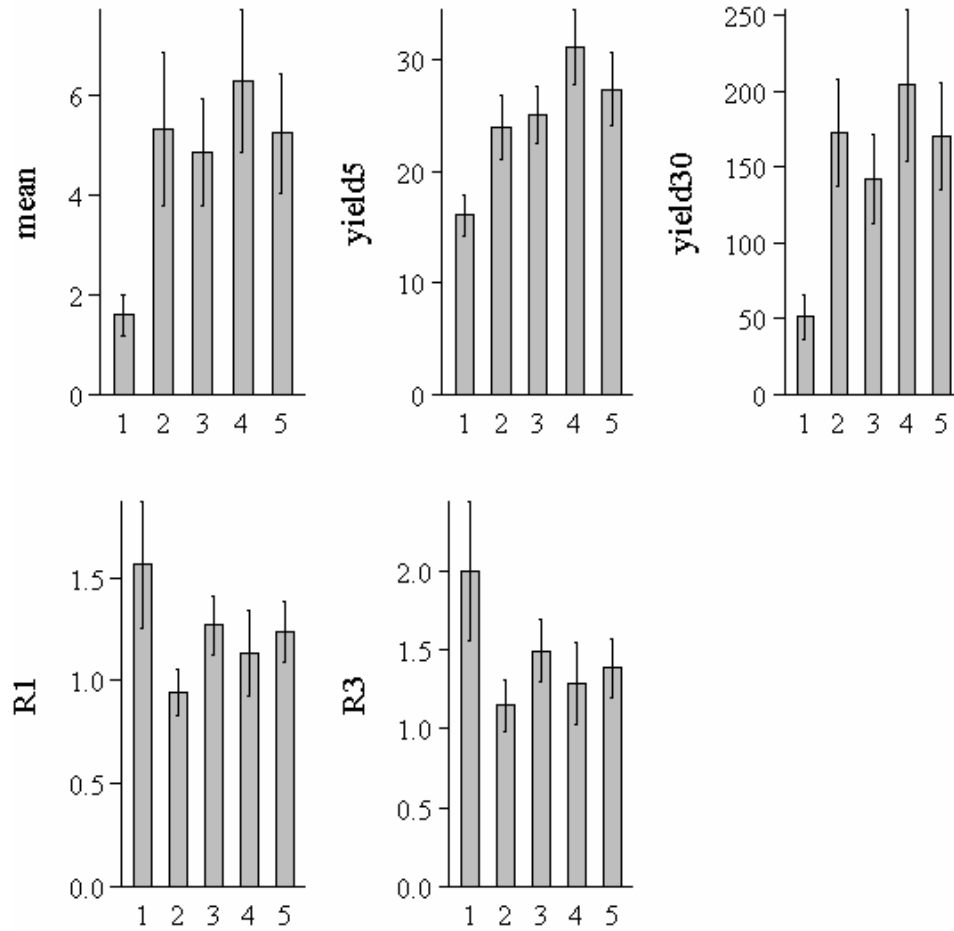
- [1] Vettters *et al.* 2013 Comparison of flight speed and exit score as measurements of temperament in beef cattle. *Journal of Animal Science* 91, 374-381.
- [2] Hall *et al.* 2011 Working chute behavior of feedlot cattle can be an indication of cattle temperament and beef carcass composition and quality. *Meat Science* 89, 52-57.
- [3] Hemsworth *et al.* 2000 Relationships between human-animal interactions and productivity of commercial dairy cows.
- [4] Graunke *et al.* 2014 Describing temperament in an ungulate: a multidimensional approach. *PLoS ONE* 8, e74579
- [5] Perez-Enciso & Misztal 2004 Qxpk.5: old mixed model solutions for new genomics problems. *BMC Bioinformatics* 12, 202
- [6] Hiendleder *et al.* (2003) Mapping of QTL for body conformation and behavior in cattle. *Journal of Heredity* 94, 496-506.
- [7] Viitala *et al.* (2003) Quantitative trait loci affecting milk production traits in Finnish Ayrshire dairy cattle. *Journal of Dairy Science* 86, 1828-1836.
- [8] Gutiérrez-Gil *et al.* (2008) Identification of quantitative trait loci affecting cattle temperament. *Journal of Heredity* 99, 629-638.
- [9] Brand *et al.* 2015 Temperament type specific metabolite profiles of the prefrontal cortex and serum in cattle. *PLoS ONE* 10, e0125044

Results & discussion

- ▶ 12 transcripts differ significantly between “fearful/neophobic-alert” and all other temperament types

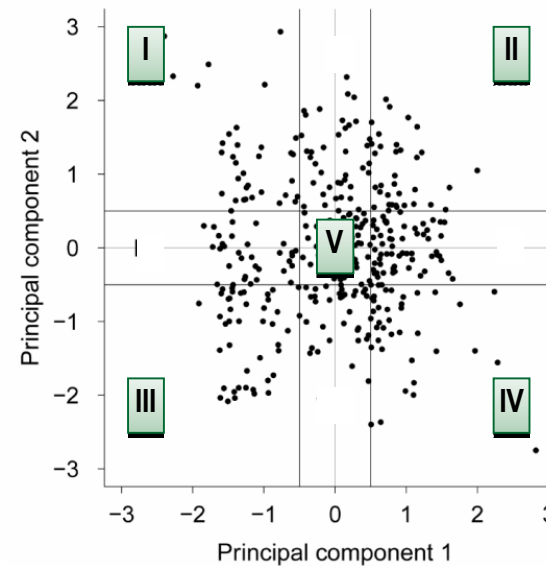


- “ 12 transcripts differ significantly between “fearful/neophobic-alert” and all other temperament types
- “ *MDK* (midkine) gene up-regulated
- “ *MDK* plays key role in adrenal development [10,11]
- “ Abundance of *MDK* was negatively associated with anxiety [12]



Behaviour	PC 1	PC 2
Contact-D	0.76457	0.05006
Contact-F	0.83250	0.12250
Contact-L	-0.89613	-0.13959
Inactivity-D	-0.41347	-0.85549
Exploration-D	0.15037	0.82661
Exploration-L	-0.19767	-0.63679
Grooming-D	-0.08038	0.42876
Activity-D	0.56716	0.61371
Activity-L	-0.49598	-0.21244
Running-D	0.47287	0.34835
Vocalisation-F	0.38216	0.07442
Change of segment-F	0.70109	0.51393
Object segment -L	-0.87210	-0.15841
Object segment-D	0.83888	0.12061
Object neighbouring segment -L	-0.73723	-0.22699

Graunke et al. 2013



- I** “fearful/neophobic-alert”
- II** “interested-stressed”
- III** “subdued/uninterested-calm”
- IV** “outgoing/neophilic-alert”
- V** “indistinct (reference) group”