DISSERTATION

AN INVESTIGATION INTO TEMPERAMENT, PRODUCTION, AND THEIR PHYSICAL INDICATORS IN BOS TAURUS BEEF AND HOLSTEIN DAIRY CATTLE

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY JENNIFER L. LANIER AN INVESTIGATION INTO TEMPERAMENT, PRODUCTION, AND THEIR PHYSICAL INDICATORS IN BOS TAURUS BEEF AND HOLSTEIN DAIRY CATTLE

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ABSTRACT OF DISSERTATION

AN INVESTIGATION INTO TEMPERAMENT, PRODUCTION, AND THEIR PHYSICAL INDICATORS IN BOS TAURUS BEEF AND HOLSTEIN DAIRY CATTLE

The objective of these research studies was to examine the relationships, in cattle, for productivity and temperament, temperament and physical indicators (attributes) and, productivity and physical indicators. Physical attributes examined were facial hair whorl characteristics, and cannon bone measurements. Three separate groups of cattle were used to evaluate the possible relationships. The first group studied were cows at a small Holstein dairy. A simple method to determine the temperament of dairy cows, without interfering with the operation of a commercial dairy, was developed. The second group studied were feedlot heifers that were simultaneously involved in a vitamin D_3 study. The third group studied were cattle being sold in auctions. Temperament tests conducted were: 1) dairy cattle reaction to a looming person, 2) force required to move the heifer into a squeeze chute, activity level during restraint, and exit speed from the squeeze chute, and 3) activity level and startle response to intermittent stimuli of auction cattle. Production measures were 1) heifer carcass characteristics, and Warner-Bratzler shear force values of steaks, and 2) dairy cow milk production. Physical attributes investigated for all three groups of cattle were location and morphology of facial hair whorls. Heifer cannon bone measurements were also recorded. Results indicated that there was an association between physical characteristics, temperament and productivity of heifer feedlot and dairy cattle. Differences in facial hair whorls were associated with temperament, milk protein yield, and showed an indication of a relationship with longevity in this dairy herd. Cannon bone measurements were related to temperament and to carcass characteristics and temperament was related to carcass characteristics. Activity level of individual cattle at auction markets was associated with startle response. Animals that were the most active were more easily startled by an intermittent sound, motion, or touch than were those cattle that had lower activity levels. Management decisions based on an understanding of the interrelatedness of temperament, physical attributes, and animal productivity will assist producers in achieving generation of a consistent and desirable product, improved animal welfare, and greater profitability.

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Some events are difficult to detect, prove or explain;
however, they are very real and significant in our lives
(e.g., creation, my families' love and this dissertation).

Misquote from dad

This event would not have occurred without the love and support of my family (human and otherwise), friends, and committee:

Mom (Martha C. Smith)
Dad (Burton J. Smith)
Bro' (Steven S. Smith)
Sis (Karen E. Smith)
Other Bro' (Abdoulhabibou Housseini)
Other Sis (Marian Krismer)

The Kids: Asante Kalena, Mai Ruwa, Oliver, Zaki, Kala, Rudy,
and those who were with me only for a blink of time

Note: List is not in any order of significance to my like, except for Asante.

Friends: Monique Myers, Kasie McGee, and fellow graduate students

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Ann Swinker and Terry Engle

These last "few" years have taught me many things. I learned that friends, health and expectations may fade, but family only grows brighter and warmer. For this, I would like to leave to my family, as part of my last will and testament, all the errors, misrepresentations, successes, and ah-has contained in this document.

Thank you for never making me feel like I had to do this.

This endeavor is dedicated to me:

I used to believe in the system and those in charge. I believed that the guardians of animals always had welfare foremost in their minds. Then I got a job. My job made me define my personal morals and ultimately resulted in my coming to graduate school. With a bachelor's degree, I could not remain a pooper-scooper and improve the lives of the animals under my care. To improve an animal's welfare meant two things: Become *somebody* on paper, and learn what "Industry Standard" really means to the public, the "industry", the animals, and me. I never really wanted to be Dr. Lanier, just an effective Lanier. Of course, "Industry Standard" defines effective as having a PhD. With this degree under my bra, I hope that effective Lanier may now begin to improve the lives and death of animals and those who care for them.

"Industry Standard" does not necessarily mean *right, moral,* or *ethical.*
Me

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Review of Literature

Hair whorls

The study of patterns of hair whorls (formally referred to as trichoglyphics) has, over the past 160 years, produced as many questions as it has provided answers. The majority of studies concentrated on whorl morphology in the mentally disabled or fetal development of cranial whorl patterns. More currently, the focus has turned to the relationship between hair whorl position and temperament in cattle and horses. Hair whorl position may be useful in predicting cattle temperament (Grandin et al., 1995).

Formation of hair whorls. The current science of whorl morphology has provided evidence for genetic and prenatal influences on whorl morphology. Most trichoglyphic researchers limited their focus to Caucasian humans, citing as the predominant reason the difficulty of determining hair patterns in curly hair. It is unknown as to why hair patterns on non-Caucasian (e.g., Orientals) were not conducted. Studies of cranial hair whorl patterns, placement, morphology and association with temperament began in the early 1800's and continue to date.

Fetal studies have shown that scalp hair whorl morphology develops between the tenth and twelfth week of gestation and, at the latest, the eighteenth week of embryogenesis (Smith and Gong, 1974; Smith and Gong, 1973a,b). Consensus has yet to be reached regarding the mechanisms involved; there are three theories: mechanical tension, inheritance, and physiologic mechanisms (Samlaska et al., 1989).

According to Samlaska et al. (1989), the theory of mechanical tension seems to have the most support from the scientific community. This theory asserts that whorl pattern and location are dependent on brain development and due to this dependence "is not under primary genetic determination, but is determined secondarily by the growth and shape of underlying and adjacent tissues" (Smith and Gong, 1974). Between the tenth and eighteenth weeks of embryogenesis, the back of the head begins to protrude in a dome-like manner in order to accommodate the rapid growth of the brain. A hair whorl forms at the focal point of skin stretch during this expeditious growth (Smith and Gong, 1974). The weakness of the mechanical tension theory is the fact that hair whorls are not localized to the head but are widespread all over the body of both humans and animals (Samlaska et al., 1989); the tension theory cannot account for these other whorls.

The second theory of whorl location and morphology is inheritance. Studies have linked various hair and skin traits such as male pattern baldness, texture and color to genetics and fingerprint patterns (Burks, 1938; Osborn, 1916). Using frontal scalp hair patterns it was determined that genetic contribution to whorls was very probable (Kiil, 1948). This possibility of genetic contributions to patterning of hair whorls was also suggested in another study (Wunderlich and Heerema, 1975). Hair follicles and neural crest cells are both derivatives of the ectoderm (Patten 1964), which is the outermost layer of the three germ layers (Dorland 1995).

Probably the most interesting theory pertaining to physiological mechanics is based on studies with guinea pigs. It is theorized that follicles release a growth-stimulating chemical into the area surrounding them, which causes asymmetrical follicular growth due to the gradient created. Perhaps the whorl is the product of one side of the follicle having an area of low metabolic activity and the other side having high metabolic activity, due to this gradient (Samlaska, et al., 1989).

A study published in 1837 found that hair whorls usually occurred on the right side of the human head in a clockwise swirl pattern (Eschicht, 1837). Approximately 20 years later this study was replicated and generated similar results (Voigt, 1856). Fifty years later another study described in greater detail the typical locations and numbers of whorls on the human head (Kidd, 1903). Consensus has been reached regarding the most common hair whorl morphology in Caucasian people; it is single whorls with a clockwise rotation on the right side of the head. Any deviation from this type is considered a hair whorl variation. There is no consensus on what is normal versus abnormal hair patterning for humans; therefore, a person with double hair whorls is referred to as having whorl variation, not as having abnormal whorls.

Hair whorls and physical indicators. Studies that associated whorls to various traits were conducted in the 1920's. One study found no relationship between whorl variation and handedness, though the authors felt that their methodology was biased (Lauterbach and Knight, 1927). The most frequent variation (18.1%) in whorl patterns detected among the general population by Lauterbach and Knight (1927) was not location of whorl, but a counterclockwise swirl. That study pointed out the tendency for retarded persons to have a greater number of hair whorl variations (26.4%), as compared to persons with normal cognitive abilities (23.4%). That finding was not statistically significant, but it was the beginning of hair whorl research on the mentally disabled. Lauterbach and Knight's study must be qualified with the fact that persons suffering from congenital cognitive disorders are more likely to have morphological variations when compared to the general population. Differences in weight, height, and ear shape between retarded persons and the overall population have been recorded (Church and Peterson, 1908). Among the normal population (n=1003) in the Lauterbach and Knight (1927) study, 6.5% of the males had double whorls, compared to 3.1% of the females. The total whorl variation for males was 25.3% while females varied from the single clockwise norm only 21.4%. In the retarded population (n=851), 3.3% of the females exhibited double whorls and 24.1% varied from the norm, compared to males: 9.4% and 28.4%, respectively (Lauterbach and Knight, 1927). Kiil (1948) showed 9.2% of Down's syndrome persons (n=65) had double whorls and 14.3% of the non-monogoloid mentally disabled (n=223) had double whorls, compared to the 8.5% of the normal group. The latter study, unlike most, included African-Americans.

In a non-blind study, by Alexander et al. (1992), 3.9% of schizophrenics had multiple whorls (n=51), compared to 5.4% of the normal population (n=1998). That study also found that 26.5% of the schizophrenics had single counterclockwise whorls versus a 13.8% occurrence (P=0.01) in the control group (Alexander et al., 1992). Lateral placement of the whorl was similar (P=0.80) for both groups with the majority of single whorls (49%) falling to the right of the midline. No gender or handedness effect was found. This conflicts with a study by Wunderlich and Heerema (1975) that suggested a trend towards handedness and swirl direction. No consensus on the correlation between handedness and whorl morphology has been reached.

Dermatoglyphic studies have linked the occurrence of human schizophrenia with varying types of fingerprint and palm characteristics, such as higher densities of secondary creases (Davis and Bracha 1996; Varma et al 1995;Cannon et al 1994) when compared to normal populations. A higher occurrence of differences in symmetry of finger and palm prints in individuals with schizophrenia than in the normal control group has been reported (Mellor, 1992).

Hair whorl studies in swine, cattle, and horses. The interest in hair whorls and their relationship to behavior extends back in time several hundred years to the Arabs and the raising of Arabian horses (Grandin and Deesing, 1998). Modern horse trainers have also reported a correlation between behavior and whorl position (Deesing, personal communication; Friedly, 1990; Tellington-Jones and Burns, 1996). Horse trainer Terry Wegener reportedly uses hair whorls as an indicator of individual personality and potential (Barker, 1990).

Heritability of whorls on swine has been shown to be a complex process (Norby, 1932). Nordby (1932) selected various matings of swine in order to determine heritability and whether the gene(s) involved were recessive or dominant. These matings produced litters as predicted with one exception; that one exceptional litter was predicted to produce only whorled offspring, but instead produced both whorled and non-whorled piglets. During the 1930s, hair whorls on pigs, particularly on their rumps, were considered a defect (Grandin, personal communication; Nordby, 1932). Swine breeders actively selected for non-whorled pigs during this time. Temple Grandin (personal communication) has noticed a resurgence of large rump whorls on modern hybrid swine.

The scientific research that has been conducted on the relationship between whorls and behavior has occurred within the last few years. Swinker et al. (1994) examined location of whorls on horses. Of the 423 Thoroughbreds and Grand Prix jumping horses observed, 47% had whorls on the left side of the face, 31% had right-sided whorls and 16% had double whorls (Swinker et al., 1994). That study focused on athletic horses and therefore may not be representative of horses in general.

Dairy cattle (n=1,379) with double whorls showed no side preference ($P<0.05$) in a milking parlor side-preference experiment (Tanner et al., 1994). Those results may support horse trainers' observations (Deesing, personal communication) that double whorled horses are less handed. Meaning these horses are just as comfortable turning to the left or right, or leading with their left or right foot. Grandin et al. (1995) reported that cattle with high whorls were significantly more excitable ($P < 0.001$) while restrained in a squeeze chute than animals with lower whorl placement. Those same cattle also had increased agitation and fear while exiting the squeeze chute, compared to cattle with whorls level with, or below, the eyes. In that study, excitement and agitation was rated on a four-point scale by an observer blind to hair whorl position (Grandin et al., 1995). Randle (1998) found that 56% of cattle (n=57) had low hair whorls, 54% middle whorls, and 18% with low whorls. Only one animal (1.8%) had double whorls. *Bos taurus* cattle with middle facial whorls had larger flight zones (P <0.01) and were more curious (P <0.05) towards novel humans than cattle with low whorls (Randle, 1998). No correlation was found between hair whorl position and response to novelty or cognitive abilities in the latter study. Differences in methodology in the two-aforecited studies may account for variation in the results.

Grandin et al. (1995) observed 1,500 cattle individually restrained in a squeeze chute, which for most animals is a novel and frightening experience. Randle (1998) observed the reactions of cattle (n=57) as they voluntarily approached either a novel object or person. Novelty that is suddenly forced on an animal is usually frightening, while novelty that can be investigated at leisure is often a strong attractant (Grandin and Deesing, 1998).

Lanier et al. (2001) reported that cattle (*Bos taurus* beef and Holstein dairy, n=1,636) facial whorls were related to temperament in a novel open-field test conducted at a commercial auction barn. Cattle with a hair whorl above the eye level or no facial hair whorl had flightier temperaments compared to cattle with whorls at or below eye level (P=0.01). Beef cattle were typically calmer than Holstein (P<0.01) cattle. Facial hair whorls were further characterized by shape and location on the face in the Lanier et al. (2001) study; abnormally shaped whorls were more common on cattle with whorls below eye level ($P<0.01$), and on cattle with whorls off of the 2.5 cm lateral centerline ($P<0.01$).

Somatotypes

Numerous studies have looked at human body types, referred to as somatotypes, and how they relate to personality, physical aptitude and health, and mental health. It is probable that Hippocrates (c.460-c.370 B.C.) was the first (on record) to study personality and its composites (Maher and Maher, 1994). Hippocrates attributed personality to various proportions of four bodily fluids: phlegm, black bile, yellow bile, and blood. In the late 1800s, Cesare Lombroso studied criminal body types and developed a composite of physical characteristics of the prison inmates (Sabbatini, 2002).

In 1921, Ernest Kretschmer, published *Physique and Character*, which advocated a relationship between somatotypes and temperament (Kretschmer, 1921). Kretschmer (1921) developed three body types: leptosome or asthenic (tall and thin), athletic (well developed muscles), and pyknic (short and fat); he concluded that athletic body types were associated with people who conducted violent crimes, while lesser crimes such as petty theft were more likely to be committed by tall and thin somatotypes. Sheldon (1954) theorized a relationship between somatotypes and personality. A 7-point scoring system to determine which of three body types (Endomorphy, Mesomorphy, and Ectomorphy) best described a person was developed by Sheldon (1954). There is no consensus on whether or not the various body types characterized by different scientists are comparable. One study attempted to compare the various groups of somatotypes

(Burdick and Tess, 1983). They found that mathematical equations would assist in comparisons made between these somatotype groups.

Somatotypes and behavior. The link between somatotype and behavior has been made by various researchers (Verdonck and Walker, 1976). Verdonck and Walker (1976) found that there was a gender difference between body types and temperament variables in children aged 6-14 years; they also noted that their study which used "difficult to bring up" but not clinically diagnosed as mentally retarded, has similar results compared other studies. Kretschmer (1921) examined the connection between somatotype and behavior; his findings suggested that the athletic build was associated with being slow, reflective, and stable. According to Maher and Maher (1994), although the athletic type was not paired with a specific psychopathology, there have been suggestions that this somatotype may be related to criminal behaviors. The leptosomes are described as having the potential for schizophrenia, while their behavior is described as cold and non-emotional. The pyknic type was described as frank, social, and likely to fluctuate from cheerfulness to serious. These somatotype-associated behaviors have since been thought to be, possibly, bipolar psychosis (Tucker, 1983).

Studies have shown that people interact with others based on body type, and paradigms about these somatotypes. Body type also influences how an individual views himself/herself (McGlenn, 1976; White, 1973; Baron, 1969). Tucker (1983) studied 142 males, their muscle strength and self-concept. He found that those who were stronger were less emotional, less anxious, and more content with themselves than those with less muscle strength. Somatotype and athletic ability as player type has been linked (Quarrie et al., 1996; Quarrie et al. 1995; Bale, et al., 1994; Bale, 1991; Hopper, 1997). Quarrie et al. (1995, 1996) found that different body types are more suitable for different positions played by rugby players. The greater mesomorphic traits that a football player had were a significant factor determining college player strength (Bale et al., 1994). This was in contrast to high school players who had fewer ectomorphic traits (Bale et al., 1994). Hopper (1997) found body type was an indicator of volleyball player position. The typical body type of athletes differs between individuals as well as between non-athletes (Toriola et al., 1985)

It is possible that the theories between body type and personality are compounded by human perceptions. A person who is esthetically appealing to another may feel better about themselves simply because others treat them as desirable.

Animal reactivity

Individual animal reactivity has been related to animal productivity. Reactivity has been measured as activity level during physical restraint in a squeeze chute (Voisinet,1997a,b), speed of exit after physical restraint in a squeeze chute (Fell et al., 1999), or in an "open field" environment such as an auction (Lanier et al., 2000). The size of the flight zone can often be used to measure temperament (Randle, 1998).

Flight zone behavior. The flight zone is the distance from an animal to a perceived threat (Smith, personal communication). This zone is sandwiched between the recognition and fight zones (Smith, 1998). These zones are thought to be oval-shaped (Grandin, 1988) but have been shown to be egg-shaped (Smith, 1998) and are elastic in nature (Huxley, 1934). The zones were first characterized in birds (Huxley, 1934). The concept of the flight zone was given a name by Hediger (1934), and later applied to mammals and its use to move animals (Hediger, 1950). It was estimated that flight zones in feedlot cattle are approximately 5 to 25 feet (Grandin, 1978). However, it is also known that flight zones of feedlot cattle can extend beyond the pen they are housed (Grandin, personal communication; Smith, 1998). Smith (1998) discusses head-on approaches and large profiles that can increase cattle flight zone, while side profile approaches by humans (side profiles are smaller than frontal profiles) minimize the flight zone. The flight zone consists of two distinct components: the boundary line and the space between this line and the animal (Smith, 1998). Livestock herders and handlers calmly move animals from point "A" to point "B" by using this boundary or edge. According to Smith (1998), invasion into the interior causes alarm to the animal by triggering the "fight or flight" response. Flight zones differ within and between herds and individuals (Seabrook 1994; Albright, 1978).

Production and temperament

Animal reactivity, also known as temperament, greatly affects animal productivity, and ultimately the producer's profitability. The inclusion of temperament in the progeny criteria for dairy calves has been determined to increase profitability of sires (Bowman et al., 1996). For this reason, producers often incorporate temperament into their breeding plans. A survey found that commercial cow/calf producers ranked disposition after birth weight, as their second most important selection trait in bulls (Cole et al., 1998). Their top three reasons for wanting bulls with calm dispositions were: (1) excitable bulls lose physical condition, (2) temperament is heritable, and (3) there is a high labor cost associated with wilder cattle. Producers know that calm handling of cattle (Stricklin and Kautz-Scanavy, 1984) and calm cattle (Grandin and Deesing, 1998; Smith, 1998) can increase the productivity of a cattle operation.

Regardless of why the animals are calm, previous experience or genetics, they have overall better feedlot performance than flightier animals (Burrow and Dillon, 1997). Excitable feedlot cattle have higher death rates, poorer average daily weight gain, and higher cortisol (the hormone used to determine stress levels) levels than calmer calves (Fell et al., 1999). Excitable animals are prone to poor carcass qualities such as tough meat and dark cutters (Voisinet et al, 1997a). Dairy cattle that had been previously handled roughly had reduced milk yield due to an increase (70%) in residual milk (milk that remains in the udder and is not collected by the dairy) when the rough handler was present (Rushen et al., 1999). Burrow and Dillon (1997) reported that crossbred *Bos indicus* feedlot cattle with minimal exposure to humans, or those with excitable temperaments, had poorer weight gain and lighter carcasses than those exposed to intensive handling or were calmer animals. Among animals with intensive human exposure (handling), there was little difference between the excitable and calm cattle in weight gain and carcass weight, though the flightier animals did gain weight slower. That study reported that regardless of why the animals were calm, (handling or genetics) they had better overall feedlot performance than did the flightier animals (Burrow and Dillon, 1997). Temperament of an animal affects its overall productivity. The inclusion of temperament into the progeny criteria for dairy calves has been determined to increase profitability of sires (Bowman et al., 1996).

Bone growth

Bones are characterized by their shape: flat, round, short, long, and sesamoid (Pasquini et al., 1997). Metacarpals, tibias, and femurs are examples of long bones (Pasquini et al., 1997). Long bones are harder than other bones in the body and have a soft center with visible spaces (cancellous bone) (Pasquini et al., 1997). Length growth of the long bone occurs by a different process than does growth of the bone in width and thickness. Bone growth rate has been shown to be similar between bulls and steers when adjusted for bone weight, in many of the bones studied including the tibia and fibula (Shahin et al., 1992).

The growth (epiphyseal) plate determines the length of long bones. The growth plate rests between the body of the long bone (diaphysis) and its broadened two ends (epiphyses). The side of the growth plate closest to the epiphysis is the area of growth. Once the growth plate has converted from cartilage to bone, the long bone ceases to lengthen (Pasquini et al., 1997). Long-bone growth is not simply adding more to its outer surface. If this were the case, the femur in the adult would be excessively heavy and its medullary cavity (within the diaphysis and containing the marrow) would be excessively small.

Bone width and thickness occur as a result of bone accumulation beneath the fibrous layer (periosteum) around the bone (Buckwalter and Cooper, 1987). This is a process termed "modeling and remodeling," and involves removing bone material from the inside of the bone and placing it on the outside (Buckwalter and Cooper, 1987). The width and thickness may be altered positively or negatively, via various mechanisms (mechanical stress) such as exercise, nutrition, hormones, and genetics. The signaling mechanism that allows the bone to react to changes in mechanical stress has not yet been identified (Buckwalter and Cooper, 1987).

Many minerals such as iron, cobalt, iodine, and manganese (Ott and Asquith, 1995) are necessary in bone formation of horses. A study in horses demonstrated that supplementation of twice the recommended levels of calcium to horses housed in stalls for 12 weeks (restricted activity) did not maintain bone mineral content (BMC), although serum calcium levels increased (Porr et al., 1998). Zinc is critical in the formation and growth of bones (Ma and Yamaguchi, 2000; Yamaguchi 1998). Research has found that bone growth is further assisted with zinc in combination with insulin-like growth factor-I (IGF-I) (Ma and Yamaguchi, 2001). Fat and fiber appears to bind Ca and thereby inhibits the function of minerals for the bone growth in horses (Hoffman et al., 1999).

Milk quality

Milk quality is determined by three main factors: (a) fat, (b) protein, and (c) content of other solids (Classnotes, 2000). The buying and selling of milk is based on these three components, and is termed Multiple Component Pricing. There are individual cow differences in the quality of the milk they produce (Smith, 1997). Standardization corrects for this difference in individual quality for purposes of buying and selling fluid milk. Methods of standardizing milk production among cows include: (a) Fat- Corrected Milk (FCM), (b) Energy-Corrected Milk (ECM), and (c) Mature-Equivalent (ME). The equation for FCM and ECM are (Factor "A" x milk yield) + (Factor "B" x fat or energy yield), where factors "A" and "B" are set values dependent on actual fat or energy values (Cassell, 1997).

Mature-Equivalent. Mature-Equivalent (ME) standardizes cow productivity by adjusting all records to a uniform, twice-a-day milking for 305 days of lactation for cows that have been milked for at least 50 days. This method of standardization provides the dairy with an indication of what a cow would have produced had she calved at particular time of the year and was of "mature" age (Stiles and Dickson, 1985). This assists in assessing how well an animal is performing compared to her herdmates.

Productive Life. Dairy producers use genetics to improve the potential for increased milk production and the quality of the milk. The Dairy Herd Improvement Association (DHIA) uses Productive Life (PL) to estimate the genetic potential of an individual to resist being removed from the herd (culled) by the producer (Wailes, personal communication). Productive life is comprised of Predicted Transmitting Ability (PTA) and is calculated as total months-in-milk at age seven with a maximum of 10 months per lactation (Holstein Type-Production, 1999). Direct and correlated traits are used to derive PTAs. Direct traits are the actual values computed by the USDA without adjusting for level of milk production, and correlated traits are Holstein Association USA- and USDA-combined projections based on a model (Holstein Type-Production, 1999). The longer an animal is in the herd, the more accurate her PL estimate becomes; however, the actual genetic value of the individual decreases as the younger cows have the newer, and hopefully improved, genetics (Wailes, personal communication). Productive Life is often finished at age 7; therefore, usually only five lactations are included for each animal and heritability is estimated to be about 8.5% (ARS/USDA, 2002).

Removal of an animal from the herd (culling) is divided into two categories, selective and non-selective. Selective culling includes production-related reasons, while non-selective culling includes everything unrelated to milk production, such as reproduction, injury, and health. Relative values are given to those cows that leave the herd based on production factors (DHI-Provo Herd Summary, 2002). A relative value of 100% represents the average animal in the herd. The lower the relative value, the more likely animals are leaving the herd for productive reasons (selective culling), rather than for non-production (non-selective culling) reasons (DHI-Provo Herd Summary, 2002). Cows are typically in a herd for 3 ½ lactations under normal herd management, and the majority of the culling of individuals occurs after the first lactation (Miller, personal communication).

Carcass characteristics

Warner-Bratzler shear force (WBS). Warner-Bratzler shear force is a standard method to obtain an objective mechanical tenderness evaluation for cooked meat. Shear force is measured in kilograms or pounds required to cut through a standardized meat core. For high consumer acceptability beef top loin steaks should have a WBS threshold value of 4.6 kg for retail supermarkets and 3.9 kg for food service, which includes fine restaurants (Shackelford et al., 1991). Meat is likely to be tough if these threshold values are exceeded. A WBS value of 4.6 kg had a 50% chance of being rated as at least slightly tender, and 3.9 kg had a 68% probability of being rated as tender (Shackelford et al., 1991). Untrained consumers who cooked the steaks at home and restaurant customers found steaks to be acceptable 98% of the time if the WBS values were 4.1 kg or less (Huffman et al., 1996). The quantity of collagen in meat affects its tenderness; as collagen increases, tenderness decreases. Tenderness also decreases as degree of doneness increases (e.g., medium rare, medium) because of shrinkage of muscle fibers during cooking (Wulf et al, 1996). Aging beef loin strip steaks for 14 days postmortem increased tenderness (WBS) and improved the eating experience (Miller et al., 1997).

Color. Color of meat is determined primarily by the absorption and reflection of light wavelengths based on the pigments (hemoglobin and myoglobin) found in the meat (Aberle et al., 2001). Color is determined by combinations of hue (yellow, green, blue, and red), chroma (intensity of the light with respect to the amount of white light present), and value (brightness in regard to the reflective capability). Muscle color (Page et al., 2001) is determined using three variables: L* (0 = black to 100 = white), a* (using values

–60 to 60; lower numbers represent more green and less red, while higher values are the opposite), and b* (using values –60 to 60; lower numbers represent more blue and less yellow, while higher values are the opposite). Although color can be explained on a biochemical level, perception of color among humans may be different from the actual color (Aberle et al., 2001). It has been shown that colorimeter reading a* and b* are related to carcass muscle pH (Page et al., 2001), while L* is correlated with lean maturity (Page et al., 2001). Green and blue colorimeter readings are associated with an increase in muscle pH, while red and yellow readings result in lower muscle pH. Page et al. (2001) discussed how a* and b* are highly correlated to one another; they present evidence that the use of hues a* without b*, and vice versa, is not as effective in determining carcass color as the use of a* and b* together.

Quality Grades (QG) and Yield Grades (YG). Quality and yield grades are used to assess carcass quality and cutability (Boggs and Merkel, 1990). In carcasses from youthful cattle, the USDA quality grades (from highest to lowest) are Prime, Choice, Select, and Standard. Depending on the relationship between marbling and maturity quality, grades are assigned (Boggs and Merkel, 1990). Quality grade is determined by the amount of marbling (intramuscular fat), estimated physiological age of the animal measured by the ossification of the vertebrae and ribs (skeletal maturity), and lean maturity. Highly marbled, youthful carcasses with a bright red color receive higher quality grades than those carcasses with darker meat and with less marbling. There are nine scores for marbling that are used in determining quality grade (Aberle et al., 2001).

While quality grades are based on subjective assessments; yield grades are based on more objective measures of expected retail yield. An equation [(YG=2.5 + (2.4 x fat thickness, in inches) – (0.32 x ribeye area, in inches squared) + (0.2 x % kidney, heart, and pelvic fat) + (0.0038 x hot carcass weight (HCW))] is used to determine yield grade, with the lowest number being assigned the value of one (Yield Grade 1) (Aberle et al., 2001). Although carcass characteristics can be somewhat predicted using the above assessments, other factors have effects on quality.

Maturity is a subjective measure of the physiological age of an animal, with maturity of the skeleton and lean (color changes as the muscle becomes meat) being used to establish final quality grade. As the animal ages, bones ossify from soft cartilage to hard cartilage, to bone (Aberle et al., 2001). This process visually changes the bones, and these changes are used to assess the skeletal maturity of the animal. Beef carcass graders determine skeletal maturity by viewing the tips of the spinous processes of the dorsal vertebrae after the carcass has been divided down the midline (Aberle et al., 2001).

Numerous factors have an influence on YG, such as the muscle-to-bone ratio, amount of fat around the kidney and heart, and degree of fatness (Aberle et al., 2001). Fat thickness is the amount (depth) of subcutaneous fat on the outside of the carcass. Fat thickness is traditionally measured in inches between the 12^{th} and 13^{th} rib interface over the ribeye muscle (Aberle et al., 2001). The ribeye area (REA) is measured in square inches and is a fairly accurate indicator of overall muscling (Boggs and Merkel, 1990).

Kidney, pelvic, and heart (KPH) fat is the amount of internal fat surrounding these organs. Fat thickness, REA, carcass weight and KPH fat are used to estimate yield grade.

Objective of research

The objective of this research was to examine the dichotomies of cattle productivity and temperament, temperament and physical indicators, and productivity and physical indicators; three separate studies were used to assess these relationships: (1) in-production dairy cows, (2) feedlot heifers, and (3) auction cattle. The feedlot heifers were involved in a vitamin trial at the time that these studies were conducted.

Chapter 1

The association between behavioral reactivity, facial whorl characteristics, and milk production in Holstein dairy cows

Abstract

The objectives of this study were first to develop a simple behavioral test for temperament that did not require interference with normal dairy operations, and then determine if there was a dichotomous relationship between physical indicators, temperament, and production. Study animals included 326 registered Holstein dairy cows from the Dyecrest Dairy, LLC, in Fort Collins, CO. Temperament testing was conducted when the cows were restrained in lockup head stanchions. The flight behavior assessment consisted of three distinct steps with which the cattle were unfamiliar: (1) presented a human side profile to each animal for 15 seconds; (2) slowly stepped forward with the inner leg towards the animal, and leaned sideways, allowing the inner arm to hang vertically, while maintaining visual contact with the animal's forehead; then (3) calmly returned to an upright position. Reaction of the cow was rated as: (1) no reaction, or stretched to sniff observer (inquisitive behavior); (2) pulled away from observer but did not pull against head stanchion; or (3) pulled against head stanchion, or head remained pulled against stanchion throughout test. Height of facial hair whorl placement was rated as high, middle, or low in relation to the eyes. Lateral whorl placement was recorded as on the right, on the left, or in the middle of the facial centerline. Whorls were categorized for type of epicenter; whether occurring singularly, in pairs, or triples; and the shape

(spiral, line, flare). Spiral whorls were further described for their rotational spin. Only cattle with a facial hair whorl were used in this study. Milk production data were obtained from the Dairy Herd Improvement (DHI) database in Provo, UT. The majority of cows (40%) were in their first lactation. Analysis of data from all individuals showed that very reactive animals had 47.3 kg less Mature-Equivalent fat production compared to the non- and mildly-reactive animal average ($P = 0.05$). Those with multiple lactations, and facial hair whorls with a bald epicenter had greater mature equivalent protein and milk yield than individuals with point epicenter whorls. Cows that remained in the herd for more than one lactation had less facial hair whorl variability than those in their first lactation. The lower the facial hair whorl, the more often the animal actively pulled away from the looming person ($P = 0.02$). Results of this study demonstrated that milk production is related to facial hair whorl type, which in turn is related to temperament. The temperament testing method developed for this study is a simple practical test that can be used in commercial dairies without disrupting farm production. Simple procedures for assessing temperament in beef cattle has been available for years; however, until now there was no simple test for dairy cows that did not require individual handling of each animal.

Introduction

Temperament tests for assessing dairy cows under commercial conditions are often difficult to conduct. Many dairies will not allow investigators to handle individual animals. Previous researchers have found that hair whorl characteristics were associated with temperament (Lanier et al., 2001; Randle, 1998; Grandin et al., 1995). The objectives of this study were first to develop a simple behavioral test for temperament that did not require interference with normal dairy operations, and then determine if there was a dichotomous relationship between physical indicators, temperament, and production.

Materials and Methods

Animals

Three hundred twenty-six registered, artificially inseminated Holstein dairy cows at the Dyecrest Dairy, LLC, in Fort Collins, CO were used in this study. Approximately 1,000 lactating individuals were milked three times a day in a double 20-stall herring bone parlor (type of milking barn), with a Bou-Matic (Madison, WI) computerized milking system. Housing was free stall (cubicles) with access to an outdoor dirt pen with approximately 100 animals per pen. Lactating cows were fed a total mixed ration twice a day while restrained in head stanchions. Lactation enhancers such as bovine somatotrophin (BST) were not used, and all milk was sold and marketed as "All Natural."

The Dyecrest Dairy herd had been closed to new animals for 25 years, but recently was opened to add 350 registered Holstein heifers. Animals were selected for inclusion in the herd based primarily upon milk protein yield, with the average selective cull rate (poor production) ranging from 11–14%: Non-selective culling (non-production reasons) ranged from 10-14%. Total removal rate for the herd varied between 21 and 25% annually, and the relative value of animals leaving the herd was 88 to 91%, where 100% represents the average individual in the herd. Thus, cows were typically culled for poor production rather than for health or reproductive reasons.

Study design

The research was designed around the following constraints required by the dairy: (1) no physical contact with the animals; (2) access only during the morning or evening feeding; (3) no interference with production or any farm procedures; (4) the researcher had to remain outside of the pens and cattle alleys. The latter constraint limited the researcher to conducting temperament tests from the vehicle alleys used for feeding and transporting cows.

The herd was fed in two different manners, with approximately equal numbers of cows in each group. One group was fed in pens with traditional concrete troughs adjacent to the vehicle alley, and the other group in pens with a ground level concrete feeding pad. All animals were held in lockup head stanchions while feeding. The latter group was used in this investigation.

Prior to data collection, different methods were tested to establish the best temperament test to assess individual temperament within the above-stated constraints and without disturbing adjacent cows or normal dairy operation. One hundred and seventy four animals were used in these preliminary tests; these animals were not used in final data collection, due to the possibility of habitation to the tests and (or) the observer.

Flight behavior assessment

The traditional startle test for flight behavior (a sudden noise or movement, such as stomping a foot) was quickly abandoned after a few initial trials. The target animal's reaction was extreme, as were the reactions of three to ten other animals on either side. These adjacent cows appeared to panic, jumping backwards and violently pulling against the head restraints in an effort to escape. Any animal that was not the individual being tested and that was visually assessed, as being affected by the researcher was not included in the study.

To prevent panic, flight behavior was assessed as the individual cow's reaction to a looming person. Reaction was scored while the animals were restrained in outdoor head stanchions during the morning feeding. The flight behavior assessment consisted of three distinct steps involving a person with which the cattle were unfamiliar: (1) presented a human side profile to the animal, one shoulder directly opposite the animal's head, at approximately 90 cm distance from the target animal's head, then waited 15 seconds (Fig. 1). This short wait period was timed by the observer counting silently 1,001, 1,002, ... 1,015. During this time, the researcher looked at the center of the cow's forehead.

After 15 seconds had elapsed, the person, (2) slowly stepped forward with the inner leg towards the target animal, and simultaneously leaned sideways, allowing the inner arm to hang vertically, all the while maintaining visual contact with the animal's forehead (Fig. 2). The combination of stepping and leaning towards the animal brought the shoulder to an approximate distance of 61 cm from the cow. The researcher remained leaning towards the animal for 2-4 seconds, and then, (3) calmly returned to an upright position, discontinued eye contact, and stepped forward to a position directly in front of the next subject. The procedure was then repeated on the next individual. During temperament assessment, the researcher walked parallel to the feed trough approximately 90 cm from the cows' heads. All animals were approached in this manner. The researcher never faced the subject using a full frontal position of her body. Experience gained during the preliminary test indicated that head-on approaches and large profiles increased cattle flight zone.

This procedure was conducted using very calm, smooth movements to prevent a startle response by the target animal that could agitate adjacent cows, thus invalidating the inclusion of all animals affected. Reaction was rated as: (1) no reaction or the animal stretched to sniff the observer (investigative behavior); (2) pulled away from observer but did not pull against head stanchion; or (3) pulled against head stanchion, or head remained pulled against stanchion throughout test (Fig. 3). Animals were tested once. The elimination of 174 cattle used in designing the test resulted in data from 326 head available for analysis.

Hair whorl categorization

Height of facial hair whorl placement was rated as high, middle or low in relation to the eyes as described by Grandin et al. (1995). Lateral whorl placement was recorded as on the right, on the left or in the middle of the facial centerline (Lanier et al., 2001). The centerline was considered to have a two and a half-centimeter width (Fig. 4). The epicenter of the spiral hair whorl was used as the reference for both vertical and horizontal location. Whorls were categorized for type of epicenter (Fig. 5a; 5b), whether occurring singularly, in pairs or triples (Fig. 6), and the shape (spiral, line, flare) of the whorl (Fig.7a; 7b). Spiral whorls were further characterized for their rotational spin (Fig. 8). Individuals without a facial hair whorl were recorded as having no whorl.

Production data

Milk production data was obtained from the Dairy Herd Improvement (DHI) database in Provo, UT. Production variables included Mature-Equivalent for Milk (MEM), Fat (MEF), and Protein (MEP). Fat-Corrected Milk (FCM), Energy-Corrected Milk (ECM), and the Productive Life (PL) of the five aforementioned variables also were used as individual production dependant variables.

After data analysis, a trend was noticed concerning hair whorl characteristics in cows (n = 10) that had remained in the herd for six to ten lactations. In an effort to increase the number of cows in this category for further analysis, an additional 16 cows that had been in the herd for six to ten lactations at the time of the original data collection were located and their facial hair whorl characteristics recorded. No data collection or analysis of reaction to a looming person was conducted using the additional 16 cows, as data not collected during the same time period and season as the original data may alter the result.

Statistical analysis

All statistical procedures included all cows regardless of number of lactations in the herd, and then included only those cows that had multiple lactations. First lactation cows do not have a production-related basis for being culled, as they do not have a production record from which to determine whether or not they are meeting the dairy's criteria. Those that had multiple lactations had potential for removal from the herd but had met the dairy production criteria. Comparisons were made between first lactation and multiple lactation animals. Only individuals with facial hair whorls were included in this study.

Productivity and temperament

Production and reaction to a looming person. Production variables were analyzed as a dependent variable in a one-way analysis of variance (SAS, 1999-2000) with the animal's reaction to a looming person as the independent variable. It was anticipated *a priori* that cows that were more reactive to a looming person would have lower production. The contrast estimate statement in PROC GLM was used to compare the average production yields of highly reactive cows to the combined average of the mildly and non-reactive cows. This analysis included the 16 animals added post hoc.

Productivity and physical indicators (attributes)

Production and hair whorl. Dependant production variables were evaluated by levels of facial hair whorls binomial characteristics (flare or no flare, one whorl or multiple whorls, and bald or point epicenter) using a two-tailed t-test in SAS® PROC TTEST (SAS, 1999-2000). When F-test for equality of variance was significant, the unequal variances t-test was used. Otherwise, the pooled variance t-test (Satterthwaite-corrected test) was used (SAS, 1999-2000). Production variables also were included as dependent variables in a one-way analysis of variance model (SAS, 1999-2000) with the cow's facial hair whorl characteristics (lateral position, height, shape, and direction of whorl spin) scored as one of three possibilities (e.g., shape was either spiral, flare, or a line) as the independent variable. Chi-squared analysis in SAS (1999-2000) was used to evaluate facial hair whorl characteristics in association with whether or not the animal had remained in the herd for one or multiple lactations, and whether she remained in the herd for three or less, or more than three, lactations. Chi-squared analysis also was used to determine if the facial hair whorl characteristic (dependent variables) differed between those in their first lactation and those with six or more lactations.

Temperament and physical indicators (attributes)

Hair whorls and reactivity analysis. Associations between facial whorl characteristics (independent variables) and reaction to a looming person were assessed using chi-squared analysis. Observed values were tested against their expected values.

Results

The number of lactations per animal ranged from one to ten, with the greatest percentage of cows (40%) being in their first lactation (Table 1). Production values for those in their first lactation, all lactations, and those with six to ten lactations are listed in Table 2a and 2b.

Productivity and temperament

Milk production and reaction to a looming person. Analysis of all cattle showed very reactive cows had 47.3 kg (s.e.m. = 24.16) less mature equivalent fat compared to the non- and mildly-reactive individual average ($t = 1.96$; $P = 0.05$). No significance was noted for the other production values. When only those cows with two or more lactations were analyzed, no significance was found between reactivity and milk production. However, a weak association was found between reactivity and Mature Equivalent Fat. The very reactive cows had 47.7 kg (s.e.m. = 29.55) less MEF compared to the non- and mildly-reactive cow average ($t = 1.61$; $P = 0.11$). The decrease in significance was most likely attributable to the small number of animals (n= 176) with two or more lactations. This analysis does not include the additional 16 added post hoc.

Number of lactations and reaction to a looming person. Due to the small number of cows in most multiple lactations, statistical analysis was not possible. Table 3 displays the data for the individuals' reaction to a looming person depending on how many lactations she had. No analysis was conducted using the additional 16 cows added to the data post hoc.

Productivity and physical indicators (attributes)

Milk production and hair whorl characteristics. No significant associations were found between hair whorl characteristics and production when all cows (regardless of the number of previous lactations) were evaluated. However, when only animals that had experienced two or more lactations were assessed, cows having a bald whorl epicenter produced higher MEP ($P = 0.02$) and MEM than those cows having a point epicenter ($P = 0.06$; Table 4). Inclusion of the 16 cows added post hoc produced similar results (MEP $P = 0.01$; MEM $P = 0.04$; Table 4). Both analyses demonstrated that multiple lactation cows with facial hair whorls with a bald epicenter had higher Mature Equivalent Protein and Milk than cows with point epicenter whorls.

Number of lactations and hair whorl characteristics. The following results were for the original 326 cattle plus the additional 16 added post hoc, unless otherwise noted. Cows in their first lactation had 74% of the hair whorls on the lateral centerline, 75% had bald epicenters, and of those with a spiral whorl, 47% had no rotational spin. The animals having been in the herd for 2-10 lactations (n=211) had 56% (not different than expected) of the whorls on the centerline, 64% had bald epicenters, and of those with a spiral whorl, 28% had no rotational spin (Table 5). These observed values differed significantly from the expected values.

Of more interest was the comparison of facial hair whorls of first lactation heifers to those of cows having been in the herd for 6-10 lactations. In Table 5 are the results of this analysis, which used the original number plus the additional 16 cows. Hair whorl height and epicenter type differed between first lactation cows (n=131) and those with 6-10 lactations (n=26). Those that remained in the herd for six to ten lactations had less variability in whorl height and more point epicenters than first lactation cows. The facial hair whorl characteristics by first, second through fifth, and sixth through tenth lactations are shown in Table 6. Only cautious inferences could be made regarding these results as only 26 cows were in the herd for six or more lactations.

Temperament and physical indicators (attributes)

Reaction to a looming person and facial whorl characteristics. The only association between whorl characteristics and cow reaction to a looming person was in the height of the whorl. The lower the facial hair whorl, the more often the cow actively pulled away from the looming person (Table 7). These values differed significantly from their expected values.

Discussion

Behavioral test development

The constraints placed on researchers by the dairy reduced the temperament test options for this research study, and necessitated the development of a new temperament test. Developing a new test required numerous trials to determine its validity. It was imperative to test the procedures on animals similar to those that were to be used in the actual study. The validation process used 174 of the approximately 500 cattle that could have potentially been used in the actual study. These 174 animals were not included in the final data collection due to the possibility of their habitation to the temperament test and the observer.

The preferred temperament test would have been to conduct individual, open-field tests in a novel environment combined with physiological measurements (e.g., heart rate, cortisol level). This would have required individual handling of each cow in a special test area. This type of test was not feasible at the dairy. When studies are conducted in the field, new procedures are often devised to conduct research within the constraints placed on researchers by managers of the commercial operation. In many species, the open-field test has been used as a measure of an individual's fear-based temperament (Hall, 1934). It has been used in several species such as rats (Eysenck and Broadhurst, 1964), cattle (Lanier et al. 2000; Grandin, 1993; Fordyce et al., 1988) and dogs (Mahut, 1958). Researchers have used various types of physiological measures such as opioid levels (Rushen et al., 1999), heart rate (Steinhardt and Thielscher, 2000), and cortisol levels (Steinhardt and Thielscher, 2000; Lyimo et al. 2000) to assess dairy cattle behavior. In a future study, it would be advantageous to determine the relationship between the newly developed looming test and physiological indicators. Incorporation of physiological measurements along with behavioral observations into a temperament test increases the validity and reliability of an individual's temperament assessments (Manteca and Deag, 1993). Agitation and increased behavioral reactivity in an open field-test or during restraint is associated with increased levels of stress-induced hormones.

Animal vision and the behavioral test

Both horses and cattle are prey species with wide set eyes; and, this fact may explain the reaction of the cows to the person leaning towards them. Animals with eyes set on the side of the head, such as horses, cattle and sheep, have different fields of vision depending on head position (Coulter et al., 1993). When a horse's forehead is perpendicular to the ground their field of vision has been reported to be directed towards the ground with a corresponding blind area directly above the visual field (Kilgour and Dalton, 1984). Assuming that cattle have vision similar to horses, it is plausible that the observer's position during the reaction to a looming object was in their blind area. It was critical to the test that the observer suspended the inner arm in order to enter the blind area, while leaning towards the cow. If the observer did not hang the inner arm, most cows did not react to the observer leaning towards them. Therefore, it is believed that the temperament test was more a test of cow reaction to sudden penetration of the visual field, than a reaction to a looming object.

Figure 9 shows the approximate height of the researcher as she leaned towards the restrained cow. The end of the hanging arm was approximately 58 cm above ground level. Figure 10 demonstrates where the inner arm may have penetrated the visual field during the temperament test. Descriptions of three-dimensional cattle field of vision are lacking in the literature.

Figure 10 is an approximation to describe cattle acute binocular vision and the plausible individual differences in this area. It is known that cattle see movement quite well and they do have difficultly in quickly focusing on objects due to weak eye muscles (Kilgour and Dalton, 1984) as do horses (Coulter et al., 1993). The cows may have been reacting to an object (the arm) approaching them, as they may not have been able to focus on the approaching object.

Although all mammals have the same basic senses, these senses have been modified and fine-tuned to serve the needs of each species. For example, the shape and location of the eyes of a predator are quite different than that of a prey species (Smith, 1998), thus the cow and the cowboy in the same novel environment may or may not see or process what is being seen in the same manner.

Prey species have visual adaptations for survival in the wild (Craig, 1981). In general, these adaptations are: (a) wide field of vision, especially while head is lowered (Coulter et al., 1993), (b) bulbous eyes on the side of the head, and (c) almond shaped (oblate spheroid) pupils (Smith, 1998). With these adaptations come reduced visual abilities: (a) poor binocular vision, (b) limited field of vision while the head is lifted, (c) difficulty recognizing horizontal lines, and (d) reduced vision above and below the eyes (Smith, 1998). This design is termed ramp retina. Ramp retina allows for better vision when looking down, than looking straight-ahead (Coulter et al., 1993). Smith (1998) also notes that prey animals have relatively weak eye muscles, which inhibit the ability to readily focus. Coulter et al. (1993) note the tendency for the horse to shy away from sudden movement is due to their weak eye muscles. The effect of prey vision is the increased ability to detect movement and thus predators while grazing. On detection of motion, prey species visually orient on the source of the movement and watch until they determine that the stimulus is or it is not a threat, at which point the animal will either return to previous activity or take appropriate action (Smith, personal communication; Hediger, 1950). It is possible that motion-sensitive cattle are simply ineffective visual searchers (Humphreys, 1996) that have a greater desire to orient on an object (e.g., the exit) than their non-motion-sensitive conspecifics. Like horses, cattle may have the tendency to shy away from sudden motion due to the design of their eyes.

Visual search in mammals is theorized to occur in one of two manners; either the search is effective or it is ineffective (Humphreys, 1996). The search is effective if the brain filters out the visual clutter before the eyes focus on the desired object. Noticeable differences, such as color, between the desired object and the visual clutter and the amount of visual distraction assist in determining an effective search. An ineffective search is characterized by the brain's inability to filter out visual clutter before the eyes focus on an object. The correlation between visual clutter and the potential for ineffective search is positively correlated (Humphreys, 1996).

Individual differences in the location of the upper edge of the visual field may have confounded the results of the temperament test. During the temperament test, a head stanchion prevented the cows from leaving the test area; however, it did not prevent cows from raising or lowering their heads, nor did it prevent cows from extending their necks. Although all cows stood on a flat concrete slab while restrained for feeding and the subsequent temperament test, cows differed in height. Shorter cows would likely have a lower field of vision than the taller cows. The potential for every cow's head to be in a different position would contribute to each cow having a differing height and angle for their visual field. This difference in the location of each cow's visual field may have caused the observer's inner arm to penetrate some, but not all, of the cows' field of vision. Of those cows whose visual field was penetrated, a difference in the amount of penetration may have occurred.

It is probable that the cows were reacting to the increased penetration of the observer (looming object) into their flight zone. A looming object requires two variables: size and speed. An object very small in size but moving quickly is not readily noticed, nor is a very large object moving slowly. The observer (large object) slowly leaned towards each animal and, the arm was an extension of the observer. The animals knew that the observer was standing in front of them. The hanging arm may have been a variable outside of the cow's ability to predict what the observer might do next, or they were attempting to focus on the arm as it moved towards them.

The researcher experimented with side and frontal profiles while designing the temperament test. Presenting a full frontal profile caused the animals to react too strongly to the presence of the observer. This strong reaction by the target animal caused the neighboring cows to become startled. A full frontal position also increases the perceived size of the observer. Approaching an animal using a side profile decreases the perceived size of the observer and assists in decreasing a startle response. The side profile position also helped reduce the responses of adjacent animals. During, testing, a full frontal body position was never used or while moving from one individual to another. Cattle assess dominance, in part, by determining the size of the other human or animal (Smith, 1998). In general, the larger the animal, perceived or actual, the more dominant the animal (Smith, 1998). During the actual temperament test, the observer never faced the cows using a full frontal position of her body.

Animal reaction may be an effect of novelty

As the researcher was restricted to conducting temperament tests from alleyways primarily used for vehicular traffic (e.g., the feed truck), her physical location might have been a novel experience for the cows. The cow's reaction to the looming person may have been a reaction to novelty. The cows were familiar with seeing people walking inside the pens and in the alleys leading to the milking parlor, but not in the vehicle alley, as neither people nor the cows used this alley. Therefore, a person walking in the vehicle alley was a novel experience for the cows. A novelty is something that is new, unusual, or out of context (Webster's, 1992). According to Temple Grandin, cows differentiate between a familiar person walking in their pen and a strange person in their alley.

Novelty increases apprehension. When something is novel, it is perceived as unpredictable (Saplosky, 1994). This creates a heightened awareness which, biochemically, changes an animal's nervous system from a calm status quo state (parasympathetic) to a state of alertness (sympathetic). The sympathetic nervous system allows an animal to quickly react to an unpredictable situation (Robertshaw, 1993). The "flight or fight" response is typical of this heightened awareness. The researcher's presence in the vehicular alleys created a heightened state of awareness in the dairy cows. The cows orientated and looked at the investigator walking in the alley. In designing the temperament test, it was critical not to trigger adjacent cows' nervous systems beyond the orienting alert stage to the "fight or flight" stage while testing the test cow. Assessing how an individual reacts to a sudden novelty is considered to be a relatively accurate measurement of that animal's temperament (Heird and Deesing, 1998).

The cows used in this study were accustomed to being restrained by the head during the morning feeding. The presence of a person in the vehicle alley during this time was a novel experience for these cows. Assessment of an animal's temperament during restraint (considered a novelty) has been shown to distinguish individual differences in cattle (Grandin, 1993; Fordyce et al., 1988).

Facial hair whorls and animal production

Hair whorl characterizations were related to production measures. According to Bill Wailes, Colorado State University dairy extension agent, most dairy cows are removed from U.S. herds by their 5th lactation. In theory, the ten cows with six or more lactations were anomalies. Different patterns were noticed in the facial hair whorl characteristics of these ten cows (Table 6) compared to those in their first, or second through tenth lactation. These patterns are of great interest when compared to the distribution of hair whorl characteristics of cows in their first lactation, as they may be related to longevity and production. Of particular interest were whorl height and the spiral-shaped whorl direction of rotation. Whorls at eye level were observed in 59% of the first lactation cows, and in 100% of the older cows. In first lactation cows with a spiral whorl, 47% had no rotation, while only 14% of the older cows had spiral whorls without rotation. Bald type epicenters in first lactation cows were observed in 75% of the whorls, and in only 60% of whorls of the older cows. Spiral-shaped whorls were present in 58% of the younger cows and 70% of the older ones. These patterns were interesting; however, it was unknown if the patterns were meaningful or due to there being only ten cows in the data set. Collection of more data was necessary to determine if cows retained in the Dyecrest Dairy herd for more than five lactations had a particular set of whorl characteristics. It was determined that there were 34 additional cows in their sixth or greater lactation at the time of the original data collection. Of the 34, only 16 were still in the herd one year later. These 16 cows were located, and their hair whorl characteristics were determined. The patterns observed on the ten cows were similar to that of the additional 16 cows (Table 5.). Further investigation into the hair whorl types of cows with extended herd longevity should be examined. Individuals with herd longevity appear to have different whorl patterns than cows that are culled after a few lactations. The Dyecrest Dairy primarily selected cows for kilograms of milk protein production. Selection for other traits such as kilograms of milk or fat may result in dairies with cows having different facial hair whorl characteristics.

Lanier et al. (2001) conducted the only other study of facial hair whorl characteristics in Holstein dairy cows. That study classified facial hair whorls, of cows (n=342) being sold at auctions, for height, lateral position, and whether or not they were spiral-shaped. Non-spiral shaped whorls accounted for 1.9% of the whorls and were termed abnormally shaped (Lanier et al., 2001). Whorl height and lateral position were predominantly at eye level (54%) and on the centerline (66%). These cattle were observed in a fast-paced setting in which the cows were free to move around the auction ring. While Lanier et al. (2001) were characterizing whorls of dairy cows culled from herds; it was unknown by them the reason the animals were being sold, (i.e. lack of performance, injury). At the Dyecrest Dairy, the researcher was able to spend a great deal of time classifying whorl types while the cows were restrained in head stanchions. The cows in the current study were in production whereas the ones in the auction study were cull cows.

Cows that reacted strongly to a looming person had less Mature Equivalent Fat than did the calmer cows. This relationship between temperament and production was expected. Studies have demonstrated a relationship between flighty temperament and poor production (Burrow and Dillon, 1997; Fell and Shutt, 1986). Regardless of why the animals are calm, (previous experience or genetics) they have overall better feedlot performance than flightier animals (Burrow and Dillon, 1997; Fell and Shutt, 1986). Excitable feedlot cattle have higher death rates, poorer average daily weight gain, and higher cortisol levels than calmer calves (Fell et al., 1999). Excitable animals are prone to poor carcass qualities, such as tough meat and dark cutters (Lensink et al., 2001). Dairy cattle that had been previously handled roughly had reduced milk yield due to an increase in residual milk (70%) when the rough handler was present (Rushen et al., 1999). Burrow and Dillon (1997) reported that crossbred *Bos indicus* feedlot cattle with minimal exposure to humans or those with excitable temperaments had poorer weight gain and lighter carcasses than those exposed to intensive handling or calmer animals. The animals with intensive human exposure (handling) had little difference between the excitable and calm cattle in weight gain and carcass weight. The flightier animals did gain weight slower. That study reported that regardless of why the animals were calm (handling or genetics), they had overall better feedlot performance than the flightier animals (Burrow and Dillon, 1997).

Temperament of individual dairy goats has been related to differences in milk production. Lyons (1989) hand-reared eight goats and compared their temperament and milk production to that of eight dam-reared goats. Mean milk residual (over seven milking events) was lower in the hand-reared goats, compared to that of the dam-reared goats. Timid goats, as measured by latency to approach a person, had greater milk residual (milk remaining in the udder post-milking) levels than did the individuals that approached people in less time (Lyons, 1989).

This study demonstrated an association between temperament, facial hair whorl characteristics of Holstein dairy cow and milk production. The use of temperament and hair whorls along with current dairy management options would further assist producers in determining the potential of an individual to remain in the herd. In addition, this study established a simple technique to determine individual temperament without interfering with dairy operations.

Conclusions

The majority of cows (40%) were in their first lactation and no individual had more than ten lactations. Very reactive cows produced 47.3 kg less mature equivalent fat compared to the non- and mildly-reactive cow average ($P = 0.05$). Multiple lactation individuals with bald epicenter facial hair whorls had greater mature equivalent protein and milk than those with point epicenter whorls. Those that remained in the herd longer had less facial hair whorl variability than those in their first lactation. The lower the facial hair whorl the more often she actively pulled away from the looming person.

Chapter 1 Tables

Table 1. Frequency of cows for each number of lactation represented

Number of lactations	Original data[1] *n*=326		Post hoc data included[1] *n*=342	
1	131	40.2%	131	38.3%
2	79	24.2%	79	23.1%
3	55	16.9%	55	16.1%
4	31	9.5%	31	9.1%
5	20	6.1%	20	5.9%
6	5	1.5%	16	4.7%
7	1	0.3%	4	1.2%
8	2	0.6%	3	0.9%
9	1	0.3%	1	0.3%
10	1	31.0%	2	0.6%

[1]Additional 16 cows included after completion of the study

Table 2a. Production values* of Holstein dairy cows, for all cows, first lactation cows and cows with 6 to 10 lactations**

Number of lactations		Age in days	Mature Equivalent Milk	Mature Equivalent Fat	Mature Equivalent Protein	Productive Life Mature Equivalent Milk	Productive Life Mature Equivalent Fat	Productive Life Mature Equivalent Protein	Fat Corrected Milk	Energy Corrected Milk	Productive Life Fat Corrected Milk	Productive Life Energy Corrected Milk
1 to 10	*means*	1388	13186	482	388	14720	508	442	13506	13495	14610	14754
n=326	*S.E.M.*	35	147	87	4	139	6	4	140	137	147	141
1	*means*	851	12653	454	368	N/A	N/A	N/A	12824	12807	N/A	N/A
n=131	*S.E.M.*	12	249	8	69	N/A	N/A	N/A	230	228	N/A	N/A
6 to 10	*means*	3279	11345	445	344	12892	458	836	12132	12098	13005	13029
n=10	*S.E.M.*	207	506	21	14	334	16	22	540	498	339	320

*All production values are from one lactation, and are provided in kilograms

**Means and their standard errors

Table 2b. Production values* of Holstein dairy cows, for all cows, first lactation cows and cows with 6 to 10 lactations**

Number of lactations		Age in days	Mature Equivalent Milk	Mature Equivalent Fat	Mature Equivalent Protein	Productive Life Mature Equivalent Milk	Productive Life Mature Equivalent Fat	Productive Life Mature Equivalent Protein	Fat Corrected Milk	Energy Corrected Milk	Productive Life Fat Corrected Milk	Productive Life Energy Corrected Milk
1 to 10	*means*	1388	13186	482	388	14720	508	442	13506	13495	14610	14754
n=326	*S.E.M.*	35	147	87	4	139	6	4	140	137	147	141
1	*means*	851	12653	454	368	N/A	N/A	N/A	12824	12807	N/A	N/A
n=131	*S.E.M.*	12	249	8	69	N/A	N/A	N/A	230	228	N/A	N/A
6 to 10	*means*	3184	11993	478	362	13301	484	398	12938	12862	13610	13648
n=26	*S.E.M.*	103	421	21	12	250	14	9	503	476	314	300

*All production values are from one lactation and include 16 additional cows in lacatations 6-10, and are provided in kilograms

**Means and their standard errors

Table 3. Cow reaction to a looming person statified by number of lactations

Reaction to a looming person	Number of lactations 1 *n=124*	2 *n=79*	3 *n=55*	4 *n=31*	5 *n=20*	1 to 5 *n=309*	6 to 10 *n=10*
no reaction	34	13	13	6	6	72	1
	27.4%	16.5%	23.6%	19.4%	30.0%	23.3%	10.0%
pulled away	43	30	15	16	4	108	8
	34.7%	38.0%	27.3%	51.6%	20.0%	36.0%	80.0%
pulled against bars	47	36	27	9	10	129	1
	37.9%	45.6%	49.0%	29.0%	50.0%	41.8%	10.0%

Table 4. Association between hair whorl epicenter type and milk production values for cows with multiple lactations

Epicenter type	Mature Equivalent Protein (MEP)		Mature Equivalent Milk (MEM)	
	mean	*S.E.M.*	*mean*	*S.E.M.*
original data	$P = 0.02$		$P = 0.06$	
point *n=55*	382	10	12958	326
bald *n=112*	408	6	13682	218
original + post hoc data	$P = 0.01$		$P = 0.04$	
point *n=64*	382	9	12901	298
bald *n=114*	407	6	13654	215

Table 5. Comparison of facial hair whorl characteristics between cows with one versus multiple lactations[1]

Number of lactations	number of whorls: one	two	whorl shape: spiral	flare	line	whorl height: above eyes	eye level	below eyes	lateral position: right	middle	left	epicenter type: point	bald	direction of spiral rotation: no rotation	clockwise	counter clockwise
1	108	20	73	40†	12	9	72	41†	10	82	19	31	95	36	19	21†
n=131	84.4%	15.6%	58.4%	32.0%	9.6%	7.4%	59.0%	33.6%	9.0%	73.9%	17.1%	24.6%	75.4%	47.4%	25.0%	27.6%
2 to 10*	185	23	118	66†	14	10	130	61†	33	104	50	72	129	34	26	63
n=211	88.9%	11.1%	59.6%	33.3%	7.1%	5.0%	64.7%	30.4%	17.7%	55.6%	26.7%	35.8%	64.2%	27.6%	21.1%	51.2%
6 to 10**	24	2	17	8†	1	1	22	3†	5	18	3	16	10	4	5	9†
n=26	92.3%	7.7%	65.4%	30.8%	3.8%	3.9%	84.6%	11.5%	19.2%	69.2%	11.5%	61.5%	38.5%	22.2%	27.8%	50.0%

[1]Includes additional 16 cows not in original study

*Chi square analysis comparing first lactation cows with cows that have had 2 to 10 lacations

**Chi square analysis comparing first lactation cows to cows that had been in the herd for 6 to 10 lacatior

†observed column values did not differ significantly from the expected values

Table 6. Facial hair whorl characteristics of cows differing in number of lactations[1]

Number of lactations	number of whorls		whorl shape			whorl height			lateral position			epicenter type		direction of spiral rotation		
	one	two	spiral	flare	line	above eyes	eye level	below eyes	right	middle	left	point	bald	no rotation	clockwise	counter clockwise
1	108	20	73	40†	12	9	72	41†	10	82	19	31	95	36†	19	21
n=131	84.4%	15.6%	58.4%	32.0%	9.6%	7.4%	59.0%	33.6%	9.0%	73.9%	17.1%	24.6%	75.4%	47.4%	25.0%	27.6%
2 to 5	161	21	101	58†	13	9	108	58†	28	86	47	56	119	30†	21	54
n=185	88.5%	11.5%	58.7%	33.7%	7.6%	5.1%	61.7%	33.1%	17.4%	53.4%	29.2%	32.0%	68.0%	28.6%	20.0%	51.4%
6 to 10	24	2	17	8†	1	1	22	3†	5	18	3	16	10	4†	5	9
n=26	92.3%	7.7%	65.4%	30.8%	3.9%	3.9%	84.6%	11.5%	19.2%	69.2%	11.5%	61.5%	38.5%	22.2%	27.8%	50.0%

[1]Includes additional 16 cows not in original study

†observed column values did not differ signifcantly from the expected values

Table 7. Relationship between facial hair whorl height and the cow's reaction to a looming person*

Reaction to a looming person		Hair whorl height		
		Above the eyes	At eye level	Below the eyes
no reaction	*n*	6	35	28
	column %	35.3%	18.7%	29.0%
pulled away	*n*	6	79	23
	column %	35.3%	42.3%	24.0%
pulled against bars	*n*	5	73	45
	column %	29.4%	39.0%	46.9%

*All values differ significantly from the expected values $P > 0.05$

Chapter 1 Figures

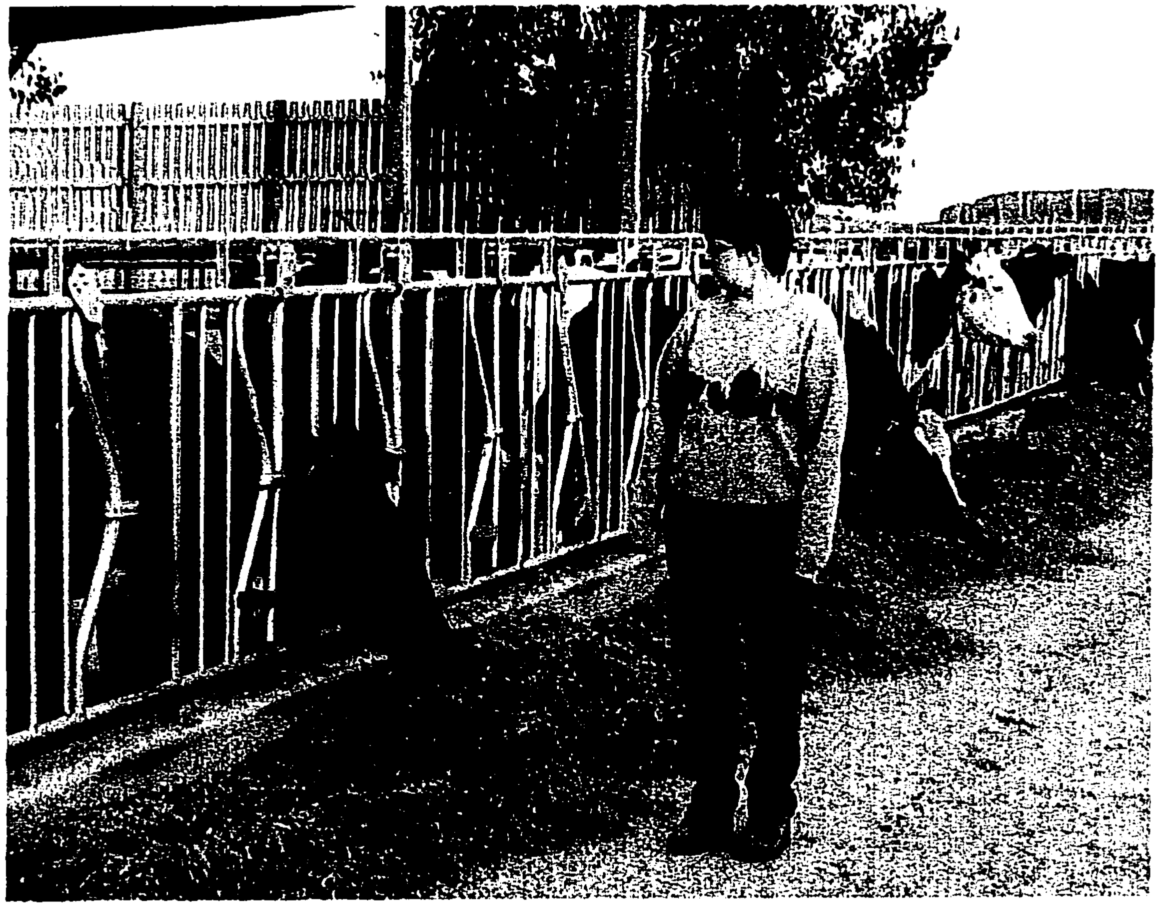

Figure 1. 15-seconds of acclimation was allowed before conducting looming-person test.

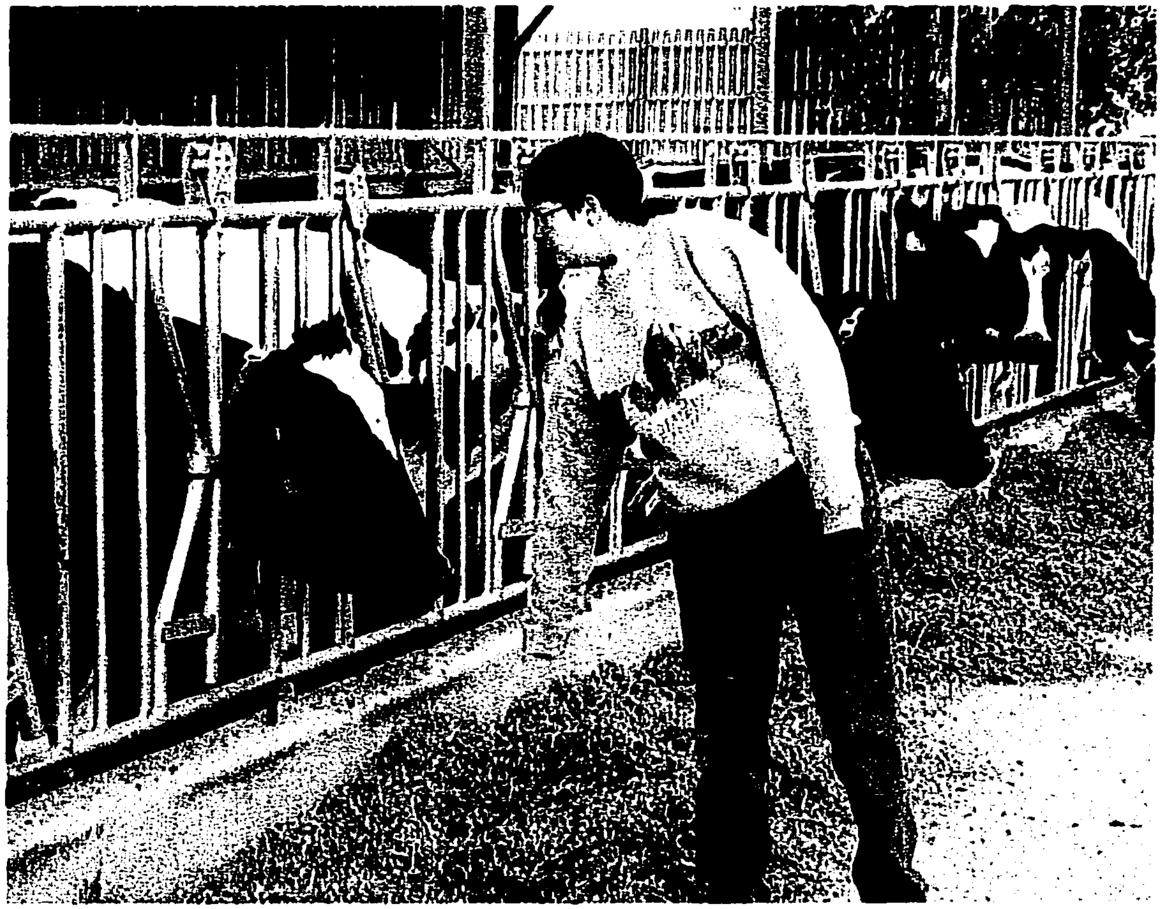

Figure 2. Conducting looming-person test by calmly leaning sideways towards the cow, allowing the inner arm to dangle.

Figure 3. Looming-person test responses: no reaction, or stretched to sniff researcher (left); pulled away from researcher, did not pull against head stanchion (middle); pulled against head stanchion, or head remained pulled against stanchion throughout test (right).

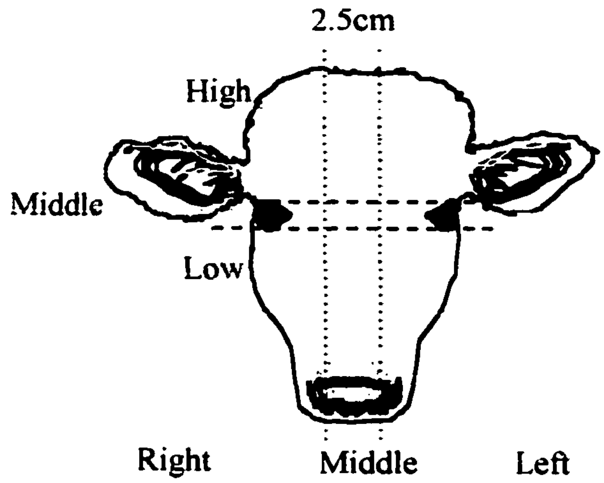

Figure. 4. Height of facial hair whorl placement was rated as high, middle, or low in relation to the eyes. Lateral whorl placement was recorded as on the right, left, or in the middle of the facial centerline. The centerline was considered to have a two and a half-centimeter width.

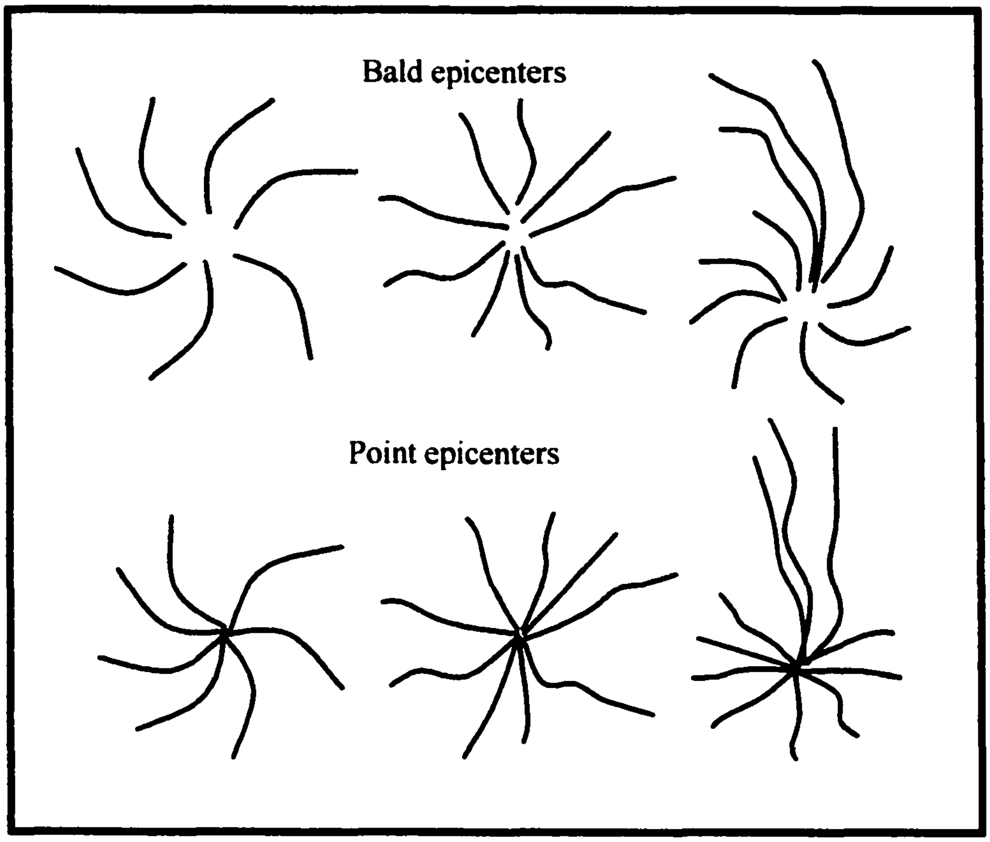

Figure 5a. Examples of bald and point epicenters of facial hair whorls found in cattle. Whorls that appear to have individual hair originating from different points around a "bald" spot were called "bald epicenters", while those that had hair that appear to originate from a common point, were termed "point epicenters."

Figure 5b. Examples of bald and point epicenters. Cow with bald hair whorl epicenter (left); cow with point facial hair whorl epicenter (right).

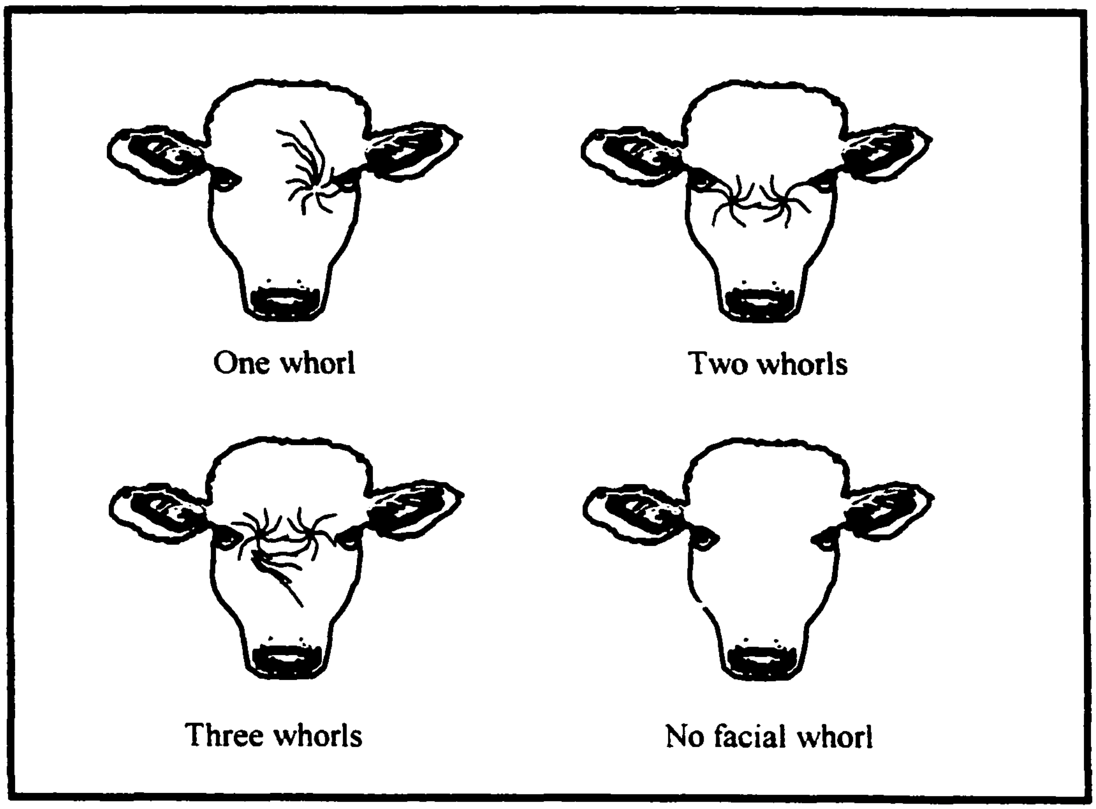

Figure 6. Illustration of cattle with 1, 2, 3, or no facial hair whorls

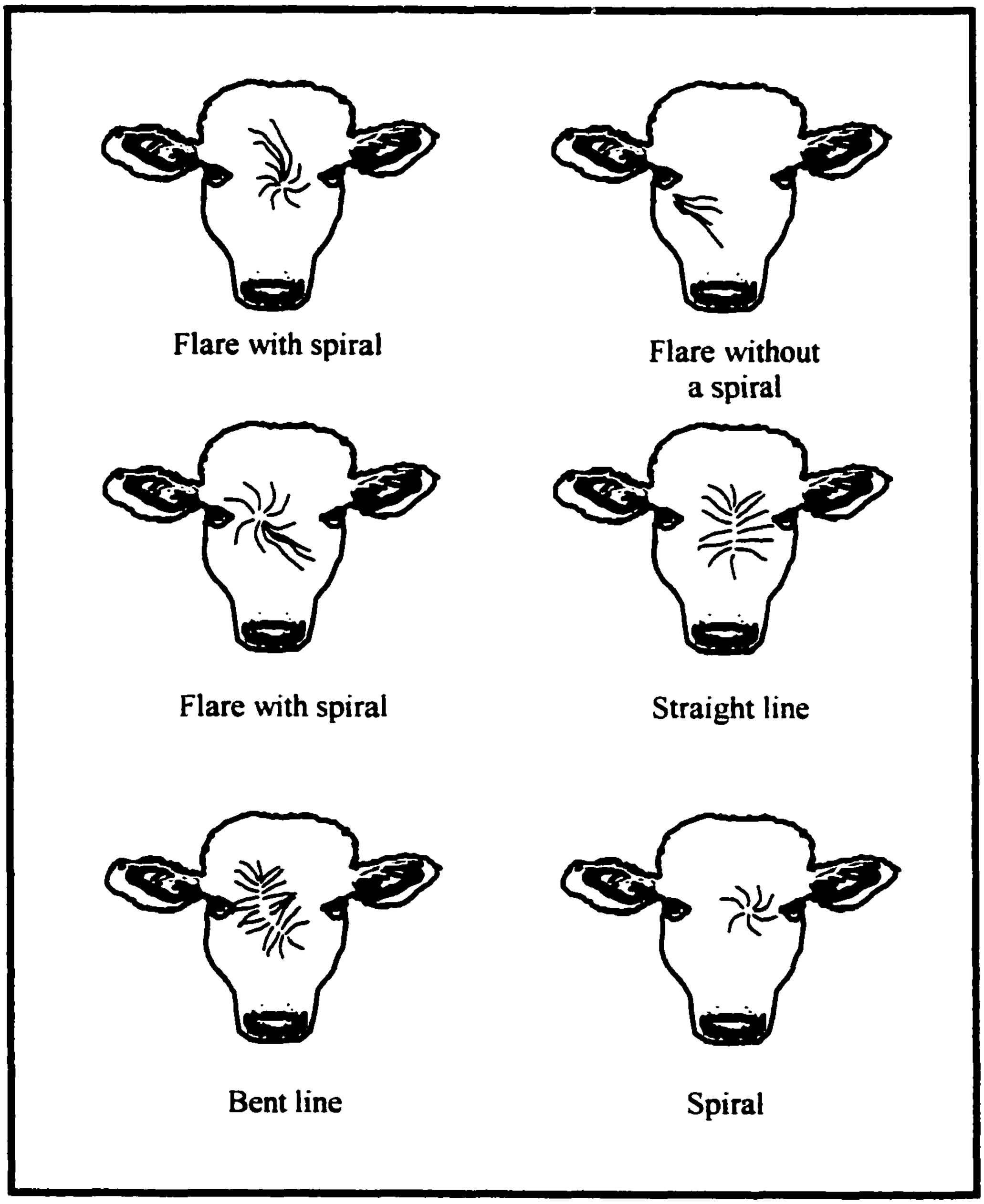

Figure 7a. Examples of three main types (shapes) of facial hair whorls: flare, line, and spiral. Various combinations of the above occur in cattle with more than one facial whorl.

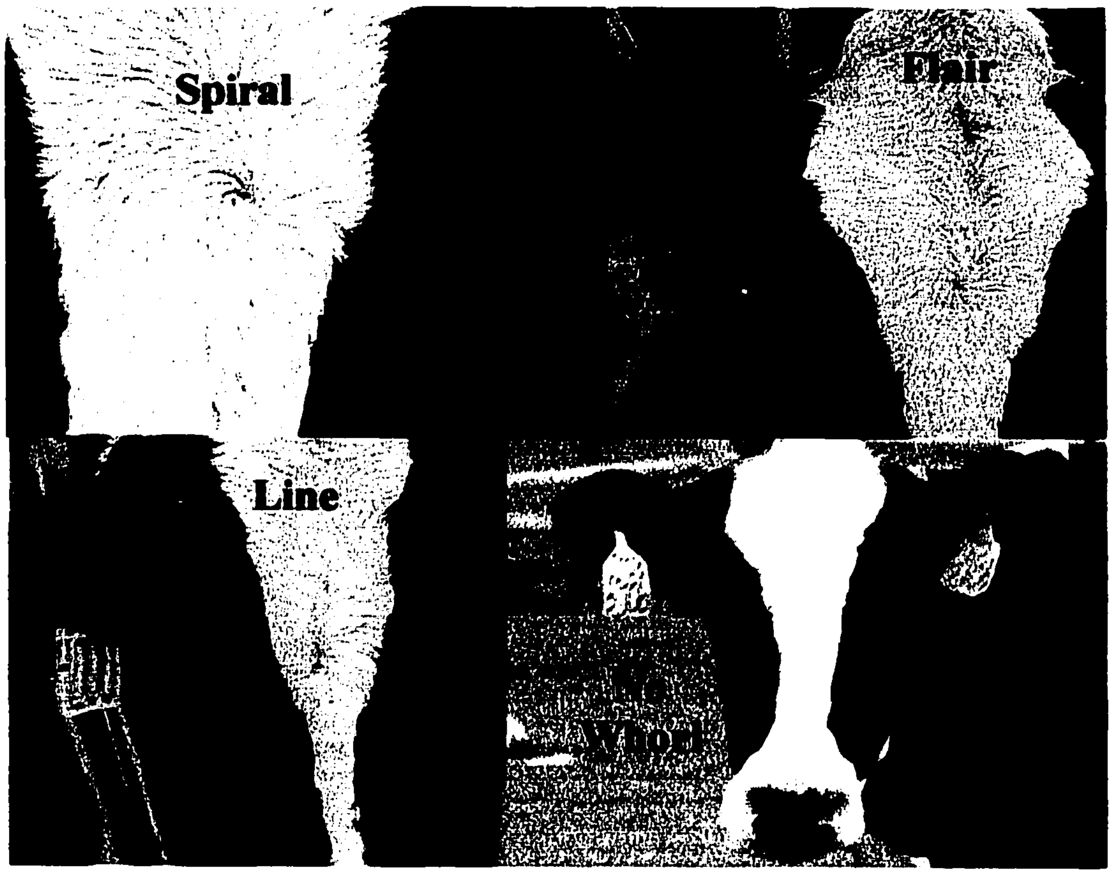

Figure 7b. Typical shapes of facial hair whorls found in cattle. Bent lines were classified as lines.

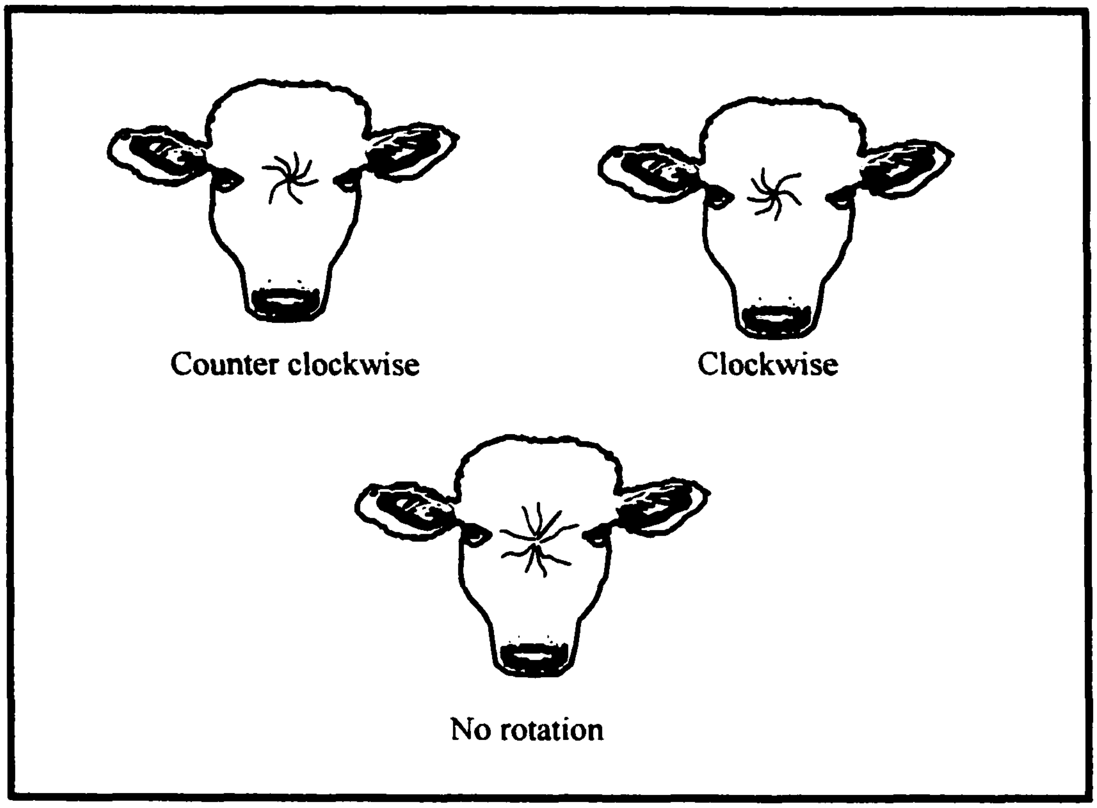

Figure 8. Typical rotations found in spiral shaped facial whorls. Cattle with multiple whorls may have combinations of whorl rotations.

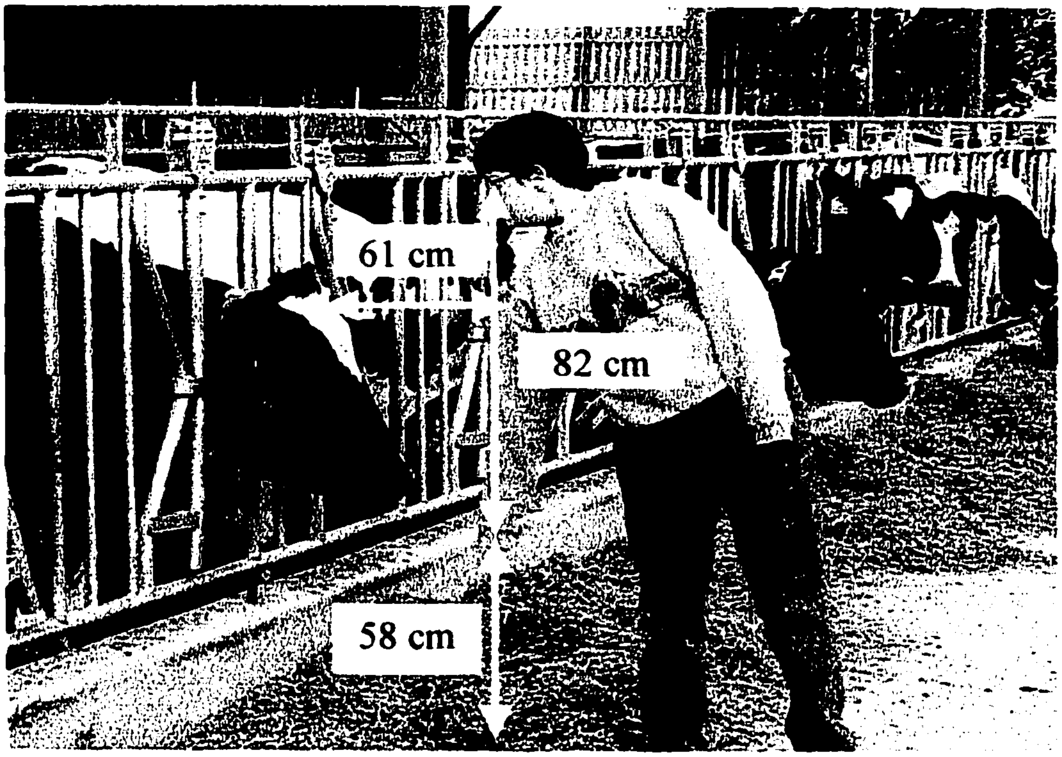

Figure 9. Approximate distances from researcher to test cow. Approximate distances from the researcher's dangled arm and eyes to the ground, and the distance from the researcher's shoulder to the cow's forehead.

Chapter 2

Dichotomous effects of physical indicators (attributes), temperament, and production on feedlot Charolais x Hereford heifers

Abstract

The objective of this study was to determine the association between physical Attributes, temperament, and carcass characteristics. This study used 192 Charolais x Hereford heifers being concurrently involved in a vitamin study. For the vitamin experiment the heifers were randomly assigned to an 8x4 factorial design consisting of one of eight vitamin D_3 and $CaCO_3$ dose combinations for nine continuous days. Temperament was assessed on day one, by activity level during restraint, reluctance to enter the squeeze chute, and reluctance to enter the head catch area of the squeeze chute (head gate balking). Heifer entry order into the squeeze chute was recorded. Facial hair whorl characteristics were assessed for height, lateral position, number, rotation, epicenter type, and shape. Postmortem measurements were taken on the left front 3rd and 4th fused metacarpal (cannon) bone. Carcass characteristics and Warner-Bratzler shear force values on steaks were also obtained. There was no effect of the nine-day nutritional trial ($P > 0.50$) on heifer temperament or on cannon bone measurements. Cattle that hesitated (balked) at having their head restrained had lower marbling scores than those that readily moved into position to have their head restrained ($P = 0.03$). Animals with longer cannon bones had tougher meat when it had been cooked well done after being aged for 21 days ($P = 0.05$). Thicker bones were related to a "whiter" colorimeter reading

($P = 0.04$) and a lower dressing percent ($P = 0.05$). Heifers with wider cannon bones ($P < 0.01$) had lower hot carcass weights, and greener and bluer colorimeter values. Multiple hair whorls were associated with lower hot carcass weights ($P = 0.05$), and greener and bluer colorimeter values ($P = 0.01$, $P = 0.04$, respectively). Meat from heifers with line shaped whorls was tougher than meat from animals with flares ($P < 0.05$) or spirals ($P = 0.05$) depending on how the meat was aged and cooked. Compared to heifers with spiral shaped whorls, those with line shaped whorls had "greener" colorimeter values ($P = 0.04$). There was a trend for taller ($P = 0.07$) heifers to balk at the head restraint, while heifers with wider ($P = 0.07$) and thicker ($P = 0.06$) bones were less likely to balk. The lower significance for the latter results may be due to a small sample size. Cattle with wider cannon bones ($P = 0.02$) required more force to be used by the handler to move the animal into the squeeze chute for physical restraint. Heifers with line shaped whorls had wider ($P = 0.01$) and thicker ($P = 0.01$) cannon bones than animals with spiraled whorls. The results of this study provide evidence for an association between physical attributes, carcass characteristics, and temperament.

Introduction

Both scientific studies and casual field observations indicate that there is a relationship between physical attributes, temperament and production. These physical attributes are easily viewed (e.g., facial hair whorls) or measured (e.g., scrotal circumference). Horse trainers have observed that horses with hair whorls high on the forehead were more excitable than those with lower whorls (Deesing, personal communication; Barker 1990). Several studies have found a definite relationship between facial hair whorl characteristics and temperament (Lanier et al., 2001; Randle, 1998; Grandin et al., 1995). Scrotal circumference has been shown to be associated with reproductive potential in bulls and onset of heifer puberty. The greater the scrotal circumference the greater the potential to be a viable breeding bull (Coe, 1993; Ott, 1986), as well as producing heifers who reach puberty earlier than those from bulls with smaller scrotal circumference (Smith et al., 1989). Learning more about the relationships between physical attributes, temperament, and production will assist producers to improve production and animal welfare. Cattle with excitable temperaments had lower weight gains (Voisinet et al., 1997b) and poorer carcass characteristics (Lensink et al., 2000; Voisinet et al., 1997a; Burrow and Dillon, 1997) than those that were calmer.

There is an increasing interest in management options for improving animal welfare. There has been extensive research conducted to assess animal stress associated with handling and husbandry procedures (Rushen et al., 1998; Jones, 1992; Mitchell et al., 1988) , as well as relating behavior of stressed animals to productivity (Voisinet et al., 1997a; Voisinet et al., 1997b; Bramlett et al., 1963) . However, there has been relatively little research to identify visible physical traits and how these traits may be used as indicators of production and behavior.

The objective of this investigation was to further explore the dichotomous relationship between physical attributes, temperament, and production in beef feedlot heifers. The physical attributes that were studied were hair whorl characteristics, and cannon bone size. These attributes were used as independent variables to determine their association with standard measures of production in the beef industry.

Materials and Methods

Animals

Charolais x Hereford heifers (n=192) were obtained from an eastern Colorado commercial feedlot. They were approximately 14 months of age and weighed an average of 491.5 kg ± 33.8 kg. They were transported to Colorado State University Beef Nutrition Unit and acclimated to feedlot conditions for 5 days before commencing this study. These heifers were concurrently in a vitamin study (Scanga et al., 2001). During the 5-day acclimation period, cattle were fed a standard finishing ration and melengestrol acetate at

0.4 $mg^{-1}/hd^{-1}/d$ (to prevent estrous cycling). At the conclusion of the 5-day period, individuals were weighed and randomly sorted into a 8x4 factorial design for the vitamin study. Treatments included one of eight vitamin D_3 and $CaCO_3$ dose level combinations: control, 1×10^6, 2×10^6, 3×10^6, 4×10^6 or 5×10^6 IU D_3/d or 2×10^6 IU D_3/d plus 75 g of $CaCO_3$ or 4×10^6 IU D_3/d plus 75 g of $CaCO_3$. Treatment was administrated orally using boluses in a hydraulic squeeze chute for nine continuous days (Scanga et al., 2001).

Temperament assessment

Temperament scores were assigned within the first 20 seconds of animal restraint in a stanchion type, hydraulic chute (Bowman Equipment) for every day for nine days. However, only data from the day two was used in the analysis. Temperament data from all days was used and reported in a study examining the effects of repetitive calm handling on ease of handling (submitted and out for review to Animal Welfare). Squeeze chute temperament scores were: (1) calm, stood still; (2) slightly agitated, struggled against the squeeze chute only once; (3) agitated, struggled against the chute two times; (4) extremely agitated, constant struggling. Reluctance to enter the squeeze chute (balking) was scored on the force required to move the animal into the chute with: (1) entered without hesitation; (2) hesitated, moved into the chute after touched on the rump; (3) hesitated, tail twisted; (4) electric prod used. Reluctance to enter the head catch area of the squeeze chute (head gate balking) was scored on whether or not the heifer hesitated (yes, no) before positioning her head in the area of the head catch. Speed of exit of the heifers from the squeeze chute was not collected due to the design of the facility. The design required that the heifer immediately exit at a right degree angle.

Handling. Gentle and quiet handling was maintained during all handling of the cattle for all days. Handlers walked, were quiet, and used slow smooth body movements. Animals were given time to move through the facility on their own before a handler touched them. The squeeze chute operator was the same on all days and was careful not to close the head gate on the cattle's head. The electric prod was seldom used to encourage cattle to move into the squeeze chute.

Physical indicators (attributes)

Hair whorl position. Height of facial hair whorl placement was rated as high, middle or low in relation to the eyes per the method in (Grandin et al., 1995). Vertical whorl placement was recorded as on the right, left, or in the middle of the facial centerline. The centerline was considered to have a two and a half-centimeter width (Lanier et al., 2001). The epicenter of the hair whorl was used as the reference for both vertical and horizontal location. Whorls were scored as having a clearly defined epicenter, and whether occurring singularly, in pairs, or triples. Whorl shapes were classified as spiral, flares, or lines. Spiral shaped whorls were further classified for direction of rotation (clockwise, counterclockwise, or no rotation). Individuals without facial hair whorls were recorded.

Metacarpal collection and preparation. Collection of the left front 3rd and 4th fused metacarpal bone (commonly referred to as the shank or cannon bone) occurred at the slaughter plant. Bones were taken directly from the carcass during routine removal by the slaughter plant personnel, post hide removal. The slaughter plant personnel individually handed each bone to a CSU personnel who placed the bone in a Ziploc® bag with a numerical identification printed on the outside of the bag and on tear proof paper inside the bag. The bones were transported immediately to CSU and stored at –30°C until analyzed. For analysis, bones, still individually bagged, were thawed in a cold-water bath. Each bone was cleaned of all organic matter in the areas to be measured. The middle of each bone was swabbed with alcohol, dried, and then their individual identification number written on the bone with a permanent marker. Each bone was given a clean Ziploc® bag with the identification number written on the outside.

Metacarpal measurements. Postmortem measurements were taken on the left front 3rd and 4th fused metacarpal (cannon) bone (n=52). Measurements were taken from the middle peak of the base to the sagittal ridge. Width (lateral to medial), thickness (cranial to caudal) and circumference measurements were taken at the exact middle of the bone. Measurements were taken with Absolute Digimatic calipers (Mitutoyo Corp., Japan) models CD-8" CS for bone width and thickness, and CD-12" CP for bone length.

Metacarpal density. Twenty-two bones were randomly selected from within each temperament group for density analysis. Bone density was determined with a dual-energy x-ray absorptiometry (DEXA) scan (Hologic QDR-1000/W whole body x-ray bone densitometer, Hologic Inc., Bedford, Mass.) by Dr. Simon Turner at the Veterinary

Teaching Hospital in Fort Collins, CO. Protocol (Grier et a., 1996) for scanning and validation of analysis was followed. All bones (n=22) analyzed were from heifers with hot carcass weights within ± 7 kg of each other.

Carcass evaluation

Cattle were processed at a commercial slaughter plant in Greeley, CO. Colorado State University (CSU) students followed the carcasses and maintained accurate identification of each carcass. Carcasses were chilled for 36 hours before USDA personnel determined USDA Quality and Yield Grade factors. After grading, strip loins (IMPS #180) were taken from the right side of each carcass and transported to Colorado State University meat laboratory. Strip loins were processed to yield eight steaks (2.54 cm thick) from which four sets of two adjacent steaks were randomly assigned to one of four postmortem aging periods (2, 7, 14 or 21 days) at 2°C. Paired steaks were randomly assigned to one of two end point cooking temperatures (70 and 85°C) to evaluate tenderness at ideal and over done degrees of doneness, respectively. After the steaks were aged, they were frozen at –30°C until further analysis.

Warner-Bratzler Shear Force (WBS)

Steaks were thawed at 2°C for 24 hours, broiled using a Hobart Char Broiler (model CB 51, Hobart, Troy, OH) to the predetermined end point cooking temperatures then cooled to room temperature (25°C). Core samples (minimum of seven/steak) of 1.27 cm in diameter parallel to the muscle fiber orientation were taken for determination of shear force from a WBS machine. Peak shear forces values were averaged to determine mean shear force (AMSA, 1995).

Statistical analysis (General statistics: Average daily gain (ADG) and individual bone measurements)

The effect of cannon bone measurements on individual average daily gain was analyzed with a general linear model using procedure GLM and with simple linear regression (SAS, 1999-2000). Single bone measurements were the independent variables with ADG as the dependent variable.

Affect of vitamin study on temperament and bone measurements. The effect of the vitamin trial on heifer temperament and cannon bone measurements was analyzed with a general linear model using procedure GLM (SAS, 1999-2000). Cattle temperament (entry order, hesitation to enter the squeeze chute, hesitation to place head in the head restraint and activity level in the squeeze chute) and bone measurements were the dependent variables.

Specific statistics: Productivity and temperament

Carcass characteristics and temperament. The effect of individual heifer temperament (balked at head gate, did not balk) on independent carcass characteristics was evaluated with a two-tailed t-test in SAS (SAS, 1999-2000). When the F-test for quality of variance was significant, the unequal variances t-test was used. Otherwise, the pooled variance t-test was used. The association of temperament (force required to move the heifer into the chute, and activity level in the chute) and carcass characteristics was analyzed with a mixed procedure in SAS (1999-2000) with temperament as the independent variable.

Specific statistics: Productivity and physical indicators

Carcass characteristics and cannon bone measurements. Relationships between carcass characteristics and independent cannon bone measurements variables were assessed using simple linear regression in SAS (1999-2000).

Carcass characteristics and facial hair whorls. Analysis of the association of the facial hair whorl characteristics and carcass characteristics used a mixed procedure in SAS (1999-2000) with individual hair whorl descriptors as the independent variable.

Specific statistics: Temperament and physical indicators

Temperament and cannon bone measurements. Average bone measurements were compared as dependent variables by the heifer temperament variable (balked at head gate, did not balk) using a two-tailed t-test in SAS proc t-test (SAS, 1999-2000). When F-test for quality of variance was significant, the unequal variances t-test was used. Otherwise, the pooled variance t-test was used.

Procedure GLM (SAS, 1999-2000) was used to determine the association between temperament (activity level in the squeeze chute, and force used to move the animal into the squeeze chute) and individual cannon bone size. Temperament was used as the independent variable.

Temperament and facial hair whorls. Analysis of the association of the facial hair whorl characteristics and temperament used Chi Square (SAS, 1999-2000) with individual hair whorl descriptors as the independent variable.

Specific Statistics: Physical indicators and physical indicators

Facial hair whorls and cannon bone measurements. Analysis of the association of the facial hair whorl characteristics and carcass characteristics used a mixed model SAS (1999-2000) with individual hair whorl descriptors as the independent variable.

Results

General Results: Affect of nutritional study on temperament and bone measurements

There was no effect of the vitamin study on individual order into the squeeze chute ($P = 0.49$; $F = 0.99$), hesitation to enter the squeeze chute ($P = 0.79$; $F = 0.78$), hesitation to place head in the head restraint ($P = 0.46$; $F = 1.01$), or activity level in the squeeze chute ($P = 0.60$). There was no influence of the vitamin study on heifer bone density ($P = 0.98$; $F = 0.28$), length ($P = 0.58$; $F = 0.90$), width ($P = 0.24$; $F = 1.32$), or bone thickness ($P = 0.79$; $F = 0.79$). These results were expected. Temperament for this study was assessed on the second day of the trial. The temperament data was collected before the vitamin treatment had time to affect the animal.

Specific Results: Productivity and temperament

Carcass characteristics and temperament. Animals that balked at the head restraint had an average marbling score of 339.61 (sem = 5.66) while those that did not balk had an average of 361.36 (s.e.m. = 3.34; $P = 0.03$). Heifers that balked at the head restraint had lower marbling scores. No other associations were found between temperament and carcass characteristics ($P > 0.20$).

Specific Results: Productivity and physical indicators

Carcass characteristics and cannon bone measurements. As cannon bone length increased, WBS values for meat aged 21 days and cooked to well done ($P = 0.049$; $R^2 = 0.08$) increased. There was trend for longer bones being related to an increase in the amount of kidney, pelvic, and heart (KPH) fat ($P = 0.076$; $R^2 = 0.06$). Bone thickness was positively related to color value "L*," and negatively correlated to dressing percent and WBS values for meat cooked to well done after being aged for 2 days. As bone thickness increased colorimeter readings became "whiter" ($P = 0.044$; $R^2 = 0.08$), while dressing percent decreased ($P = 0.054$; $R^2 = 0.07$), and a trend for an increase in tenderness ($P = 0.087$; $R^2 = 0.06$) was found.

Cannon bone width was related to hot carcass weight ($P = 0.021$; $R^2 = 0.10$) and color values "a*" ($P = 0.004$; $R^2 = 0.15$) and "b*" ($P = 0.005$; $R^2 = 0.06$). There was a correlation trend for fat thickness ($P = 0.072$; $R^2 = 0.06$), quality grade ($P = 0.089$; $R^2 = 0.06$), and WBS values for meat cooked to medium done after being aged for 2 days ($P =$

0.074; $R^2 = 0.06$). As cannon bone width increased, hot carcass weight decreased, and colorimeter values became greener and bluer. Fat thickness and quality grade decreased with an increase in bone width. Tenderness also decreased as bone width increased.

Carcass characteristics and facial hair whorls. Hair lateral position, their shape, and number of facial whorls were associated with various carcass characteristics (Table 1). Carcasses from heifers with whorls to the right of the centerline had less fat thickness than those with laterally centered whorls ($P = 0.051$). Hot carcass weight differed between individuals with one or multiple whorls ($P = 0.053$) with multiple whorled animals being lighter.

Steaks from heifers with line-shaped facial whorls were tougher than those from animals with flare whorls when the meat was aged for 2 days and cooked to either medium done ($P = 0.059$) or well done ($P = 0.02$). Steaks from animals with line whorls were also tougher than those from heifers with spiral whorls when the meat was aged for 2 days and cooked to medium done ($P = 0.019$) and aged for 21 days and cooked to well done ($P = 0.034$).

Meat color hues "a*" and "b*" ($P = 0.015$; $P = 0.04$, respectively) were different between animals with one or multiple whorls. Both colorimeter readings were lower (greener and bluer) for individuals with multiple facial whorls. Color values for "a*" differed between heifers with spiral and line shaped whorls ($P = 0.043$) with line shapes having a greener reading.

Specific results: Temperament and physical indicators

Temperament and cannon bone measurements. Heifers with wider ($P = 0.07$) and thicker ($P = 0.06$) bones tended to be less likely to balk at the head restraint (Table 2). The opposite was found for animals with longer cannon bones ($P = 0.074$). Those with longer cannon bones tended to balk at the head restraint. Activity levels in the squeeze chute and cannon bone measurements were not related ($P > 0.40$). Force required to move an animal into the squeeze chute increased as the width of the cannon bone increased ($P = 0.021$; $F = 5.64$; $R^2 = 0.10$). Length, thickness, and density were not related to force used on cattle. Heifer entry order into the squeeze chute was not associated with cannon bone length ($P = 0.45$), width ($P = 0.94$), thickness ($P = 0.68$), or density ($P = 0.16$).

Temperament and facial hair whorls. There may be an association between having facial hair whorls and whether or not an individual balked at the head restraint ($P = 0.082$). Those without a facial hair whorl were more likely to balk at placing her head in the head restraint area than those with a whorl. Thirty two percent (n=6) of the heifers without hair whorls balked at the head gate, compared to 16% (n=26) of those with one or more facial whorl. No other relationships were found between facial hair whorl characteristics and individual temperament.

Specific results: Physical indicators and physical indicators

Facial hair whorls and cannon bone measurements. Shape of facial hair whorls was associated with depth ($P = 0.013$) and width ($P = 0.0116$) of heifer cannon bones. Heifers with spiral shaped whorls had thinner and narrower bones than those with line shaped whorls (Table 3).

Discussion

Productivity and temperament

Our results have shown that cattle temperament and production are associated. Other studies have demonstrated similar results (Fell et al., 1999; Burrow and Dillon, 1997; Voisinet et al., 1997a,b). Excitable feedlot cattle have higher death rates, poorer average daily weight gain, and higher cortisol levels than calmer calves (Fell et al., 1999). In our studies, both the dairy cattle temperament and the heifer temperament were associated with their production.

Productivity and physical indicators (attributes)

Taller cattle are typically leaner than shorter cattle at the same age (McKiernan, 2000). Our results agreed with this finding. Heifers with longer cannon bones had less carcass fat than the cattle with shorter bones. Kretschmer's body types: leptosome or asthenic (tall and thin), athletic (well developed muscles), and pyknic (short and fat), also looked at the relationship of skeletal size and body fat (Kretschmer, 1921). Specifically, Kretschmer noted that the leptosome body type are tall and thin compared to the short and fat pyknic somatotype. These results suggest that our bone measuring technique was accurate in its ability to discriminate between individuals with varying bone size.

It is unknown how hair whorl characteristics are related to dairy milk production. It may be an extension of the relationship between hair whorls and temperament, and temperament and production, being extended to hair whorls and production.

Colorimeter readings and bone measurements. Colorimeter readings from the heifer carcasses showed a correlation with cannon bone size. It has been shown that colorimeter reading a* and b* are related to carcass muscle pH (Wulf and Wise, 1999), while L* is correlated with lean maturity (Wulf and Wise, 1999; Orcutt et al., 1984). Page et al. (2001) discuss how a* and b* are highly correlated to one another. Our results correlating an increase in bone width and darker (greener (a*) and bluer (b*) meat may suggest that cannon width may be related to muscle pH, with wider bones signifying carcasses may have higher muscle pH values. Heifers with longer cannon bones had whiter (L*) colorimeter readings, suggesting that bone length may be an indicator of lean maturity.

Physical indicators such as higher foot angels, which have been associated with longer animal life and fewer claw problems (McDaniel, 1995) or scrotal circumference as an assessment of breeding potential (Coe, 1999), are common management tools used by the industry to remove (cull) or target an individual for increased surveillance. The primary values of such indicators are their relative ease of use and non-invasiveness. Our findings relating to cannon bone measurements and hair whorl characteristics may provide additional physical indicators for the cattle industry to increase herd potential and production.

Temperament and physical indicators (attributes)

Various physical attributes have been connected to temperament in humans. This connection is useful in the diagnosis and treatment of behavioral problems. There is a relationship between minor physical anomalies (MPAs) such as attached ear lobes and multiple hair whorls (Paulhus and Martin, 1986), and infant personality (Burg et al., 1978). This study found that infants with several MPAs were more irritable than those with fewer MPAs. An increase in the number of MPAs in a human male increases the likelihood that he will be more masculine, aggressive, and clumsy (Paulhus and Martin, 1986). High numbers of MPAs in men are also linked to hyperactive behavior (Paulhus and Martin, 1986; Fogel et al., 1985; Bell and Waldrop, 1982) and Type A personalities (Paulhus and Martin, 1986). In women, a greater number of MPAs is related to shy and timid behaviors and short attention spans (Fogel et al., 1985; Bell and Waldrop, 1982). The effect of MPAs on behavior has been suggested not to be due to a particular MPA or specific combination, but possible due to many MPAs occurring together (Paulhus and Martin, 1986).

An example of a specific physical trait being connected to temperament is the relationship of hypermobility joint syndrome (HJS) and anxiety disorders. Hypermobility joint syndrome is a condition of the cartilage and ligaments (connective tissue) and is characterized by extremely flexible joints (Nef and Gerber, 1998; Bulbena et al., 1996). People who have HJS typically are afflicted with sprained ankles, back pain, bad knees and dislocated shoulders. HJS is heritable and found in women more often than in men (Nef and Gerber, 1998; Bulbena et al., 1996). Studies have found a relationship between HJS and anxiety disorders such as panic attacks and agoraphobia, and the fear of novel surroundings (Martin-Santos et al., 1998; Bulbena et al., 1996).

It is unknown whether one type of facial hair whorl characteristic, ear dimension, or cannon bone measurement maybe considered as a minor physical anomaly or a specific physical attribute, or even a combination of the traits to qualify as a "bovine somatotype". However, just as Kretschmer (1921), Sheldon (1954), Verdonck and Walker (1976), Maher and Maher (1994), Nef and Gerber (1998) and others, have demonstrated a connection between physical attributes and temperament in humans, these three studies have shown a similar relationship with cattle. Perhaps those dairy cows that remained in the herd for more than one lactation are individuals with specific or fewer MPAs than those that were removed from the herd.

Dr Temple Grandin has noticed a correlation between temperament and physical attributes in multiple livestock species. During a recent trip to Brazil, Dr. Grandin noticed that approximately 20% of the Zebu-*indicus* type (nelory) cattle had extremely high facial hair whorls. These cattle when stressed did not become frenzied, but instead were very deliberate in their retaliation towards the stressor. This observation fits with the proposed theory that cattle without a facial hair whorl are similar to cattle with very high whorls

(Lanier et al., 2000). It is plausible that during a confrontational test such as the looming person, the individuals with high whorls or no facial whorls (of which there were none in the dairy cattle) would be more likely to stand their ground and not pull away from a looming person. Unfortunately, there were only 17 dairy cows with high hair whorls.

It is possible that with a larger number of cattle with high whorls and those without facial whorls, their temperament may be better assessed and would demonstrate that these cattle may remain in control of their behavior until they reach a stress threshold, at which time they react in a calculated and controlled manner.

Conclusions

There was no effect of the nine-day vitamin trial on individual temperament ($P > 0.50$) or on cannon bone measurements ($P > 0.50$).

Cattle that hesitated (balked) at having their head restrained had lower marbling scores than those that readily moved into position to have their head restrained ($P = 0.03$).

Carcass characteristics and bone measures were correlated. Animals with longer cannon bones were had tougher meat when it had been cooked well done after being aged for 21 days. Thicker bones were related to a "whiter" colorimeter reading ($P = 0.04$) and a lower dressing percent ($P = 0.05$). Heifers with wider cannon bones had lower hot carcass weights, and colorimeter "a*" (more green) and "b*" (more blue) values ($P < 0.01$, $P < 0.01$, respectively). Facial hair whorl characteristics were associated with carcass characteristics. Multiple hair whorls were associated with lower hot carcass weights ($P = 0.05$) and colorimeter "a*" (more green) and "b*" (more blue) values ($P = 0.01$, $P = 0.04$, respectively). Meat from heifers with line shaped whorls was tougher than meat from animals with flares ($P < 0.05$) or spirals ($P = 0.05$) depending on how the meat was aged and cooked. Compared to heifers with spiral shaped whorls, those with line-shaped whorls had "greener" colorimeter values ($P = 0.04$).

Temperament was found to be associated with bone measurements. There was a trend for taller ($P = 0.07$) heifers to balk at the head restraint, while those with wider ($P = 0.07$) and thicker ($P = 0.06$) bones were less likely to balk at having their head restrained. The lower significance for the latter results may be due to a small sample size. Cattle with wider cannon bones ($P = 0.02$) required more force to be used by the handler to move the animal into the squeeze chute for physical restraint.

Heifers with line-shaped whorls had wider ($P = 0.01$) and thicker ($P = 0.01$) cannon bones than those with spiraled whorls.

Implications

Our results demonstrated a link between temperament and production variables, temperament and physical attributes, and physical attributes and production. Facial hair whorls are physical indicators of cattle temperament (Lanier et al., 2000; Grandin et al., 1995; Randle, 1998). Using the association between hair whorls and temperament, and our results that demonstrated a link between temperament and production variables, complicated relationships may be explored. Using simple mathematical logic (Transitive Property of Equality: if a = b and b = c, then a = c), if facial whorls are related to temperament, and temperament is related to production, then it is probable that facial hair whorls are linked to cattle production. Although, whorl position does not equal temperament, it is an indicator of an individual's temperament. The complicated connection between the above mentioned variables are not understood, but nonetheless, they do appear to be intertwined. These findings suggest a connection between physical attributes, temperament, and production in relationship to beef and dairy cattle. These connections may assist in the dairy and beef industry in providing improved welfare as well as a consistent and quality product.

Chapter 2 Tables

Table 1. Association between heifer meat qualities (± s.e.m.) and facial hair whorl characteristics

	Number of Whorls		Lateral position			Shape		
Carcass Quality	**One**	**Multiple**	**Right**	**Center**	**Left**	**Spiral**	**Flare**	**Line**
Hot Carcass Weight	302.06kg±1.92^{a}	277.3kg±12.54						
Fat Thickness			0.84cm±0.05^{a}	0.91cm±0.31^{b}	0.86cm±0.03^{ab}			
a*	9.8±0.13^{a}	7.6±0.87				9.92±0.15^{a}	9.26±0.54^{ab}	9.2±0.31^{b}
b*	10.89±0.11^{a}	9.33±0.75						
Warner-Bratzler shear force								
Steaks, medium-done aged 2 days						5.82kg±0.4^{a}	6.35kg±0.15^{ab}	7.1kg±0.36^{b}
Steaks, well-done aged 2 days						7.21kg± 0.38^{ab}	7.13kg±0.14^{ab}	8.02kg±0.34^{a}
Steaks, well-done aged 21 days						4.39kg±0.1^{a}	4.7kg±0.34^{ab}	4.9kg±0.19^{b}

^{a,b}Means within a row lacking a common superscript letter differ ($P < 0.05$).

Table 2. Association between temperament of heifers and postmortem cannon bone measurements*

	Cannon bone measurements in mm			
	Length	**Width**	**Thickness**	**Density**
	n=52	*n=52*	*n=52*	*n=22*
Temperament	*mean (s.e.m.)*	*mean (s.e.m.)*	*mean (s.e.m.)*	*mean (s.e.m.)*
	$P = 0.74$	$P = 0.07$	$P = 0.06$	$P = 0.97$
Balked	220.77 (4.29)	36.09 (4.55)	23.62 (2.99)	0.0616 (0.0005)
Did not balk	213.95 (1.42)	40.05 (0.36)	26.24 (0.17)	0.0617 (0.0003)

*p-value (Ho: Bone size means between temperament variables are equal)

Table 3. Association between heifer cannon bone measurements (± s.e.m.) and shape of facial hair whorls

Bone measurements	Shape of the Whorl		
	Spiral	**Flare**	**Line**
Length	213.68mm±2.09	216.04mm±9.82	220.76mm±4.01
Depth	26.03mm±.18[a]	27.07mm±.89[ab]	27.11mm±.36[b]
Width	39.96mm±.35[a]	42.62mm±1.71[ab]	42.07mm±.70[b]

[a,b]Means within a row lacking a common superscript letter differ ($P < 0.05$).

Chapter 3

The relationship between reaction to sudden intermittent movements and sounds to temperament

Abstract

Casual observations indicated that some cattle are more sensitive to sudden movement or intermittent sound than other cattle. Six commercial livestock auctions in two states and a total of 1,636 cattle were observed to assess the relationship between breed, gender, and temperament score on the response to sudden intermittent visual and sound stimuli, such as the ringman swinging his arm for a bid and the sound of him briefly yelling a bid. A 4-point temperament score was used to score each animal while it was in the ring. The scores used were: 1) Walks and(or) stands still, with slow smooth body movements; 2) Continuously walks or trots, and vigilant; 3) Gait is faster than a trot (runs even a couple of steps), with fast, abrupt, jerky movements, and very vigilant; 4) Hits the ring fence, walls, partitions, or people with its head. Animals were observed for flinches, startle responses, or orientation towards sudden intermittent sounds, motions, and tactile stimulation, such as being touched with a cane or plastic paddle. The cattle observed were mostly *Bos taurus* beef breeds and Holstein dairy cattle. Holsteins were more sound sensitive ($P = .02$) and touch sensitive ($P < .01$) than beef cattle. Sensitivity to sudden intermittent stimuli (e.g., sound, motion, and touch) increased as temperament score (excitability) increased. Cattle with a temperament score of 1 were the least sensitive to sudden intermittent movement and sound and those with a temperament score

of 4 were the most sensitive ($P < .01$). This same relationship was sometimes observed for touch, but was not statistically significant. Motion-sensitive cattle were more likely to score a temperament rating of three or four than non-sensitive cattle ($P < .01$). Steers and heifers were more motion sensitive than the older bulls and cows ($P = .03$). Beef cattle urinated ($P < .01$, n=1581) and defecated ($P < .01$, n=1582) more often in the ring than did dairy cattle. Cattle that became agitated during handling in an auction ring were the individuals that were most likely to be startled by sudden intermittent sounds and movements. Reactivity to sudden intermittent stimuli may be an indicator of an excitable temperament.

Introduction

There is an increasing interest in management options for improving animal welfare. There has been extensive research conducted to assess stress associated with handling and husbandry procedures (Zavy et al., 1992; Lay et al., 1992; Mitchell et al., 1988; Rushen et al., 1998). There is a significant relationship between cattle temperament and productivity. Cattle that become agitated during restraint in a squeeze chute had lower weight gains and tougher meat (Voisinet, et al. 1997a,b). Burrow and Dillon (1997) found that cattle that exited more slowly from a squeeze chute had greater weight gains than those that exited the squeeze chute quickly. Drugociu et al (1977) reported that dairy cows with calm temperaments had increased milk production. Stressful treatment during growth can have adverse effects on meat quality in lambs (Bramblett et al., 1963). Producers are becoming increasingly interested in assessing temperament as excitable animals have reduced weight gain (R.D. Green, unpublished data). Temperament is definitely heritable (Shrode and Hammack, 1971; Hearnshaw and Morris 1984; Fordyce et al 1988;).

Casual observations at auctions indicated that cattle in the auction ring are most likely to flinch and startle in response to sudden intermittent stimuli such as a ringman waving his arm, yelling for a bid and children running near the ring. The purpose of the study was to determine if the reaction of cattle to sudden intermittent motions, sounds and touch in an auction ring are related to their overall temperament. This could be useful to producers for temperament-testing cattle.

Materials and Methods

Animals

Two observers collected data in six different commercial auctions during the summer of 1998. Five auctions were located in Colorado and the sixth was in Texas. All five auction houses in Colorado were east of the Rocky Mountains. Two were located in the north, one in central Colorado and the last two were in southern Colorado. The Texas auction house was 161 km of Fort Worth. A total of 1,636 beef cattle were observed. They were 74.4% British and European breeds (*Bos taurus*) and 21.4% Holsteins (*Bos taurus*). Ninety-three *Bos indicus* cattle consisted of Brahman, Watusi, and crosses with *Bos taurus* breeds. Most of the European and British breeds were Angus, Hereford, Charolais, Simmental, and their crosses. Breeds were categorized based on the auctioneer's announcement of cattle breeds. Cattle with longer ears, loose dewlap and a dorsal hump were classified as Brahman crosses. Single cattle (n=1,543, 94.3%) and cow/calf pairs (n=93, 5.7%) weighing 182 kg or greater were recorded. Only 3.2% of the total sample were Brahman or Brahman cross. Interviews with ranchers indicated that they were not selling their heat-tolerant cattle (Brahman or Brahman crosses) due to drought conditions. Data were collected only on the cow when a cow-calf pair was sold. Cattle weighing less than 182 kg were considered juveniles and were not part of the study. Data were collected while each animal was in the auction ring, while the gates were closed and the auctioneer was soliciting bids. Figure 1 shows a typical auction ring layout. Animals that initially entered the ring alone or with a calf were scored. Cattle that were taken out of the ring and later brought back through were not scored.

Observers

Observers were always centered in the first to third rows of seats nearest the auction ring or three meters from the center, towards the gate from which the cattle entered the sale ring (Figure 2). Seating near the entrance gate was ideal for the collection of data because the majority of the cattle remained in this area of the ring during bidding. Inter- and intra-rater reliability tests conducted at two of the auctions used in the study, with two separate observers, demonstrated reliability between the two experienced observers ($P>.05$). However, the reliability does decrease if the observer is unfamiliar with cattle behavior, cattle flight zones, or has not previously practiced scoring cattle behavior in an auction ring.

Prior to the collection of data, the observers practiced the recording of data at three different auctions (140 cattle). These data were used to refine methodology and were not included in the study. During the study, the first 10 animals observed at each new auction were used for practice and were not included in the analysis of data.

Scoring Temperament

The first observer collected data on animal weight, breed, color, gender (bull, steer, cow, heifer). A second observer collected behavioral data. Both observers sat in the spectator area of the auction barn, and both had full view of the animals and the auction ring (Figure 1). Reactivity to external stimuli (e.g., noise, being touched) was not used to determine temperament score. Activity level of each animal was the primary scoring criterion, followed next by the head and neck position of the animal. All scoring was done while the amplified auctioneer chanted (Figure 2). Each animal was in the auction ring for a period of approximately 15 to 30 s.

The following scoring system was used to rate cattle behavior in the auction ring:

Temperament Rating: Activity Level in the Auction Ring.

1 = Walks and (or) stands still. Slow smooth body movements.

Head and neck in a lowered, relaxed position.

The head and neck may be thrust forward.

2 = Continuously walks or trots. Vigilant.

Head and neck is slightly raised above back, slightly lowered below back, or level with back.

3 = Gait is faster than a trot (runs even a couple of steps). Fast, abrupt, jerky movements. Very vigilant.

4 = Hits the ring fence, walls, partitions or people with its head. Contact with the ring fence, walls, partitions or people due to licking, smelling, or bumping into or brushing up against with its body were not considered as a rating of 4. A 4 was given if the animal attempted to go under, through, or jump or climb over a barrier, regardless of activity level (i.e., standing, walking, or running).

Behavior Rating: Aggression or Escape.

Animals that were rated as either a 3 or a 4 were furthered rated for aggressive behavior (A), or escape behavior (B).

(A) Aggression Behavior

Pawing the ground while the head is lowered, lunging forward at a person or object with the head slightly lowered, lowering and shaking head at a person or object, or charging a person or object.

Aggressive Behavior Head Position

Head and neck were held high above back, held close to the ground, or slightly raised above back.

(B) Escape Behavior

Escape Behavior Head Position

Head and neck were stretched forward and either slightly raised above back, slightly lowered, or level with back.

For example, a cow that was walking continuously around the ring with the head held slightly raised above back would rate a 2. However, if the cow then attempted to climb out of the auction ring, the rating of 2 would be void and she would be recorded as an "escape" 4.

Scoring Animal Response to Sudden Intermittent Environmental Stimuli

Animals that flinched and (or) oriented immediately towards a sudden sound, motion, combination of sound and motion, or touch were scored as sensitive to those particular stimuli. A flinch was scored if the animal gave a startle response or its skin quivered immediately after the stimulus. The auction houses would not allow the use of a controlled movement or sound stimulus to test each animal's startle reaction. One hundred and forty cattle were observed in three different *practice* auctions to determine the naturally occurring intermittent movements, sounds, and touches that were most likely to cause cattle to flinch, jump, quiver, or orient.

Stimuli Scoring

The following naturally occurring intermittent movements, sounds, and touch stimuli were used.

Movements: 1) ringman swinging an arm to take a bid; 2) audience deliberately waving at an animal; or 3) young children running within 2 m of the ring. Sounds: 1) ringman briefly yelling a one syllable bid without the aid of a microphone; 2) air hoses used to move cattle outside of the auction ring but audible in the spectator seating; 3) children yelling; or 4) a "rattle-paddle" shaken or hit on a wall or fence. Touch stimuli: 1) hit with a paddle, cane, or whip by the ringman; or 2) poked with a cane by the audience.

Movements related to startle response and not flight zone were recorded. To avoid being confounded by an animal reacting to a movement made directly in front of its face, motions that were close to the animal's face were not scored. All other occurrences of the above movements, touches and sounds were scored. The observer must have been able to discern between an animal reacting to a movement that applies pressure to the flight zone and causes the animal to move away, and a movement that does not affect the flight zone and causes a startle response. Response of an animal to a stimulus was not used in determining the animal's temperament. For example, if the ringman touched a cow with a cane, and the cow jumped and flicked her ears, a temperament rating based on this response was not given.

Animals exposed to the above movements, sounds, and touches were scored. Animals were either scored as "yes", sensitive or "no", not sensitive. Reactions of an animal to sudden environmental stimuli used to score an individual as "yes", sensitive were: flinching, jumping, whole body quivers, ear, and(or) head orientation towards the stimulus. Only one of the criteria was needed in order for an animal to be scored as "yes", sensitive to sudden environmental stimuli. Reactions to motion, tactile stimulation, and combinations of auditory and visual (motion) stimulation were scored as discrete binomial variables.

Scoring of an animal's reactivity to sudden sounds, motion, or being touched was recorded for those animals for which the stimulus occurred while the animal was in the ring and the auctioneer was chanting. The first sound, motion, and touch detected by the observer were used for scoring sensitivity. Inter-observer reliability tests demonstrated that neither all behaviors nor reactions to all behaviors could be reliably observed and recorded, due to the speed of the auction. It was found that inter-observer reliability was very high (92%) if each observer recorded the first behavior that they observed, rather than attempt to record the first behavior that occurred.

If a sudden stimulus occurred while the auctioneer was silent, the response was not scored. This was done for consistency for the type of background noises all animals would receive, and to control variance. In addition, during the practice recording of cattle behavior in the auction ring, it was observed that the constant chant of the auctioneer appeared to separate out those individuals that had become accustomed to a low volume of noise and stress, but who were actually reactive under extreme conditions. Reactivity to external stimuli was not used to determine temperament score.

Animals that urinated and(or) defecated in the auction ring were recorded as either "yes", they did, or "no", they did not.

Statistical Analysis

Data analyses were conducted with the use of Chi-square (SAS, 1991). The effect of breed, and gender were controlled for by Chi-square and logistic regression genmod procedure (SAS, 1995). General linear model procedure (SAS, 1985) controlled for auction, breed, and gender. Results and conclusions were identical from both analytical methods. Intra- and inter-observer reliability were verified using paired t-test (SAS, 1991).

Results

The breakdown of genders within Holsteins was 4.4%, 8.5%. 6.8%, 80.3% for steers, bulls, heifers, and cows, respectively. Genders of the beef type cattle were 7.2%, 21.4%, 15.8%, and 55.6% for steers, bulls, heifers, and cows, respectively.

Sound Sensitivity

There were differences in responses to sudden intermittent sounds among the temperament score groups (Table 1) (Chi-square=51.31, $P < .01$, n=928; GLM $P < .01$, F=18.03). Analysis by least significant differences found the same effect. Holstein cattle were significantly more sound sensitive ($P = .02$, n=918) than beef cattle. Of those individuals scored for sound sensitivity, 34.9% were Holstein and 27.4% were beef cattle. The percentage of bulls and steers that were aggressive in the sale ring and were sensitive to sound was 14.6% ($P = .01$, n=64).

Motion Sensitivity

Motion sensitive cattle were more likely to score a temperament rating of 3 or 4 than non-sensitive cattle (Chi-square=85.27 $P < .01$, n=1082; GLM $P < .01$, F=30.74) (Table 1). There was no significant difference between Holstein (38%) and beef cattle (44%) that were motion sensitive (P=.13). The percentages of motion sensitive cattle were 50.65% of the heifers, 38.26 % of cows, 43.27% of the bulls, and 46.91% of the steers (Table 2).

Sound and Motion Sensitivity

Cattle sensitivity to sudden sound and motion, (e.g., a ringman swinging his arm upward as he called out a bid) increased as overall temperament score in the auction ring increased (Chi-square=15.42, $P < .01$, n=190 GLM; $P < .01$, F=5.48) (Table 1). There was no difference in reaction between Holstein and beef type cattle for combinations of sound and motion sensitivity.

Touch Sensitivity

Holsteins were significantly more touch sensitive ($P < .01$, n=208) than beef cattle (Table 2). Heifers (63.6%) were the most touch sensitive, followed by bulls (55.4%), steers (50.0%), and cows (38.5%) ($P = .05$, n=214) (Table 2).

Combined Stimuli Effects

Ninety-one percent of the motion sensitive bulls and steers and 89% of the cows and heifers were sensitive to combinations of sound and motion ($P < .01$, n=42, and $P > .01$, n=72, respectively). Sixty-nine percent of the cows and heifers that were sound sensitive were also sensitive to being touched ($P = .01$, n=32).

Gender Differences

Differences between temperament score and genders were found. Bulls were the calmest in the auction ring, followed by cows. Steers and heifers were the most agitated in the ring ($P < .01$, n=1,614).

Urination and Defecation

Beef cattle urinated ($P < .01$, n=1,581) and defecated ($P < .01$, n=1,582) more often in the ring than dairy cattle; 95% of beef cattle versus 5% of Holsteins and 85% of beef cattle versus 15% of Holsteins, respectively. Bulls and steers defecated in the ring more often than females ($P < .01$, n=1,635). Cattle with a temperament rating of 3 or 4 were less likely to defecate in the auction ring ($P < .01$, n=1,613). These highly excitable cattle probably defecated before reaching the auction ring.

Auction Effect on Temperament

The effect of auction on all measured behaviors except vocalization and motion sensitivity was significant ($P < .05$). Motion sensitivity was not affected by auction (location). Temperament scores at some auctions were significantly higher ($P<.05$) than at other auctions.

Discussion

Our results indicate that reactivity to intermittent sounds and sudden movements is significantly related to numerical ranking of cattle temperament during handling in a commercial auction ring. One of the advantages of observing cattle in commercial auction houses was that it made it possible to observe very large numbers of cattle. The disadvantage of commercial auctions was that it was not possible to control all the variables. Conducting observations in six different auction houses and visiting the auctions more than once (except for the Texas auction) helped prevent variables that were unique to one auction from confounding the results. Eight auction houses were visited but two were not used in our observations because rough handling and over use of electrical prods made a very high percentage of animals become extremely agitated with a temperament score of 3 or 4. Differentiation of the temperament scores and observing the animal's reaction to intermittent stimuli would have been impossible. Correlation between methods used to move animals and temperament scores were not evaluated.

The sounds that were most effective for eliciting a response were often accompanied with sudden movement. For example, the ringman would yell while swinging an arm into a raised position. Stimuli that were most effective for eliciting a startle response were intermittent high pitched sounds and sudden movements. In rats, sound pulses of low 3,000 to 7,000 hz elicited less of a startle response than 15,000 to 23,000 hz sound pulses (Blaszczyk and Tajchert, 1997).

The intermittent stimuli chosen in our observations were based on observations made at the three different auctions used for practice. The stimuli chosen were the ones that were most effective for eliciting a startle reaction. It is of interest to note that the authors noticed that high pitched intermittent sounds of the ringman yelling "Hey" or a young child yelling had a greater effect on the cattle than the amplified auctioneer's chant, gates slamming, or phones ringing. Waynert et al. (1999) found that sounds made by people while handling cattle had a greater effect on heartrate and reactivity than equipment sounds such as gates banging. Pajor et al (1999) reported that shouting at cows was very aversive. Our own observations indicated that the constant sound of the auctioneer's chant did not directly elicit a startle response compared to sudden intermittent stimuli. However, the background noise of the chant may sensitize the animal to intermittent stimuli. Research with rats shows that a constant background noise enhances an acoustic startle response (Schanbacker et al 1996). High-pitched sounds have a greater effect on an animal's heartrate then low-pitched sounds (Talling et al., 1996). High-pitched sounds with a rising pitch are used in dog training to signal an animal to do something. For example, a whistle signals an animal to come. A low-pitched sound is used to inhibit an activity (McConnell, 1990).

Talling et al. (1996) reported that piglets had increased heart rates when they were exposed to high frequency and high intensity (sound pressure) sounds, whereas piglet movement was associated only with loudness. In another experiment (Talling et. al., 1998), swine exposed to intermittent, sudden sounds were more reactive than when exposed to a constant sound. This study is of particular interest because it showed that intermittent sounds had a greater effect.

Cattle and horses have ears that are more sensitive than human ears. They are especially sensitive to high frequency sounds (Heffner and Heffner, 1983; Grandin 1996; Smith, 1998). Therefore, noises that are a whisper to humans are quite audible to cattle. Trnka (1977) reported an inverse relationship between level of sound and abnormal behavior in dairy cattle. Noises in auction houses are diverse in frequency and source and as such provide a good setting for observing cattle reaction to intermittent sound.

The physiology of the eye and how that relates to instinctual behavior may explain the results found for reaction to a sudden motion. Prey species have visual adaptations for survival in the wild (Craig, 1981). In general, these adaptations are wide field of vision (especially while the head is lowered) (Prince, 1970; Coulter and Schmidt, 1993) and bulbous eyes on the side of the head. They also have slit-shaped pupils whereas most predatory animals have round pupils (Smith 1998). Grazing animals have a smaller binocular field of vision compared to predatory animals and a reduced ability to see objects above them compared to humans (Prince 1970, Lynch et al 1992). Prey animals have relatively weak eye muscles which inhibits the ability to quickly focus on nearby objects and this may explain the tendency for a horse to shy from nearby sudden movement (Prince 1970, Coulter and Schmidt 1993). While grazing, the visual system of a prey animal has an increased ability to detect movement, which helps protect the animal from predators. The latest research indicates that cattle, sheep, and goats are dichromats with cones that are most sensitive to yellowish-green (552 to 555 nm) and blue-purple light (444-445nm) (Jacobs et al. 1998). Dichromatic vision may provide an animal with better vision for detecting motion than full color vision (Miller and Murphy, 1995; Pick et al. 1994). LeDoux (1996) states that sudden movements have the greatest activating effect in the amygdala. The amygdala is a region in the brain that controls fearfulness (LeDoux, 1996; Rogan and LeDoux, 1996).

It is possible that motion sensitive cattle are simply ineffective at visual search (Humphreys, 1996) and have a greater desire to orient to an object (e.g., the exit) than their non-motion sensitive conspecifics. Like horses, cattle may have the tendency to shy from sudden motion because of the morphology of their eyes.

There was no difference in temperament between single animals alone in the ring and cows with a calf at her side. It was not within the scope of this study to investigate the behavior of larger groups of animals. Grouped cattle tend to be less behaviorally agitated during routine handling (Grandin. 1987; Ewbank, 1968).

The differences found between genders were also expected. Voisinet et al., (1997b) found that heifers were more excitable than steers. Fleming and Luebke (1981) demonstrated that virgin female rats were more excitable than mature male rats. Härd and Hansen (1985) found that female rats became less fearful after parturition and the onset of lactation. This may explain why cows had lower temperament scores than heifers.

Predictions of cattle temperament in unfamiliar environments are becoming increasingly important in today's cattle industry. Animals that are calm and placid on their ranch may become agitated and stressed when they are confronted with a novel situation such as the fair grounds, feedlots, auctions and slaughterhouses (Grandin and Deesing, 1998; Grandin, 1997). This is especially a problem in cattle that have an excitable nervous temperament. Visual stimuli can disrupt handling (Grandin, 1996, 1980). Both cattle and deer will orient and face a moving person in a field (Grandin and Deesing, 1998; Hodgett et al., 1998). On detection of motion, prey species visually orient to the source of the movement and watch until they determine that the stimulus is or is not a danger. After such a determination, the animal will either return to its previous activity or take appropriate evasive action (B. J. Smith, personal communication, 1999). This reaction to visual stimuli can adversely affect smooth animal handling. For example, cattle that are going down an alley may balk at seeing a hat blowing in the wind. Once the animals have determined that the hat is not a danger, they will proceed calmly down the alley.

Temperament scores at some auctions were significantly higher ($P<.05$) than at other auctions. This may be due to differences in animal handling before the cattle entered the auction ring. No data was collected regarding animal handling outside of the auction ring. Electrical prods were used extensively and indiscriminately in the two auctions in which data were not collected. Use of electrical prods in this manner caused normally calm cattle to become agitated, aggressive and(or) injure themselves during the auction. The relationship between overall behavior in the auction ring and reactivity to sudden intermittent stimuli was significant in all six-auction houses. The differences in animal handling between auctions may have had an effect on cattle temperament. Two auctions in Texas were excluded from the study, as the extremely rough handling and excessive electrical prodding caused all animals that entered the auction ring to run (ring score of 3). All other auctions surveyed had a consistent percentage of animals in each ring score and therefore the effect of auction handling on temperament was thought to be minimal. No data was collected on individual auction handling practices other than brief notes.

A survey conducted by R.D. Green, (unpublished data) found commercial cow/calf producers ranked disposition after birth weight, as their second most important selection trait in bulls. Their top three reasons for desiring bulls with calm dispositions were 1) excitable bulls lose weight, 2) temperament is heritable, and 3) there is a high labor cost associated with wilder cattle. Producers know that calm handling of cattle (Stricklin and Kautz-Scanavy, 1984) and calm cattle (Burrow and Dillon, 1997; Voisinet et al., 1997a,b; Smith 1998) can increase productivity.

Implications

Cattle that become agitated during handling in an auction ring are more sensitive to sudden touches and sudden intermittent movements and sounds, such as the ringman yelling and waving his arm, a plastic "rattle-paddle" slapping a fence, or children yelling or running. Reactivity to intermittent stimuli may be useful for predicting which cattle would be more likely to become agitated when exposed to a new place such as a auction, feedlot or meat packing plant.

Chapter 3 Tables

Table 1. Percentage and fraction of each temperament score group that was sensitive to an environmental stimulus

Temperament Score	Intermittent motion	Intermittent sound	Sound and motion	Touch
1	20.43%	13.07%	43.33%	29.41%
	38/186	26/199	13/30	10/34
2	38.54%	29.58%	74.58%	47.62%
	227/589	147/497	88/118	60/126
3	61.02%	42.34%	82.5%	52.17%
	180/295	94/222	33/40	24/46
4	66.67%	70.0%	100.0%	33.33%
	8/12	7/10	2/2	1/3

All are significant at the alpha = .05 level (GLM & Chi-square SAS, 1985) except for touch sensitivity. Fractions are actual numbers. Numerator is the number of animals sensitive. Denominator is the total number of animals with that particular ring score who were scored for sensitivity. Ring scores ranged from a calm animal scoring 1, to a highly agitated animal scoring 4.

Table 2. Percentage and fraction of cattle that were sensitive to an environmental stimulus

Animal sex	Intermittent motion	Intermittent sound	Sound and motion	Touch
	Holstein and beef-type cattle			
Heifers	50.65%	34.09%	82.61%	63.64%
	77/152	45/132	19/23	14/22
Cows	38.26%	31.94%	70.53%	38.52%
	251/656	183/573	79/112	47/122
Steers	46.91%	29.69%	41.17%	50.00%
	38/81	19/45	5/12	7/14
Bulls	43.27%	20.57%	75.00%	55.36%
	90/208	36/175	36/48	31/56
	Holstein cattle only			
Heifers	31.58%	58.82%	100.00%	80.00%
	6/19	10/17	2/2	4/5
Cows	35.15%	33.33%	82.35%	57.90%
	84/239	71/213	14/17	11/19
Steers	50.00%	55.56%	0.00%	66.67%
	7/14	5/9	0/2	2/3
Bulls	60.00%	23.53%	100.00%	81.82%
	12/20	4/17	10/10	9/11
	Beef-type cattle only			
Heifers	53.23%	58.82%	84.21%	62.50%
	66/124	10/17	16/19	10/16
Cows	40.00%	33.33%	68.89%	35.35%
	162/405	71/213	62/90	35/99
Steers	46.15%	55.56%	50.00%	45.45%
	30/65	5/9	5/10	5/11
Bulls	41.53%	23.53%	67.57%	50.00%
	76/183	4/17	25/37	22/44

All are significant at the $P = .05$ level. Fractions are actual numbers. The numerator is the number of animals sensitive. The denominator is the total number of animals of that sex that were scored for sensitivity to the stimulus.

Chapter 3 Figures

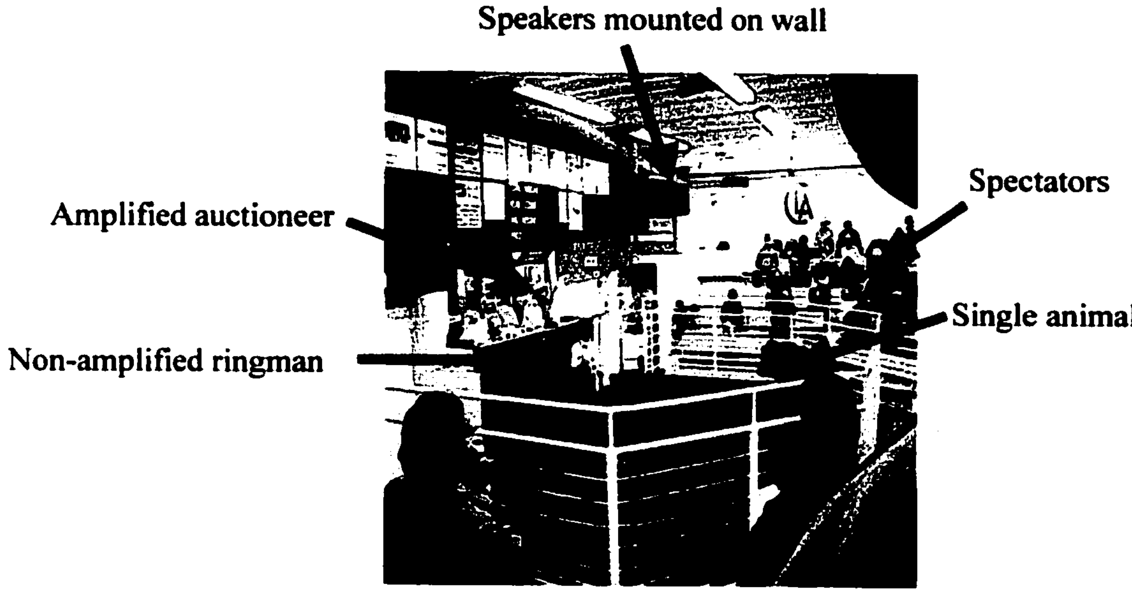

Figure 1. Typical auction ring layout

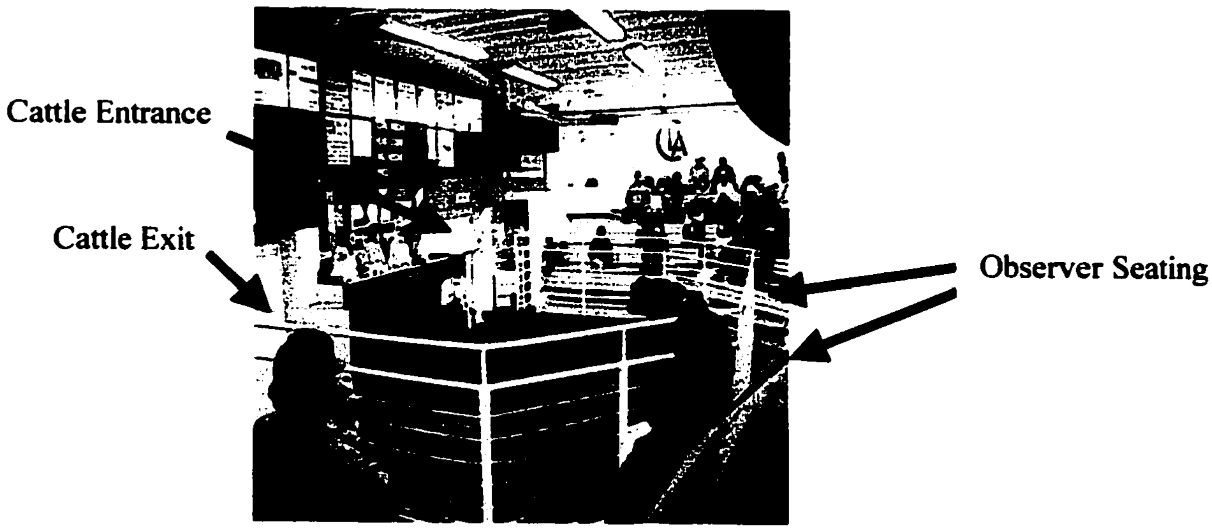

Figure 2. Observer seating in relation to cattle entrance and exit

Dissertation Summary

Summary of Dissertation Findings

The objective of these investigations was to examine the dichotomous relationship between cattle productivity and temperament, temperament and physical indicators (attributes), and productivity and physical indicators. Two separate studies were used to assess this relationship: (1) in production dairy cows, and (2) feedlot heifers. The feedlot heifers were involved in a vitamin trial at the time that this study were conducted. A third investigation was conducted at six different auctions to determine the relationship between temperament and reaction to intermittent external stimuli.

There was no affect of the vitamin trial on the heifer's physical attributes or temperament. The association between the vitamin study and productivity were not reported in this dissertation but may be found in Scanga et al. (2001).

The null hypotheses for these two investigations were that: (1) cattle production was not associated with cattle temperament; (2) there are no physical attributes of cattle temperament; (3) there are no physical attributes of cattle production. The results of these three studies suggest that the alternative hypotheses were correct: (1) cattle production was associated with cattle temperament; (2) there are physical attributes of cattle temperament; (3) there are physical attributes of cattle production.

Holstein dairy cows. The majority of cows (40%) were in their first lactation. The remaining cattle represented up to ten lactations. Those individuals that had remained in the herd longer, as measured by the number of lactations at the time of the study, had less variability in hair whorl characteristics than those in their first lactation.

Cattle Production was Associated with Cattle Temperament

Holstein dairy cows. Analysis of all dairy cows showed very reactive cows had 47.3 kg less mature equivalent fat compared to the non- and mildly-reactive cow average.

Feedlot heifers. Heifers that hesitated (balked) at having their heads restrained had lower marbling score than those that readily moved into position to have their heads restrained.

Cattle Production was Associated with Various Physical Indicators

Holstein dairy cows. Dairy cows with bald epicenter whorls had greater Mature-Equivalent Protein (MEP) and Milk (MEM) than cows with point epicenter whorls.

Feedlot heifers. Carcass characteristics of heifers and bone measurements were correlated. Heifers with wider cannon bones had lower hot carcass weights, and more green and blue colorimeter values. Facial hair whorl characteristics were associated with carcass characteristics. Multiple hair whorls were associated with lower hot carcass weights, and more green and blue colorimeter values. Compared to heifers with spiral shaped whorls, those with line shaped whorls had "greener" colorimeter values.

Physical Attributes of the Cattle are Indicators of their Temperament

Holstein dairy cows. The lower the facial hair whorl the more often the dairy cow actively pulled away from the looming person.

Feedlot heifers. Temperament was found to be associated with bone measurements. There was a trend for taller heifers to balk at the head restraint, while heifers with wider and thicker bones were less likely to balk at having their head restrained. The lower significance for the latter results may be due to a small sample size. Cattle with wider cannon bones required more force by the handler to move the animal into the squeeze chute for physical restraint.

Relationship Between Various Physical Attributes

Feedlot heifers. Heifers with line shaped facial hair whorls had wider and thicker cannon bones than those with spiraled whorls.

Relationship between activity level in an auction ring and sensitivity to sudden intermittent stimuli

Holsteins were more sound sensitive and touch sensitive than beef cattle. Sensitivity to sudden intermittent stimuli (e.g., sound, motion, and touch) increased as temperament score (excitability) increased. Cattle with a temperament score of 1 were the least sensitive to sudden intermittent movement and sound and those with a temperament score of 4 were the most sensitive. This same relationship was sometimes observed for touch, but was not statistically significant. Motion-sensitive cattle were more likely to score a temperament rating of three or four than non-sensitive cattle. Steers and heifers were more motion sensitive than the older bulls and cows. Beef cattle urinated, and defecated more often in the ring than did dairy cattle. Cattle that became agitated during handling in an auction ring were the individuals that were most likely to be startled by sudden intermittent sounds and movements.

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Appendix 1

Variables used in Dairy Analysis

Hair whorls	Production	Reaction to a looming person
Height	*Mature Equivalent*	
Above eyes	Fat *(MEF)*	No reaction
At eye level	Protein *(MEP)*	Mild Reaction
Below eyes	Milk *(MEM)*	Strong reaction
	Energy Corrected Milk *(ECM)*	
Lateral position	Fat Corrected Milk *(FCM)*	
Right		
Middle	*Productive Life*	
Left	of the above Mature Equivalent variables	
Shape		
Spiral		
Line		
Flare		
Rotation		
No rotation		
Clockwise		
Counter clockwise		
Type of Epicenter		
Bald		
Point		
Number of Whorls		

Appendix for Statistical Analysis

One-way ANOVA with a contrast statement used to determine the association of the cows reaction to a looming person and productivity values. Analyzed with all cows (lactation 1 – 10) and then with cows of multiple lactations (2-10).

Two-tailed-test used on all dependent variables with only discrete data (e.g. flare, number of whorls, epicenter type) to determine the association with productivity values. Ran 1^{st} with all cows (lactation 1 – 10) and then with cows of multiple lactations (2-10).

Productivity and Temperament

Cow reactivity and production analysis

One way ANOVA with a contrast statement

```
options ls=110 ps=60;
proc glm;
class <Reaction to a looming person>;
model <production values> = <Reaction to a looming person>;
estimate '3 vs 1 and 2' <Reaction to a looming person>.5 .5 -1;
lsmeans <Reaction to a looming person> /pdiff cl;
run;
```

Productivity and Physical Indicators

Hair whorl and production analysis

Two-tailed t-test

```
options ls=110 ps=60;
proc ttest;
class <dichotomous hair whorl variables>;
var <production values>;
run;
```

One way ANOVA

```
options ls=110 ps=60;
proc glm;
class <hair whorl variables>;
model <production values> = <hair whorl variables>;
lsmeans <hair whorl variables> /pdiff cl;
run;
```

Chi squared

Analysis was preformed interactively using **SAS/ANALYST**.

Dependant = <production values>

Independent = <hair whorl variables>

Temperament and Physical Indicators

Hair whorls and reactivity analysis

Chi squared

Analysis was preformed interactively using **SAS/ANALYST**.

Dependant = <Reaction to a looming person>

Independent = <hair whorl variables>

Appendix 2

Variables used in Heifer Analysis

Physical Indicators		Production	Temperament	Nutritional Study
Hair whorls	***Bone measurements***	***Meat***		
Height	*Length*	*Hot carcass wt*	***Force used to move animal into chute***	***Steer feedlot supplement***
Above eyes	*Width*	*Yield grade*		*1 of 8 D_3 and $CaCO_3$ combinations*
At eye level	*Thickness*	*Ribeye area*	*None*	
Below eyes	*Density*	*Fat thickness*	*Touched*	***Miscellaneous***
Lateral position		*Percent yield grade*	*Tail twist*	*Average daily gain*
Right		*Adjusted %yg*	*Electric prod*	
			Reluctance to have head restrained	
Middle		*Kidney, pelvic, and heart fat*		
Left				
Shape		*Marbling*	*Yes*	
Spiral		*Quality grade*	*No*	
Line		*Percent kidney, pelvic, and heart fat*	***Activity level in the chute***	
Flare			*Stands still*	
Rotation		*Meat color (L*, a*, b*)*	*Slightly agitated*	
No rotation		*Dressing percent*	*Agitated*	
Clockwise			*Extremely agitated*	
Counter clockwise		***Warner-Bratzler***		
Type of Epicenter		*$70^{\circ}C$ aged 2, 7, 14, 21*		
Bald		*$85^{\circ}C$ aged 2, 7, 14, 21*		
Point				
Number of Whorls				
one				
more than one				

Appendix for Statistical Analysis

General Statistics

Average daily gain and individual bone measurements

```
options ls=110 ps=60;
proc glm;
class < individual bone measurements >;
model <Average daily gain> = <individual bone measurements>;
run;
```

Simple Linear Regression Procedure Regression in SAS Analyst (1999-2000) with ADG as the dependant variable and individual bone measurements as independent variables.

Association of nutritional trial on temperament and individual bone measurements

```
options ls=110 ps=60;
proc glm;
class < nutritional trial >;
model < individual bone measurements > < temperament > = < nutritional trial >;
random <nutritional trial>;
run;
```

Specific Statistics

Productivity and Temperament

Meat quality and temperament

```
options ls=110 ps=60;
proc ttest;
class <dichotomous temperament variables>;
var <meat values>;
run;


options ls=110 ps=60;
proc mixed;
class <temperament variables >;
model <individual meat qualities> = <temperament variables>;
lsmeans <individual temperament variables> /pdiff cl;
run;
```

Specific Statistics continued

Productivity and Physical Indicators

Meat quality and cannon bone measurements

Simple Linear Regression Procedure Regression in SAS Analyst (1999-2000) with individual meat variables as the dependant variables and individual bone measurements as independent variables.

Meat quality and facial hair whorl descriptions

```
options ls=110 ps=60;
proc mixed;
class <hair whorl variables>;
model <individual meat qualities> = <individual hair whorl variables>;
lsmeans <individual hair whorl variables> /pdiff cl;
run;
```

Specific Statistics continued

Temperament and Physical Indicators

Temperament and cannon bone measurements

```
options ls=110 ps=60;
proc ttest;
class <dichotomous temperament variables>;
var <bone measurements>;
run;

options ls=110 ps=60;
proc glm;
class < temperament >;
model < individual bone measurements > = <temperament >;
run;
```

Temperament and facial hair whorls

Analysis was run interactively using **SAS/ANALYST**.

Dependant = <Exit speed>

Independent = <hair whorl variables>

Specific Statistics continued

Physical Indicators and Physical Indicators

Hair whorls and bone measurements

```
options ls=110 ps=60;
proc mixed;
class <hair whorl variables>;
model <individual bone measurements> = <individual hair whorl variables>;
lsmeans <individual hair whorl variables> /pdiff cl;
run;
```