AN ABSTRACT OF THE THESIS OF

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Title: Effects of Early Rearing Environment on Learning Ability and Behavior in Laying Hens.

Abstract approved:

Candace C. Croney

The effects of enriching the rearing environment of laying hens on their learning ability and behavior were investigated. Day old ISA brown layer chicks were group housed in open floor pens that were either enriched or unenriched. The enriched rooms contained visual stimuli in the form of hanging decorations, auditory stimuli via classical music, and nutritional and tactile enrichment consisting of mealworms, plants, hay, and daily human contact. Human approach tests were conducted with a familiar handler at 2, 4, and 6 weeks of age and with novel handlers at 8, 10 and 11 weeks of age. Ability to locate food presented in novel food and water containers was also examined at week eight. At week 10, a barrier test was conducted and at week 13, a foraging test was done, both to investigate the effects of rearing environment on the birds' problem solving and spatial navigation abilities. Additionally, the productivity of the hens was observed. Egg numbers, egg weights, and locations of eggs laid were recorded for 13 weeks following the onset of lay at 17 weeks of age. The level of aggression birds displayed toward each other during the laying period was also recorded once a week for three weeks using 20-minute scan

sampling. Bird weights were also recorded every two months. At the end of the study at the start of week 30, feather scores were recorded.

Enriched birds were less fearful of familiar and novel humans ($p=0.05$), but there was no difference in ability to locate food and water in novel containers as a function of rearing environment ($p>0.05$). Also, there was no effect of enrichment on performance of the birds on the barrier test ($p>0.05$). However, the enriched birds located more food patches and demonstrated more vertical investigations than the unenriched birds in the foraging test (both $p=0.05$). No differences were found between enriched and unenriched birds in regards to egg numbers, egg weights, or the number of eggs laid on the floor. While enriched birds broke more eggs than unenriched birds ($p=0.05$) they also used the nest boxes more fully, laying more eggs in the top tier of the nest box ($p=0.05$) than unenriched birds. Additionally, enriched hens weighed more than the unenriched birds ($p=0.005$) and had better feather condition ($p<0.0001$).

Overall, the results suggest that enrichment positively affects hen behavior in that it reduces fear of humans and novel environments, reduces feather pecking and inter-bird aggression, increases and improves the use of vertical space and ability to locate resources in the vertical plane, without impairing productivity.

Effects of Early Rearing Environment on Learning Ability and Behavior in Laying Hens

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APPROVED:

Major Professor, representing Animal Science

Head of the Department of Animal Sciences

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Hannah M. Morris, Author

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Chapter 1
Introduction

Human – Animal Relationships

People's attitudes towards animals today are inevitably colored by ideas from the past. Humans have been fascinated by questions of right and wrong and as a result, moral concerns have permeated mankind's activities with animals. As societies progressed, humans began questioning the moral status of non-human animals (Rollin, 1992). Aristotle's belief that man had a unique standing within creation because of his ability to reason was shared by philosophers whose thoughts about the community and nature of justice excluded animals (Grayson, 2000). The Cynics, an influential group of philosophers in 4th century B.C., saw animals as superior to humans, while ancient Egyptians believed that animals were manifestations of the divine. Alternatively, early Christians believed that humans should have a neighborly attitude towards animals because of their common gift of life from God. This idea was reinforced by St. Thomas Aquinas in the 13th century, who suggested that although irrational animals had no right to human consideration, their good treatment might be part of the duty that man owed to humanity (Grayson, 2000). This anthropocentric view was given added credence during the Renaissance and by the rise of humanism which affirmed the worth of humans due to their ability to do right and wrong by appealing to rationality.

In the 17th century, René Descartes argued that nonhuman creatures lacked the capacity to feel pain and did not have minds in the normal sense. He argued that the bodies of both humans and animals were simply complex automata, but that men could be distinguished from machines by their possession of intellect, language, and soul (Grayson, 2000). Descartes maintained that humans were absolved of any crime or guilt in killing, eating, or experimenting on animals. These views were accepted by many scientists and philosophers of the seventeenth and eighteenth centuries. The concept of the 'robot animal' held great attraction for the scientific community who could therefore conduct anatomical and physiological studies on animals without any sense of moral repercussions. However, some scientists who used animals at the time had a different approach. While they recognized that animals felt pain, they did not see pain as a moral concern, as humans had dominion over animals (Orlans *et al*., 1998). In contrast to Descartes, David Hume believed that animals could understand and reason. Hume attributed the capacity to reason to some animals, such as non-human primates, on the grounds that they were like humans in the "principles of their nature, their patterns of learning, and their use of tools" (Orlans *et al*., 1998). Jeremy Bentham reasoned that although there were important differences between animals and humans, there were also relevant similarities (e.g. the capacity to experience pleasure, pain, and suffering). Bentham argued that humans had a duty to not cause animals pain and suffering (Orlans *et al*., 1998). Conversely, Immanuel Kant of the 18^{th} century argued that although animals had reduced value because of their status as subhuman animals, humans had no direct obligations to them. However, he noted that people should not be cruel to animals as this would make them cruel in dealings with other people (Orlans *et al*., 1998).

In 1975, Peter Singer, the father of the animal liberation movement and contemporary utilitarian, argued that any sentient individual has interests and therefore must be given moral consideration. He maintained that humans need to justify their involvement of animals on a basis that accounts for the animals' interests (Orlans *et al.*, 1998). He also stated that it is immoral to discriminate against an individual simply because he or she is not a member of one's own species (speciesism). Singer believed that equal consideration of interests was important and that "pain is pain no matter what species is experiencing it" (Shapiro, 2000).

In more recent history and in direct disagreement with Kant's principles, Tom Regan, widely recognized for influencing the animal rights movement, argued in 1983 that what matters is not whether a being is rational or conscious but whether it is alive and goal oriented. Regan argued that animals had moral rights based on the concept of inherent value and that there was no identifiable characteristic all human beings have that is not also possessed by some non-human beings. Therefore, Regan proposed that animals must have the same moral rights as humans (Shapiro, 2000).

Such obvious changes in perceptions of the value of animal life and intelligence led to the introduction of a social ethic for animals which dictated acceptable treatment and use of animals. According to Rollin (1995), as long as humans have domesticated animals, there has been an ethic for their treatment. The traditional ethic forbade animal cruelty which encompassed "deliberate, sadistic, useless, unnecessary infliction of pain, suffering, and neglect on animals" (Rollin, 1995). The current social ethic states that if animals are to be used by humans, they should live lives that respect their natures. In addition, the interests of animals count for themselves (Rollin, 1995).

Rollin's sentiments were preceded by the ideas of Ruth Harrison (1964) who highlighted the problems with intensive farming of animals for food. Harrison's book, *Animal Machines* (1964), broached the term "factory farms", and inspired the British government to charter the Brambell Commission in 1965 to investigate the welfare of agricultural animals in intensive confinement systems. Intensive systems entail large numbers of animals in close confinement where human labor is often replaced largely by machines (Rollin, 1998). Intensive agricultural farming practices were developed as animal productivity significantly increased after World War II with the transition from family farms to vertically integrated production systems.

As intensive farming became more popular and as fewer people were raised on farms, and more began to be exposed to ideas such as Harrison's, Singer's and Regan's, people increasingly became concerned about the welfare of farmed animals (Rollin, 1995). Consequently, it became imperative for scientists and others involved in animal agriculture to make significant efforts to understand and improve animal welfare.

Defining Animal Welfare

To address public concern for animals and improve animal welfare, one must first define welfare. Defining welfare continues to be a contentious issue and there is still a lack of consensus on a general definition. However, an essential criterion for a useful definition of animal welfare is that it should refer to a characteristic of the individual animal rather than something given to the animal by man (Broom, 1986). In 1965, the Brambell Committee stated that "welfare is a wide term that embraces both the physical and the mental well-being of an animal. Any attempt to evaluate welfare must therefore take into account the scientific evidence available concerning the feelings of animals that can be derived from their structure and function and also from their behavior" (Brambell Committee, 1965). Hughes (1976a) later defined welfare as "a state of complete mental and physical health where the animal is in harmony with its environment", while Carpenter (1980) has said that "the welfare of managed animals relates to the degree to which they can adapt without suffering to the environment designated by man". One of the most widely accepted definition of animal welfare, however, is that welfare is "the state of an animal as it attempts to cope with its environment" (Fraser & Broom, 1996).

Different definitions of welfare focus on comfort, health, the opportunity to display natural behaviors, and various ethics and animal rights (Barnard & Hurst, 1996). These categories are the basis for the five freedoms proposed by the UK Farm Animal Welfare Council in 1992 (Appleby & Hughes, 1997; Barnard & Hurst, 1996). The five freedoms include freedom from hunger and thirst; freedom from thermal and physical discomfort; freedom from pain, injury and disease; freedom from fear and distress; and freedom to exercise normal behavior (Appleby *et al*. 2004). Although there is evidence of these five freedoms in modern welfare programs, the freedom to exercise normal behavior is often overlooked.

In 1991, Duncan & Petherick took a very progressive view when they asserted that animal welfare is primarily dependent on how an animal "feels". In other words, the animal's psychological and cognitive needs matter. It has been argued that if the animal's mental needs are met, this will cover their physical needs. Duncan & Petherick (1991) argued that health, the most obvious of the physical needs, is not necessarily a prerequisite for welfare. There is a close relationship between physical health and welfare but Duncan & Petherick (1991) suggested that it is the "feeling" ill that matters from a suffering and welfare point of view.

Understanding Animal Welfare

Three broad approaches to understanding animal welfare have emerged. "Feelings-based" approaches define animal welfare in terms of the subjective experiences of animals (feelings, emotions). These emphasize the reduction of negative feelings such as suffering and pain, and the promotion of positive feelings like comfort and pleasure (Duncan & Fraser, 1997). Most people believe that animals can experience affective states and that they can suffer if conditions are poor. Many scientists have emphasized the subjective feelings of animals as a key component of their well-being (Dawkins, 1980, 1990; Baxter, 1983; Duncan & Dawkins, 1983; Duncan, 1987; Fraser, 1993). According to this approach, welfare is reduced by negative subjective states such as pain, hunger, fear, frustration, and can be improved by positive states such as comfort, contentment, and the pleasure of certain types of social interaction. One research method for investigating animal welfare using this approach involves studying the preferences of animals for different environments and the relative strengths of their motivation to obtain or avoid certain parts of their environment (Duncan & Fraser, 1997). Performance of abnormal behavior is often interpreted as a symptom of a negative affective state. For example, various stereotypies, defined as uncontrolled, repetitive movements within a restricted pattern, have been interpreted as indicating frustration, boredom, hunger, or desire to escape unpleasant features of the environment (Rushen *et al*., 1993a; Wemelsfelder, 1993).

An alternative approach to assessing animal welfare is based on whether an animal's biological functioning is normal. According to this "functioning-based" approach, welfare can be reduced by disease, malnutrition and injury. Good welfare is indicated by high levels of growth, reproduction, high rates of longevity, and biological fitness (Duncan & Fraser, 1997). Practically speaking, changes in biological functioning are easier to demonstrate scientifically than are changes in animal experiences. However, the link between biological functioning and an animal's welfare is not always apparent.

The third approach suggests that to promote animal welfare, we must raise animals in "natural" environments and allow them to behave in "natural" ways (Duncan & Fraser, 1997). According to Rollin (1992, 1993), each animal species has an inherent nature called its "telos". Rollin (1993) suggests that to promote the welfare of animals, we need to raise them in ways that respect their natures or telos. However, a central question in the study of animal welfare is whether or not animals should be allowed to carry out most or all of their normal behavior patterns. There is a widespread belief that behavioral restriction or deprivation will cause animals to suffer. It has been suggested that welfare is more likely to be jeopardized when behaviors that are largely internally motivated are prevented or restricted, and when motivation remains high if the behavior cannot be performed (Petherick & Rushen, 1997).

Scientists have attempted to design environments that allow animals to express their full behavioral repertoire. For example, Stolba & Wood-Gush (1984) studied domestic pigs in a partly wooded area and noted that they often rooted in the soil and rubbed against trees. They then designed a multi-area pen where these natural behaviors were possible. Other research has attempted to identify environments that promote normal behavioral development. The behavioral repertoire of domestic animals is sometimes drastically different from their wild counterparts, and may include patterns of behavior that are adaptations to cope with adverse circumstances (Dawkins, 1980). The natural argument, however, is a fundamental consideration in the design of animal environments wherein the welfare objective is to make provision for as much natural behavior as is possible (Webster, 2005).

Agricultural animals generally cannot perform many of the behaviors they would normally use to attain their functional goals because of the restrictive nature of the environments in which they are typically housed. The implicit philosophy behind such impoverished and restrictive animal management has been that if the animal's functional requirements are met, then the often energetically expensive behavioral repertoire need not occur. For many animal welfare groups, such behavioral deprivation or restriction is a source of concern about intensive animal husbandry (Dawkins, 1988). Further, there is a widespread belief that animals which are restricted or prevented from performing their full repertoire of behavioral patterns may suffer in the same way that they might if their physical requirements are not met. For example, domestic hens and pigs engage in extensive nest building behavior even when provided with a pre-constructed nest (Hughes *et al*., 1989; Arey *et al*., 1991) and young ruminants, separated from their mothers, perform non-nutritive sucking of pen mates, parts of the pen and nonfunctional teats even after drinking milk (de Wilt, 1985; de Passillé *et al*., 1993).

Natural behavior of animals is expected to be adaptive and should promote biological functioning. Pleasant and unpleasant subjective experiences are also seen as adaptations that promote the same outcomes by motivating animals to avoid harm and perform beneficial actions (Dawkins, 1980). Research indicates that feelings-based and functioning-based interpretations often correspond. For example, studies have shown that laying hens have a lower mortality and produce more eggs when space allowance is high and group size is low (Hughes, 1975). Also, testing has shown that hens prefer larger spaces and smaller group sizes. Permitting animals to perform natural behavior also promotes positive biological functioning and presumably improves welfare.

Behavior and Animal Welfare

According to Mench & Mason (1997), to know what the behavior of an animal means with regards to its welfare, it is necessary to have a detailed understanding of the behavioral characteristic of the animal's species. Animal behavior is one of the most easily observed indicators of welfare. Moreover, because behavior is the manner in which animals exert control over their environment, it can provide information about animals' needs, internal states, and preferences. Comparisons of free-living and captive animals can show which behavior is absent in captivity and provide cues as to which behaviors may be important for the animal to perform. One way to do this is to develop an ethogram, which is a catalogue of behaviors (Banks, 1982). For zoo animals, observation of wild conspecifics is necessary and can provide information about the range and frequency of the behavior of individuals, but the situation is more complicated for domesticated animals because humans have selected for traits that are correlated with behavioral traits and as a result, have caused changes in their behavior (Price, 1984).

It is sometimes suggested that welfare is promoted if animals are able to perform the activities that most closely resemble the behavioral repertoire of their free-ranging conspecifics (Brambell Report, 1965). However, differences in behavior between free-ranging and captive environments do not necessarily imply suffering (Hughes, 1978). The question is whether the differences in behavior indicate that the animal has adapted its behavior to suit a different environment or that its ethological needs are not being satisfied (Hughes, 1978).

Hughes & Duncan (1988) argue that there are cases in which the performance of behavior has motivationally significant consequences not necessarily related to the animal's functional requirements, such as in contrafreeloading and instinctive drift. The issue of whether an animal needs to express certain behavioral patterns to maintain a good state of welfare is difficult to answer. However, it is more difficult to answer whether the animal's welfare is reduced by not being able to perform some behavioral patterns. Hughes & Duncan (1988) suggest that while wild animals carefully budget their time, the intensively farmed animal's problem is to fill the time available with the often limited number of behaviors available to it. Intensive housing does not allow an animal to perform its full behavioral repertoire due to the restrictive environment.

Another reason why animal behavior is important to understand is that it may provide indirect evidence of what an animal is feeling, thereby giving some insight into the emotional and mental aspects of welfare (Duncan, 1998). Behavioral observations of negative states such as pain, frustration and fear have been used as welfare indicators in the past, and positive emotional states may provide evidence of contentment or happiness (Duncan, 1998). For both practical and moral reasons, it is important not only to minimize negative emotions in animals but to also promote positive experiences for them.

To fully understand the relationship between animal behavior and welfare, one must also understand abnormal behaviors in animals, such as stereotypies like excessive licking, eating of hair, wool, or feathers, and persistent biting at the tails of other animals. Abnormal behavior has been defined as a "persistent, undesirable action, shown by a minority of the population which is not due to any obvious neurological lesion and which is not confined to the situation that originally elicited it" (Broadhurst, 1960; Fox, 1968). Fraser (1968) argues that in addition, abnormal behavior should be defined as maladaptive and harmful to the animal. There is a wide range of behavior patterns that are considered abnormal. Some extreme behaviors involve the mutilation of others such as cannibalism in poultry and swine. Other less severe forms of abnormality make judgments about welfare more difficult (Duncan & Dawkins, 1983).

Abnormal behavior has been equated with poor welfare because it is usually prevalent in environments judged as inappropriate for the specific species, may develop from frustrated motivation, and correlates with other signs of poor welfare (Mench & Mason, 1997). The conventional interpretation of stereotypic behavior is that it is a mechanism for coping with a lack of the resources necessary for normal behavior. This may be extended to the assumption that it is a response to the denial of behavioral needs and therefore is an indication that welfare has been compromised (Webster, 2005). This suggests that abnormal behavior may be indicative of poor welfare but such suggestions are not without examples demonstrating just the opposite. Individuals may differ in their abnormal behavior and individual differences in physical fitness, levels of hormones, and fundamental properties of pathways in the brain can also affect how animals fare when faced with frustration and their tendencies to develop stereotypies (Mench & Mason, 1997). Additionally, the exact stressors the animal is exposed to can affect what sorts of behavior it displays and how persistent the behavior is. Thus an animal's expression of abnormal behavior is the product of many interacting factors, some of which have nothing to do with welfare (Mench & Mason, 1997). Stereotypies specific to poultry include feather pecking, object pecking, bobbing, head flicking, neck extending, and pacing (Hughes & Black, 1974; Tanaka & Hurnik, 1992). These behaviors can be harmful causing a general waste of energy, injury and even death, along with a decrease in performance. Thus, many of the animal industries are beginning to incorporate information gleaned from investigations of farm animal behavior to inform decisions that relate to the well-being of their animals.

Chapter 2
Literature Review

Poultry Welfare and Behavior

The chicken and egg industries are the most intensive and industrialized divisions of animal agriculture (Rollin, 1995). As a result, the welfare of birds in these industries has been subjected to intense scrutiny and criticism. Animal rights organizations, the general public and members of the scientific community have recently insisted that the poultry industry change several housing and management practices. These developments have resulted in several European Union nations banning the use of conventional battery cages. Subsequently, the U.S. poultry industry has begun to examine its practices and housing operations to gain consumer acceptability and recently, citizens in the state of California voted to ban the confinement of certain farm animals in a manner that does not allow them to turn around freely, lie down, stand up, and fully extend their limbs. As a result of this legislation, veal crates, sow gestation crates and battery cages for laying hens are to be phased out.

Such new legislation makes it imperative to explore alternative housing designs for farm animals that not only permit more space, but allow the animals to perform a wider range of behaviors. Increasing the social and physical complexity of captive environments with environmental enrichment provides animals with more options for responding to stimulation from their surroundings (Carlstead, 1996). Environmental enrichment can also provide animals with increased mental stimulation and more opportunities to exhibit natural behaviors, thereby increasing their behavioral repertoires.

While some might object to legislation aimed at allowing farm animals to perform a larger repertoire of behaviors, there is increasing evidence that domestic poultry do have certain behavioral needs and that there are consequences of hindering these (Hughes & Duncan, 1988). Some behavior patterns may be strongly motivated and if they are not allowed to be expressed, can lead to frustration, potentially impacting the bird's welfare. For example, the importance of some aspects of feeding behavior may be overlooked in husbandry systems focused on efficiently providing feed to birds. Poultry scientists, for instance, have used their knowledge and expertise to provide birds with such concentrated rations that a laying hen can consume her daily requirements in approximately fifteen minutes (Duncan & Wood-Gush, 1972a). However, this is problematic because a hen may be strongly motivated to peck and scratch for feed for several hours. Although this behavior is not necessary for survival, its performance may still be important to the bird. Likewise, providing perches, dust baths and nest boxes for laying hens may satisfy some of the birds' other behavioral needs, such as the need to roost, dustbathe, and partially seclude themselves during oviposition (Jones, 2004).

In addition to the welfare concerns associated with not satisfying a bird's behavioral needs, other concerns exist, which have implications for the types of housing used for poultry. Birds kept for meat production (broilers) are usually raised on the floor, which permits birds space to move about in, to forage and dustbathe. The drawback to open floor systems is that birds remain in contact with feces and when litter is not added or changed frequently, dirty litter can cause foot ulcers and lesions (Duncan, 2004). For laying hens, battery cages are the most commonly used commercial housing systems in the U.S. Cages present some welfare benefits, including a separation between the bird and its feces, increased hygiene, and a decrease in disease and infection (Duncan, 2001, 2004). However, the main drawback of battery cages is that virtually all aspects of hen behavior are thwarted. Nesting behavior, social behavior, dustbathing, exercise, foraging and the ability to move and stretch are all prohibited. This creates a large discrepancy between chicken behavior under extensive management conditions and the behavior that can be exhibited in confinement.

Lack of exercise is a serious problem for poultry due to the fact that under free-range conditions, chickens spend a large portion of their daily time budgets walking and searching for food sites. Wing flapping, preening, and leg stretching are also very common in free-range birds but these behaviors are completely truncated in cages. Lack of exercise also has serious effects on bone and muscle development and strengthening. Caged birds have a greater incidence of lameness, bone brittleness, osteoporosis and muscle weakness than uncaged birds.

Nesting behavior is a particularly important aspect of a laying hen’s behavior. Prior to egg-laying, poultry perform a characteristic sequence of behaviors associated with the selection of an appropriate nest site (Mench, 1992). Hen demand for nest sites is inelastic and studies have shown that they are important enough that birds are willing to work to gain access to them (Mench, 1992). When a nest site is selected, the hen performs nest-building movements and oviposition can occur at a variable period of time following these behaviors (Mench, 1992). Obviously, battery cages cannot satisfy these needs and behavioral signs of frustration may be seen such as agitated pacing and escape behaviors (Wood-Gush & Gilbert, 1969).

Depriving poultry of the ability to dustbathe can also have detrimental effects on welfare. Hens provided with loose material will perform dustbathing behaviors every other day with each bout lasting approximately thirty minutes. Caged hens without access to litter often exhibit dustbathing behavior as a vacuum activity given that the appropriate external stimulus (substrate) for the behavior is not present (Mench, 1992). Performance of these vacuum behaviors suggests that hens have a high motivation to dustbathe even when the appropriate external stimulus, litter, is not available. For example, hens prefer cages with a litter floor to those with a wire floor and will in fact enter a smaller cage in order to have access to litter (Dawkins, 1981). Additionally, Duncan & Hughes (1972) have shown that when given a choice, hens will work for food rewards rather than eat food that is freely available to them (contrafreeloading). Enriching the environments of poultry, therefore, may help to alleviate boredom and reduce undesirable behaviors such as feather pecking and cannibalism often seen in unenriched cages and open-floor systems.

There are a number of ways in which modification of cages can improve the behavior of birds, prevent undesirable behaviors and benefit producers. Such improvements include increasing movement which increases muscle and bone strength, allowing escape which reduces bullying and the tendency of lower-ranking birds to go out of lay, and reducing fearfulness, which can cause injury (Appleby & Hughes, 1991). These improvements can be achieved by increasing cage area, providing some divisions within the cage, and including a perch. In addition, allowing birds to use loose material, like sand in a dust bath, has both behavioral and physical effects: pecking, scratching, and dust bathing behavior results in improved foot, claw and feather condition (Fickenwirth *et al.,* 1985). To summarize, many behavioral problems for the producers and the birds can be improved or prevented by making relatively simple changes to the cage area by adding an appropriate enrichment device such as a nest box, dust bath, and perch (Appleby & Hughes, 1991).

An additional behavioral problem that could be remedied using enrichment is excessive fear. Fear is widely recognized as an undesirable state of suffering and is one of the major problems facing the poultry industry (Jones, 1997). For example, inappropriate fear responses in chickens can result in illness, injury and even death through trampling and suffocation. Furthermore, fearful birds are more difficult to manage, show poorer growth, food conversion efficiency and egg production, and are less able to cope with challenges (Jones, 1997).

Fear is such a powerful emotion that it can inhibit behavior patterns generated by other motivational systems (Jones, 1987a, 1996). Kendrick (1992) stated that birds under constant stress do not learn well because they cannot selectively pay attention to the changes in the environment that learning tasks require. As a result, a frightened bird is less likely to express exploratory, social, feeding, and sexual behaviors (Kendrick, 1992). High underlying fearfulness is also associated with delayed maturation as well as reduced growth, food conversion, egg production, eggshell quality and plumage condition (Jones & Hughes, 1986; Hemsworth & Barnett, 1989; Mills & Faure, 1990).

Some degree of contact between humans and chickens is inevitable regardless of the production system. In most forms of animal management, there are regular periods of contact between humans and animals. Human intervention is necessary at least to monitor conditions and the health of the animals and often, to impose routine husbandry procedures. Regular interactions can result in the animals developing fear responses to humans, which can have effects on the animal's behavioral motivation. Reducing fear levels is therefore of great importance for improving the welfare of poultry kept in confinement and it appears to be at least partially remedied with environmental enrichment.

Enrichment

The term environmental enrichment refers to a variety of objects and strategies that can be used to increase the stimulus value of an animal's environment (Shepherdson, 1998; Jones, 2004; Gvaryahu *et al.,* 1989). The primary goal of enrichment is to improve the physiological and psychological well-being of captive animals. Specific goals include "keeping animals occupied, increasing the range and diversity of behavioral opportunities, and providing more stimulating and responsive environments" (Shepherdson, 1998). For any species, enrichment is unlikely to be effective unless it reliably attracts and sustains appreciable interest (Jones *et al.,* 2000), and has functional utility (Newberry, 1995). Additionally, environmental modifications that facilitate use of behavioral skills are likely to be more effective in improving welfare than a random assortment of objects (Mench, 1998).

Many agricultural animals are kept in barren environments where even the ability to turn around is prohibited (Mench & Tienhoven, 1986) and social contact may also be limited in some production systems. According to Fraser (1975), even the addition of bedding, such as wood shavings to the cages of laying hens can be seen as a significant form of enrichment under such restrictive conditions.

Environmental enrichment has been widely used in zoos and is required by the Animal Welfare Act for laboratory primates and dogs. However, there are currently no enrichment requirements for farm animals and the lack of enrichment in the environment of agricultural animals is considered one of the major causes of behavioral abnormalities. Additionally, enrichment strategies for farm animals are constrained by their economic impacts on production and when they are used, enrichment devices may be chosen for their durability and appeal to the investigator rather than any properties they have that are salient for the animal (Newberry, 1995).

Some methods of enriching the environments of captive animals include altering the social environment, nutritional environment or changing the physical and sensory environment (Newberry, 1995). The social environment may be changed by housing animals in appropriately sized or mixed sex groups or by improving animal-human interactions. Use of different feed types and provision of a larger variety of feeds may promote food searching and improve the animal's nutritional balance (Newberry, 1995; Pereira *et al.,* 1989). Altering feeding methods to reduce food-related stereotypies has been a focus of enrichment research in the past and such methods include increasing the time or skill required to extract, process or ingest food, increasing the fiber content to increase satiety, hiding food in unpredictable locations and feeding smaller quantities of feed more frequently (Chamove *et al.,* 1982; Kastelein &Wiepkema, 1989; Carlstead *et al.,* 1991; Gilloux *et al.,* 1992; Shepherdson *et al.,* 1993; Robert *et al.,* 1993; Reinhardt, 1994; Brouns *et al.,* 1994; Young *et al.,* 1994).

The physical and sensory environment for most agricultural animals in captivity is featureless and "lacking internal structure" (Newberry, 1995). This could be changed by altering the landscape with televised images, playing music or animal sounds, increasing the amount of space available and by adding varying odors or toys. Additionally, animals may benefit from a greater feeling of security through the addition of hiding places or artificial cover (Newberry, 1995). Some changes to the physical environment which may be of significance for poultry include the addition of biologically relevant features such as perches and dust bathing sites which can increase environmental complexity. Also, access to additional areas can increase opportunities for exploration (Newberry, 1993) which could be very important for animals adapted to unpredictable environments. It is important to note that not all methods for achieving environmental enrichment are appropriate or beneficial and the most effective enrichment devices are those of biological relevance to the particular species (Newberry, 1995). Environmental enrichment designs are crucial in the effort to fully address both the psychological and physiological needs of domestic animals.

Animal Cognition, Learning and Enrichment

Environmental enrichment provides greater mental stimulation and increases behavioral opportunities. Understanding an animal's cognitive abilities may therefore help to determine its psychological needs and interests with regards to its environment. Cognition refers to the mental capacity of "knowing". This knowledge is obtained when an animal senses and interacts with individuals and objects in the environment and gains knowledge about their physical properties in order to respond to and recognize them in the future. Studying cognition in farm animals can provide insight into how they perceive and interact with their environments, and thus may provide indirect benefits for their mental and physical well-being.

For example, understanding an animal's cognitive abilities may also help to determine its psychological needs. If an animal is housed in a barren environment, its psychological needs may not be met, resulting in deprivation that can cause boredom and frustration (Croney, 1999). Craig (1981) found that pigs housed in barren environments exhibited undesirable behaviors such as biting and chewing of conspecifics' ears and tails. A better understanding of an animal's behavioral needs could help prevent this undesirable situation. Further, it seems likely that if an animal has behavioral needs, it may have expectations about how the world around it works and how it can fulfill its needs. The animal must therefore rely on problem-solving, learning and memory to determine how to behave in given situations. Consequently, the study of farm animal cognition should include exploration of specific mental processes such as learning and memory to evaluate their effects on welfare (Croney, 1999).

Duncan (1987) defines learning as the "formation of new neural systems by the establishment of connections among neurons or in the increased disposition to form these connections". Farm animals are constantly presented with many learning and memory challenges. Their learning and spatial memory abilities are critical to locating important resources like food and water (Mendl *et al*., 2001).

Additionally, learning that occurs during ontogeny can have long-lasting effects on future behavior. The effects of environmental enrichment on behavior are therefore pronounced during the rearing phase (Fox & Millam, 2004). Adaptation to a new environment may be influenced by adverse effects of early rearing environments on brain development and spatial learning ability (Carughi *et al.,* 1989; Widman *et al.,* 1992). For example, animals transferred from a simple to a complex environment may have trouble locating resources like food and water. If an enriched environment is beneficial to the animal, then it follows that transfer to an environment lacking enrichment features will have adverse effects (Newberry, 1995).

"Adaptation" refers not only to evolutionary processes, but also to changes in behavior brought about during the lifetime of an individual animal by processes of learning. Consequently, learning processes should also be considered when assessing an animal's ability to adapt to and cope with a given housing system. Studies of adaptation in the past have emphasized physiological mechanisms, but it is equally important to consider the behavioral plasticity and rules underlying decisions made in captive environments (Newberry, 1995).

Because animals develop through learning or evolution a set of expectations about their environments (Wiepkema, 1987), there may be times when a mismatch occurs between animals' expectations and the situations in which they find themselves. This mismatch may subsequently result in frustration, which can motivate animals to seek a solution or to find ways to cope. Wechsler (1995) defined coping as "behavioral responses that aim at reducing the effect of aversive stimuli on fitness or physiological measures related to fitness". If the aversive situation can be removed by the coping response, this should lead to a change in the animal's assessment of the situation and cause it to alter its future behavior. As a consequence, successful coping responses will result in learning (Wechsler & Lea, 2007).

The ability of farm animals to adapt to and cope with their housing conditions is therefore likely to be influenced by their learning processes and these should be considered when designing their environments. Farm animals need to learn about specific resource patches, about what to eat, about housing equipment, about characteristics of group members, and about characteristics of humans. Further, if animals will be moved to a certain type of housing system or will have to be handled in certain ways, it may be useful to give them opportunities to learn about these features. For example, laying hens that will be kept in aviary systems during their laying period should be raised in aviary systems that allow them to use different vertical levels, thus enhancing their ability to cope with this particular housing system (Häne *et al.,* 2000). Thus, rearing animals in enriched rather than barren environments is one approach for enhancing their learning abilities and preparing them for future challenges.

Additionally, lack of predictability of and control over aspects of animals' environment can negatively impact their well-being by increasing their physiological symptoms of stress (Weiss, 1971; Wiepkema & Schouten, 1990). This has been associated with decreased productivity (de Jong *et al.,* 1996). Complex environments offer opportunities for an animal to explore, interact with and manipulate features of its environment, thus exercising greater control over its own behavior and surroundings.

The precise nature and function of exploration has always been difficult to define, but there can be little doubt that exploratory behavior provides animals with information about their environment. Cognitive models of behavior regard the ability to gather and process information as a primary motivator in the quest for survival (Wemelsfelder & Birke, 1997). Inglis (1983) proposes that information gathering and the resulting reduction of uncertainty are primary activities of animals living in variable environments. Persistent movement through an environment allows animals to acquire knowledge about the spatial and temporal relationships around them. This allows them to form expectancies, to detect novelty, and to file information into appropriate categories (Inglis, 1983). Exploratory behavior, by providing contact with the environment, can also be considered an end in itself. Animals try out varying ways of interacting with their environment when given the opportunity. However, animals in captivity live in highly structured environments where they are challenged infrequently due to the highly predictable nature of their environments. The richer the environment, the more opportunities the animal has and the more expansive its behavioral repertoire becomes (Wemelsfelder & Birke, 1997).

Effects of Enrichment on Brain development and Cognitive Processes

Environmental enrichment has been studied extensively by experimental psychologists to determine its effects on learning, social behavior, and neurophysiology (Renner & Rosenzweig, 1987). Enriched environments in these experiments, which typically utilize rodents, have often been defined as cages containing social companions. Stimulus complexity is increased by the addition of toys which are changed frequently to ensure ongoing novelty (Mench, 1998). Enrichment research in rodents has focused on the hippocampal region, including the dentate gyrus, which is intimately associated with spatial learning and memory (McNamara & Skelton, 1993). Neurogenesis in the dentate gyrus in young mice has been shown to be facilitated by enriched environments. Enrichment has also been shown to enhance memory function in various learning tasks (Renner & Rosenzweig, 1987). Enriched mice, for instance, were shown to do better on a Morris water-maze task (a test of spatial memory) than control mice in standard housing (Kempermann *et al.,* 1997).

Since morphological changes occur in regions of the brain associated with learning and memory as a result of enrichment, it follows that cognitive processes may be likewise altered with the addition of enrichment. Nilsson *et al*. (1999) found that adult rats housed under enriched conditions showed improved performance in a spatial learning test. Similarly, Williams *et al*. (2001) found that performance of mice in a Morris water maze was improved when physical enrichment of the environment was administered. In a more recent study, Leggio *et al.* (2005) conducted a radial arm and Morris water maze test and found that environmental enrichment improved performance in almost all parameters of both spatial tasks.

Additionally, studies have indicated changes in functional activity of the hippocampus of pigs housed in barren conditions when compared to pigs from enriched housing conditions (Van der Beek *et al.,* 2000). Sneddon *et al*. (2000) found that enriching pigs' rearing environment had clear influences on their ability to successfully complete two learning tasks, an operant and a maze test. The enriched pigs mastered the operant and maze task more quickly during the training phase and made fewer errors during the testing phase. In contrast, de Jong *et al*. (2000) did not find an effect of environmental conditions on the acquisition of a spatial task in pigs. However, they did find that enrichment improved long-term spatial memory in their study.

There is no research on the effects of enrichment on morphological changes in the poultry brain although there are studies in this area using food-storing birds as subjects. For example, Patel *et al*. (1997) found that birds with food storing experience had a larger amount of cell proliferation in the hippocampal ventricular zone and more total hippocampal cell and neuronal numbers than birds without experience. Gunnarsson *et al*. (2000) found that pullets that had been reared with access to perches showed a more flexible use of a more complex new test situation than pullets reared without access to perches. The authors interpret these results as indication that pullets with access to perches developed better cognitive spatial learning ability. One study looked at the effects of enrichment on learning ability in the domestic chicken (Krause *et al.,* 2006). The results indicated that chickens kept in enriched conditions (litter floor system with short term free-range access) performed significantly better in a Y-maze task than chickens without free range access. It was concluded that the increased performance was most likely due to a decrease in fearfulness as more fearful chickens take longer at the first attempt to gather information after being placed in a new environment (Krause *et al.,* 2006). Therefore, environmental enrichment reduces fear responses and improves performance on learning tasks by stimulating multiple sensory systems and exposing animals to complex spatial environments.

When presented with dynamic, stimulating environments, animals are not only given the opportunity to display a wider range of behaviors, but they may also increase their behavioral flexibility or ability to adapt to different situations. Behavioral flexibility is defined by Fagen (1982) as "the capacity of an animal to alter its behavior when faced with novel challenges". By providing an animal with the opportunity to express varied behaviors, its ability to cope with stressors and changes in the environment may be improved (Carlstead, 1996).

Additionally, providing an enriched environment can increase cerebral cortex weight, the number of glial cells and the number of dendritic branches in the visual cortex (Greenough, 1976). Environmental enrichment has also been found to speed-up or facilitate the repair of brain damage (Farrell *et al.,* 2001; Dahlqvist *et al.*, 2000; Torasdotter *et al.,* 1998; Hannigan *et al.,* 1993; Schrott *et al.,* 1992) and often results in improvement of cognitive or motor functions (Tang *et al.,* 2001; Williams *et al.,* 2001; Duffy *et al.*, 2001; Ickes *et al.,* 2000; Hoplight *et al.,* 2001; Woodcock & Richardson, 2000; Prusky *et al.,* 2000; Pham *et al.,* 1999; Xerri *et al.,* 1996). Moreover, environmental enrichment can protect against cognitive deterioration caused by stressors and aging (Young, 2003). There is increasing evidence that enrichment can improve cognitive functioning in rodents, especially in the area of spatial information processing and memory (Healy & Tovée, 1999; Blakemore & Mitchell, 1973; Tees, 1999b).

Furthermore, several reports demonstrate that lack of early experience with specific stimuli can have long-lasting effects on brain development and behavior in mammals (Inglis, 1975; Rosenzweig & Bennett, 1996). Animals kept under low sensory input levels are more likely to overreact to novel events and may find it difficult to acquire new knowledge and cope with changes in the environment (Kendrick, 1992; Jones, 1996). Therefore, keeping animals in environments that limit external stimulation and reduce the opportunities to make decisions and control the environment may engender monotony, cognitive impairment, and the development of behavioral vices (Kendrick, 1992; Mench, 1992; Jones, 1996).

Effects of Enrichment on Livestock

Investigating enrichment devices for livestock species is a growing area of research. Although pigs have received the most attention in this field, there are some studies involving dairy and beef cattle maintained in feedlots. Feedlot cattle spend the majority of their time idling and it has been hypothesized that the lack of stimulation in bare environments leads to frustrated motivation and the development of aggression and abnormal behavior (Pelley *et al.,* 1995). Cattle-brushes have been reported to be a suitable environmental enrichment device based on the percentage of animals that make use of them and on the frequency and duration of usage (Tuyttens, 2005).

Wilson *et al*. (2002) assessed several potential enrichment devices for feedlot cattle. They examined the duration and frequency of use of four enrichment devices situated in feedlot pens. The enrichment devices included two scratching/rubbing devices, one of which was moveable, and two scent devices. They found that both scratching/rubbing devices had higher frequencies and durations of use than either scent devices. Also, habituation did not take place with the scratching devices and this may be due to their facilitation of grooming behavior (Philips, 1993). Scratching devices, therefore, appear to be valuable enrichment for cattle. More recently, Westerath *et al*. (2009) found that bulls housed in barren environments performed more exploratory behavior in a novel object test (using crossed hosepipe) than bulls housed in enriched environments.

There are also several studies that have addressed enrichment for horses. Foraging enrichment shows great potential for the stabled horse, aiming to promote more natural feeding behavior. When stabled horses were provided with multiple forages in short term trials, their foraging behavior was closer to that seen in free ranging horses (Goodwin *et al.,* 2002). Thorne *et al*. (2005) showed that horses on a multiple forage diet foraged more frequently and for longer periods than horses on a single forage diet. Stereotypic weaving behavior, which is thought to be induced by social isolation, only occurred in the single forage diet. Also, results indicated that horses on a multiple forage diet expressed significant preferences for certain forages but still sampled all forages available, suggesting a preference for variety in the diet. It therefore appears that foraging enrichment of stabled horses may increase foraging behavior and decrease weaving.

A large portion of the research on enrichment with agricultural animals has been devoted to pigs housed in intensive systems. Straw is generally regarded as a valuable and functional form of enrichment for pigs (Tuyttens, 2005). The provision of straw has been linked with lower incidences of undesirable behaviors (Ruiterkamp, 1987; Lyons *et al.,* 1995; de Jong *et al.,* 1998; Kelly *et al.,* 2000; Guy *et al.,* 2002a; van de Weerd *et al.,* 2005; Scott *et al.,* 2006a; Day *et al.,* 2008) and when it is provided as bedding, increases the proportion of time pigs can spend manipulating the substrate, resulting in higher levels of activity (Arey & Franklin, 1995; Lyons *et al.,* 1995; Kelly *et al.,* 2000; Guy *et al.,* 2002a; van de Weerd *et al.,* 2005; Scott *et al.,* 2006a; Day *et al.,* 2008).

The advantages of enrichment for pig welfare are evident. Beattie *et al*. (1995) found that when the behavioral time-budgets of pigs from alternative enriched-housing with straw were compared to an unenriched group, there were differences in the levels of exploration, aggression and harmful social behaviors. Stolba & Wood-Gush (1980) presented a tire to pigs in a semi-natural, wooded environment and found that these enriched pigs reacted less strongly to the tire in comparison to pigs from three other intensive systems. They noted that with increasing barrenness of the environment, the reaction to novelty became stronger and a greater proportion of animals tested interacted with the object and sessions lasted longer.

A number of studies have also investigated whether the behavioral diversity of pigs is increased by being housed in enriched pens compared to pigs housed in barren conditions (Haskell *et al.,* 1996; Mendl *et al.,* 1997; Wemelsfelder *et al.,* 2000). Haskell *et al*. (1996) found that pigs housed in enriched pens had greater diversity of behavior when manipulating their home environment. Similarly, pigs reared in a barren environment show increased interaction with a familiar handler (Pearce *et al.,* 1989; Schouten, 1986), and this level of social interaction has been explained as a substitution for environmental stimulation (Schouten, 1986).

Environmental enrichment also appears to reduce the levels of injuries, tail-biting and lameness in pigs (Fraser *et al.,* 1986). Waran & Broom (1993) found that when piglets were provided with a metal barrier behind which they could hide, the frequency of aggressive interactions was lower. McGlone & Curtis (1985) reported that piglets provided with hiding areas in a wall in which they could stick their heads and shoulders, had shorter attack durations during the initial 30 minutes following regrouping. Ishiwata *et al*. (2002) also found that a hide box reduced agonistic behavior of weaner pigs on the first day after mixing. With such positive effects of environmental enrichment in pigs, there is growing interest in applying enrichment strategies to improve the welfare of poultry.

Effects of Enrichment on Poultry

The use of environmental enrichment presents a feasible solution for improving the welfare of poultry. Increased environmental complexity in standard poultry houses has been investigated as a means to achieve practical goals (Newberry, 1995; Wemelsfelder & Birke, 1997; Mench, 1998). The benefits of enrichment to chickens are extensive and include encouraging a more even distribution of birds in a given area (Cornetto & Estévez, 2001), reducing fear responses and stress (Jones, 1982; Nicol, 1992; Reed *et al.,* 1993; Grigor *et al.,* 1995; Bizeray *et al.,* 2002) and reducing disturbances and aggression (Cornetto *et al.,* 2002).

Environmental enrichment that increases exposure to novelty during development has been successfully employed in avian species to modulate fear responses, as evidenced by increased activity in novel environments (Fernandez-

Teruel *et al.,* 1997; Escorihuela *et al.,* 1994; Hughes & Black, 1974; Gvaryahu *et al.,* 1989; Jones & Waddington, 1992) and decreased fear responses to novel objects (Jones, 1982; Jones & Waddington, 1992). Other studies have shown that chicks reared in an environment with increased complexity, including the addition of perches (Brake *et al.,* 1994; Rose *et al.,* 1995), music (Gvaryahu *et al.,* 1989), objects such as balls, strings, or drawings on the wall (Jones, 1982; Jones & Waddington, 1992), or the addition of all three types of enrichment (Nicol, 1992), were less fearful than birds raised in a standard environment.

Similarly, regular episodes of gentle handling or the association of human contact with a food reward reduced flightiness, avoidance of humans and tonic immobility in chicks (Ginsburg *et al.,* 1974; Hughes & Black, 1976; Jones & Faure, 1981; Gross & Siegel, 1982). Jones & Waddington (1992) investigated the effects of handling and enrichment on the behavior of individually housed female chicks. Enriched chicks showed less freezing in response to a novel object placed in their home cage. They also approached the object sooner, spent more time near it, and pecked at the environment more often than did those reared in non-enriched environments. The duration of tonic immobility (T.I.) was also attenuated by environmental enrichment. Jones & Waddington's (1992) results support previous suggestions that increased environmental complexity during rearing reduces chicks' fear of unfamiliar stimuli (Candland *et al.,* 1963; Jones, 1982, 1986a). Their results also indicate that environmental enrichment may alleviate fear of human beings, possibly by reducing general, non-specific fearfulness.

Grigor *et al*. (1995) found that exposure to an outside area reduced fear in birds with regular human handling and outdoor exposure. Regular handling alone did not significantly reduce birds' fear levels, as measured by tonic immobility, nor did it increase birds' willingness to use the unfamiliar outside area, as measured by emergence latencies and the amount of time spent in each designated area. Murphy & Duncan (1978) examined the effects of different degrees of human contact during rearing on subsequent reactions of hens towards humans. Birds with no human contact displayed greater withdrawal than birds which had previous contact with humans. Similarly, regularly handled growers and pullets displayed less avoidance behavior than non-handled birds (Hughes & Black, 1976).

Several other beneficial consequences of regular handling and environmental enrichment regimes for birds have been noted. For example, environmental enrichment improved growth and food conversion in layer and broiler chickens (Thompson, 1976; Jones, 1996; Jones *et al.,* 1980; Jones & Hughes, 1981; Gross & Siegel, 1982; Collins & Siegel, 1987; Gvaryahu *et al.,* 1989). Furthermore, environmental enrichment has been shown to reduce bird mortality and improve performance (Jones, 1996).

Novel objects can also be effective forms of environmental enrichment. Newberry (1999) showed that space containing novel objects or supplementary resources was of greater value to chickens than empty space, and this form of enrichment had no adverse effects on production traits. Broiler chickens readily moved from their home pens through a gate into a nearby area when those areas contained novel objects that were changed daily (Newberry, 1999). Chickens will actively seek stimulation (Mench, 1994; Jones, 1996) and the opportunity to engage in foraging and exploratory behaviors is considered particularly important to them (Appleby *et al.,* 1992; Rogers, 1995; Newberry, 1999). For example, both chicks and adult hens readily investigated and manipulated non-food as well as food related items (Gvaryahu *et al.,* 1994; Huber-Eicher & Wechsler, 1998; Jones & Carmichael, 1999a). Despite this, intensively housed birds are often reared in invariant environments that minimize the opportunities for exploration. Environmental impoverishment such as this can compromise the birds' welfare by reducing productivity (Appleby *et al.,* 1992; Mench, 1992; Jones, 1996, 1997; Wemelsfelder & Birke, 1997), increasing fearfulness, feather pecking, and cognitive impairment.

Providing enrichment may also decrease the level of stress (Jones *et al.,* 1980; Jones & Waddington, 1992; Nicol, 1992), which has been shown to have negative consequences for reproductive function in poultry. It appears that environmental enrichment may not only benefit welfare by providing birds with increased behavioral opportunities and greater control over their environment, but it can also positively affect farmer returns.

The availability of cover is an important feature of natural environments, providing birds with the opportunity to hide from predators and aggressive conspecifics (Elton, 1939). Cover also provides a way to reduce inter-animal communication by reducing visual contact between conspecifics (Estep & Baker, 1991). In a captive environment, the presence of cover has been shown to reduce aggression in chickens (Estévez *et al.,* 1998). Several studies have examined the effect of vertical cover panels on poultry behavior. Leon & Estévez (2008) investigated the effects of environmental enrichment by providing cover panels made from a PVC pipe frame and mesh covering in commercial broiler houses. Improved reproductive performance, hatchability, and egg production, were noted as a result of using the cover panels (Leon & Estévez, 2008). In broiler production, birds tend to favor the walls and corners and in the event of a fear response, they often pile on top of each other in these areas, sometimes suffocating the birds on the bottom. Cornetto *et al*. (2002) showed that the provision of artificial cover to pen centers can reduce the frequency of such interactions between broiler birds.

Just as providing cover has beneficial effects on poultry welfare, so too does the provision of perches. Providing perches increases the environmental complexity of the poultry house, which may be important to the overall well-being of birds (Newberry, 1995). Perches also offer increased utilization of the vertical space (McBride, 1970). Because birds often rest around the perimeter of the house (Newberry & Hall, 1990), perches placed in the center of the space could increase the usage of this area, much like what happens when broilers are offered cover in a central area (Newberry & Shackleton, 1997). Perching and roosting high off the ground is an important predator defense mechanism for ground-dwelling birds. In an aviary system, the ability to use perches is important for chickens as food and water may be provided off the ground (Gunnarsson *et al.,* 2000). In most commercial settings, however, the ability to learn how to move between different levels is not available as chicks are reared solely in horizontal space. Additionally, young chicks reared without access to perches are less adept at using them later in life (Appleby & Duncan, 1989). Perches may influence the behavior of hens by either increasing muscle mass or bone strength or by helping to develop the cognitive skills necessary for moving around in three-dimensional space (Gunnarsson *et al.,* 2000).

Gunnarsson *et al*. (2000) investigated the effects of perches on spatial skills in laying hens and found that birds reared with perches differed significantly from birds reared without them in their ability to reach food presented on high tiers (80 cm and 160 cm high) versus low ones. These results suggest that rearing without early access to perches seems to impair the cognitive spatial skills of laying hens which dictates how easily birds move through housing systems like aviaries (Gunnarsson *et al.,* 2000). Similarly, Bizeray *et al*. (2002) found that increasing the complexity of the environment with wooden barriers modified the time budgets and the organization of activity in meat-type chickens. They observed that perching behavior was highly stimulated by the presence of the barriers and suggest that this may have beneficial effects on animal welfare by stimulating natural behavior and increasing a variety of motor patterns that could reduce certain skeletal disorders.

The effects of enrichment on reducing feather pecking have also been examined. Feather pecking remains a serious problem in commercial egg production. It has been argued that feather pecking occurs as a result of misdirected pecking, so a possible solution would be to increase the likelihood that such pecking was targeted at other objects in the environment rather than at the feathers of conspecifics. Feather pecking was reduced when turkeys were provided with a variety of objects such as screws, chains and ropes (Sherwin *et al.,* 1999), and when various foraging materials such as straw, blocks, sand, and wood shavings were placed in pens of chickens (Huber-Eicher & Wechsler, 1997, 1998; Johnsen *et al.,* 1998; Huber-Eicher & Sebo, 2001 b). A static device made of strands of white string was readily pecked at by chickens of various strains and ages (Jones *et al.*, 1998; Jones *et al.,* 2000; Jones, 2001) suggesting that the string device could exert beneficial effects. McAdie *et al*. (2005) found that incorporating string devices in the home pens of chicks from a line known to show high levels of feather pecking decreased the expression of both severe and gentle feather pecking behavior. Additionally, Guy *et al*. (2001) found that adding a yellow tennis ball, a blue rubber ball, and a blue ring to the food trough at the front of laying hens' cages improved feather condition by way of reducing feather pecking.

In addition to feather pecking, fearfulness is a large concern for poultry producers. Fear competes with and exerts progressively inhibitory effects on behavior patterns motivated by other systems (Hogan, 1965; Gray, 1987; Jones, 1987a). The deleterious consequences of heightened fear on poultry welfare and performance are diverse. Indeed, chickens are often frightened by sudden changes in their environment and may panic and show violent escape responses when exposed to human beings (Jones, 1989a). At a practical level, if flightiness can be reduced with regular positive exposure to humans, it would make sense to employ this type of environmental enrichment. Environmental enrichment and regular human exposure are therefore powerful tools and their independent or integrated application may alleviate underlying fearfulness.

Poultry Cognition

As has been demonstrated for other species, the ability of domestic fowl to adapt to their adult housing conditions may depend in part on their early experiences or rearing conditions. For example, a greater complexity of rearing conditions may lead to reduced reactions to subsequent environmental change (Broom, 1980). Animals gradually learn the characteristics of their environment which forms the basis for comparisons when the environment changes (Broom, 1969). Environmental enrichment provides extra stimulation in the home environment, which may lead to the development of a more complex environmental model, thereby enhancing the animals' ability to adapt to novelty.

It has been argued that the study of cognition can help enlighten discussions about the welfare and treatment of animals, in that knowledge in the area of cognition can help identify situations that could lead to pain, boredom and frustration (Allen, 1998). Information about the cognitive abilities of chickens is important when assessing chicken welfare as it can help to identify situations in which the birds may suffer (Nicol, 2004). Understanding poultry cognition can also help in the development of improved methods of welfare assessment and the design of housing that better meets the bird's behavioral and mental needs. Research on chicken cognition is relatively sparse, but recent work has looked at their spatial ability, time perception, and social learning (Nicol, 2004). The ability to adapt to new situations is extremely important in commercial strains of chickens that are handled, moved around, and presented with sometimes aversive and novel stimuli. As legislation is proposed to ban the use of battery cages and other forms of confinement housing for laying hens, it is important to understand how hens will be impacted by and able to cope with alternative housing systems and management practices. There are still many unanswered questions with regards to environmental enrichment in poultry, including how to effectively use enrichment to meet the specific behavioral needs of poultry, as well as how enrichment affects cognitive abilities such as problem-solving, spatial memory and learning.

Consequently, the objective of this study is to determine the effects of early rearing environment on learning ability, behavior, and productivity in laying hens. By rearing birds in enriched versus unenriched environments, it is hypothesized the enriched birds will perform better than unenriched birds in all behavior and learning tasks presented. Such findings would provide evidence that enrichment should be considered for commercial situations to increase the adaptability of laying hens to changes in their environments.

Chapter 3
Materials and Methods

Pilot Study

A pilot study was conducted beginning June 26, 2008 (ACUP # 3743).

Subjects

Forty eight 18 month old Lohmann brown laying hens were obtained from a study which was terminating. All birds were originally maintained in individual cages in 200 house at the Oregon State Poultry Unit. Prior to pilot testing, birds were randomly assigned to one of two treatment groups, enriched and unenriched, with one replicate of each treatment for a total of four groups. The birds were leg banded with colored and numbered plastic bandettes before they were placed into rooms in 100 house measuring 2.7 m by 3.9 m in groups of twelve.

Treatments and diet

The unenriched rooms contained a hanging feeder, a nipple line drinker and wood shavings for litter. The enriched rooms contained all of the above husbandry equipment as well as a wooden perch (97 cm x 9.5 cm x 13 cm), a nest box, and a vertical cover panel constructed of PVC and wire mesh (55 cm x 106 cm). The birds were fed Purina Mills Layena Sunfresh Crumble. Food and water were provided *ad libitum*. Birds were maintained on a 16 hour light cycle.

Measures

All birds were feather scored using the scoring method of Bilčík & Keeling (1999). They were then removed from their cages and placed in open pens in their assigned groups of twelve in a staggered manner in order to observe their behavior for twelve hours immediately following the transition to the new environment. Observations were also done on the second day in the new environment. Continuous sampling of all behaviors was used. Behaviors recorded included eating, drinking, nesting, perching, use of cover panels, dustbathing, preening, feather pecking, and aggressive pecks to the head of another bird. Eggs were also collected twice daily and the number of eggs collected per room was recorded.

Testing

Video recording

Video recording was done to verify all live observations. The equipment used included two Sony Handycam Camcorders (DCR-SR85, Japan) with a Sunpak 0.5x wide angle converter lens (CAL-1030KI). The camcorder was mounted onto a Sunpak platinum plus Ultra 7500TM tripod so as to afford the greatest coverage of the room. All recordings utilized the same tripod setup and camera angles. Video was uploaded onto a Dell Inspiron 1521 laptop computer using the Sony Picture Motion Browser software that accompanied the camcorder and was saved to an external hard drive before being transferred to DVD. All video footage was uploaded and transferred to DVD's the same day as testing.

Novel water containers

After two weeks in the open pens, all groups were tested on their response to a novel water container. Their nipple line drinker was raised to prevent access to it. Three one-gallon plastic jug drinkers were placed under the water line equidistance from one another atop 3 cinder blocks (20.3 cm high X 20.3 cm deep X 40.6 cm wide). Live and video observations were made for eleven hours immediately after placement of the drinkers to determine how quickly birds found and successfully drank from the novel drinker. After eleven hours, the three jug drinkers and cinder blocks were removed and the nipple line was lowered. Drinking behavior of each bird within the room was then recorded for an additional hour.

Novel food

A novel food test was done twenty days after birds were re-homed to the open floor pens. Birds in all four rooms were tested on the same day within a two hour period in random order. Three cut up egg flats containing 6 super worms (each measuring 5 cm in length) were randomly placed in the home pen. Latency to approach and consume the mealworms was recorded and verified using video recordings.

Barrier test

A barrier test was conducted 21 days post-placement to assess the birds' spatial reasoning skills. Typically, such tests require an animal to navigate around an obstacle in order to reach a target such as a food reward or conspecific (Wynne, 2001). Feed was removed four hours prior to testing. The barrier used in this experiment was transparent and made of PVC and wire mesh measuring 1.016 m X 1.016 m. Nine birds were randomly selected from each room to be tested. All nine birds per room were tested individually one after another, and the order of rooms tested was randomized. The test began by gently hand-carrying the test bird into the test room and placing her behind the barrier at its center. The target was Layena crumbles feed placed in a food container that all birds had experience with prior to testing. The latency of each bird to navigate the barrier and eat was recorded and validated using video recordings. A maximum testing time of five minutes was allowed before each bird was returned to her home pen. Video recording was done to verify live observations.

Thesis Experiment

Thesis experiments began on August 14, 2008. An amendment was made to the existing ACUP to add new subject birds.

Subjects

One hundred and seventeen day-old female ISA brown layer chicks were obtained from Featherland Farms in Coburg, OR (120 birds were ordered, however hatchery miscount resulted in only 117 birds arriving). All birds were housed in 100 house at the Oregon State University Poultry Unit.

Chicks were leg banded upon arrival at the unit (day zero) with a size four colored and numbered plastic bandette on the right leg. At four weeks of age the leg bands were replaced with size 6 colored and numbered plastic bandettes. Leg bands were again changed when the birds were six, eight and sixteen weeks of age using size 9, 11 and 12 leg bands, respectively. The birds were not beak-trimmed.

Housing

Six rooms measuring 2.7 m X 3.9 m were utilized for bird housing and one additional room was used for testing. Each room, excluding the test room, contained a 0.10 m layer of wood shavings for litter, a gas brooder, a hanging feeder and a nipple line drinker. The gas brooder hung 0.762 m from the ground and was set to level 3 (low) so that the room was maintained at a temperature between 26°C and 32°C. As the birds grew adult feathers, the brooder was lowered to level 1. Each room was also equipped with an exhaust fan that turned on whenever the temperature of the room exceeded 29°C and ran for one minute of a five minute cycle. The feeder was placed on the ground initially and then raised as the chicks aged. The water line was hung 0.10 m from the ground and was raised as the birds got older. For the first two weeks, two egg flats measuring 30 cm X 30 cm filled with grain were placed in each room.

Feed

To ensure that the location of food was known, all birds were placed on top of the grain on day zero. Chicks were also shown how to drink from the nipple line on day zero. Food and water were provided *ad libitum*. All chicks were fed Purina Mills Flock Raiser Sunfresh Crumble for the first four weeks and then fed Purina Mills Start and Grow Sunfresh Crumble. When birds reached 10% lay, as measured by total number of eggs divided by total number of birds (12 eggs total in this experiment), they were transitioned to Purina Mills Layena Sunfresh Crumble over the course of four days and remained on this ration for the rest of the experiment.

Lighting

All rooms had a light level between 30 and 40 lux. Chicks were kept on a 24 hour light cycle upon arrival to the unit (day zero). The light cycle was adjusted as the birds aged. A detailed description of the light cycle is presented in Table 3.1.

Treatment groups

Birds were randomly allocated to one of two treatment groups (enriched vs. unenriched) with each room containing one treatment group consisting of 20 chicks. There were three replicates of each treatment for a total of 60 birds per treatment. Due to uneven bird numbers upon arrival, one unenriched room had 17 birds. Additionally, over the course of the rearing period, two birds had to be humanely euthanized leaving 115 for subsequent testing.

The unenriched rooms contained only the previously mentioned rearing equipment. The enriched rooms were intended to provide physical, visual, auditory, tactile and nutritional enrichment. The enriched rooms contained two perches, three live plants for cover, a dustbathing box, two hanging party decorations and hidden mealworms measuring 2.54 cm in length. Also, classical music ("Beethoven: Piano Sonatas #8-10, 13 & 14") was played for eight hours daily.

Physical enrichment

Each wooden perch that was initially used measured 61 cm long X 7.6 cm high. When the birds were 10 weeks old, larger perches measuring 63 cm long X 47 cm high were substituted for the smaller ones. The dust-bathing box was a beige plastic cat litter box measuring 48 cm long X 33 cm wide X 15 cm deep and contained 1½ 50-lb bags of Premium Play Sand (Quikrete, Atlanta, GA). The box was placed along the center of the back wall of the room. Two types of grass plants were used for cover. The first was a single Carex Flagellifera Bronzita sedge perennial grass. Two All Gold Japanese Forest grasses were also used. Each plant was placed in an eight inch diameter orange plastic pot placed 15 cm from each other in a semicircle. Grasses were switched out weekly to increase longevity. Due to a change in season, the Japanese grasses could not be provided after the birds reached nine weeks of age. Instead, two of the plant pots were filled with pasture grass hay (Timothy hay and fescue mix) that was fanned out to resemble the structure of the Japanese grasses. When birds were 15 weeks of age, the plants and hay were removed and replaced with a hay bale (47 cm wide X 110 cm long).

Visual enrichment

Visual enrichment was provided in the form of two hanging party decorations with streamers (Greenbrier International INC., Chesapeake, VA). The first was a green, gold, and silver metallic palm tree with large green hanging leaves that hung above the streamer section. The tree hung from the ceiling by string allowing for 76.2 cm of space between the bottom of the metallic streamers and the ground (Figure 1). The second was a "happy birthday" wind waver with metallic blue and silver cutouts (Figure 1). It was also suspended from the ceiling in the same manner at the same height as the first. As the birds aged, the visual enrichment was raised so as to prevent them from physically interacting with the streamers.

Tactile enrichment

Enriched birds were handled daily for the first four days by picking each bird up and gently stroking her from head to tail. It was noted on day four that the handling appeared to be somewhat aversive to the chicks, so it was stopped. Instead, starting on day five, the experimenter sat quietly in the room with her legs outstretched for a period of fifteen minutes. For the first two weeks, birds were rewarded with mealworms for approaching the experimenter. When the birds reached 14 weeks of age, the time spent in the room was reduced from 15 minutes to 5 minutes to minimize inappropriate interactions (pecking at and climbing on the experimenter).

Nutritional enrichment

Beginning on day four, six mealworms were placed on top of the grain in the bird feeder and on top of two egg flats placed in the enriched pens once daily for two weeks. Starting on day ten, four small cut out egg flats containing a random number of mealworms each (20 mealworms total) were placed randomly throughout the enriched pens daily. The number of mealworms eaten and the patches that were depleted were recorded. By day 29, small pieces of cheesecloth were used to cover two randomly chosen egg cartons. When the birds were 10 weeks old, an additional egg carton was added and the number of mealworms given was increased to 45 per enriched room.

Auditory enrichment

Auditory enrichment in the form of classical music was played to the birds for eight hours a day. The album “Beethoven: Piano Sonatas #8-10, 13 & 14” was played on a continuous loop on an Apple iPod using Sony 2.0 Active Multimedia Speakers. The speakers remained on full volume and the iPod volume was 1/2 full volume. The speakers were mounted 1.83 m off the ground in the back corner of each room close to the power outlet on a triangular section of plywood.

The chicks were reared in their respective rooms for six weeks. At the end of the 6 week rearing period, testing began and lasted approximately 10 weeks.

Testing

A series of experiments were conducted to assess fearfulness towards humans and novel objects. Experiments to assess spatial navigation ability, learning ability and behavior were also conducted. All tests were video recorded using the same video equipment used in the pilot study to verify live observations. For tests in the novel pen, one camera was mounted inside the room in the far right corner 1.83 m off the ground.

Familiar Human Approach Test in home pen

In order to assess fearfulness of familiar humans, a human approach tests was conducted with a familiar handler in a familiar environment.

Birds were tested in their home pens every two weeks for the 6 week rearing period. At the beginning of testing, a familiar experimenter (the same person who provided tactile enrichment) opened the pen door, walked into the room and sat cross-legged with her back against the floor board secured just inside the doorway. Distances of 0.5 m and 1.0 m were marked on the walls of the pens prior to testing. Latency to approach the experimenter, the number of birds to approach, and the duration of time spent within these distances relative to the handler was recorded. Testing concluded after a 10 minute period at which point the experimenter quietly rose and exited the room. Video recording was done to verify the live observations.

Novel Human Approach Test in home pen

In order to assess fearfulness of novel handlers, two human approach tests were conducted with novel male experimenters.

Birds were tested in their home pens with an unfamiliar male experimenter. Distances of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 meters were marked on the wall of the test room prior to testing. The test began with the experimenter rapidly opening the pen door. The flight distances of the birds were recorded. The experimenter then stepped inside the door and stood in the closest right corner, 25 cm from the door itself. The number of birds to approach the experimenter, latency of first bird to approach, and the distance at which the closest and furthest bird approached was recorded. The test ended after a 3 minute period.

A second novel human approach test was conducted one week following the first in which a new experimenter entered the room and stood 1.5 m along the right side wall. The number of birds to approach, the latency of the first bird to approach, and the distance of the closest and furthest bird were recorded. The test ended after a 3 minute period. Video recording was done to verify live observations.

Novel and Familiar Human Approach Test in Novel Pen

In order to assess fearfulness of novelty, a human approach test was conducted with a familiar and an unfamiliar handler in a novel environment.

Birds were tested in a novel pen with a familiar handler and then with an unfamiliar handler. Ten birds per room were tested with the unfamiliar handler and the remaining birds per room were tested with the familiar handler. The order of pens tested as well as the handler order was randomized. Distances of 0.5, 1.0, 1.5, 2.0, 2.5

and 3.0 meters were marked out on the walls prior to testing. Birds were given an adjustment period of two minutes once placed in the novel pen. The test began when either the familiar or unfamiliar handler (depending on the test) entered the room and walked to the back right corner and turned 180° to face the birds. Latency to approach, the number of birds to approach and the closest distance of approach were recorded. The test ended after a five minute period at which point the handler exited the room. Video recording was done to verify the live observations.

Novel Food and Water Container Test

To assess the birds' fearfulness of novelty, a novel food and water container test was conducted. This novelty test also assessed the birds' ability to locate essential resources when presented in different ways.

Feed was pulled 12 hours in advance of testing. Birds were randomly tested over a two day period in their home pens. Food and water were presented in novel containers (two 1-gallon plastic jug-drinkers and four 10 cm in diameter medium sized blue plastic dog bowls per pen). To begin, the birds were quietly corralled into a corner of the room using a free standing PVC and mesh horizontal panel (55 cm X 106 cm) to avoid distress. Once birds were corralled, a three minute adjustment period began. During the adjustment period, food and water was placed in a diamond configuration (Figure 2) within the room. After the three minute adjustment period, birds were released from the corral at which point testing began. The latency of the first bird to find food and water and the numbers of birds that ate and drank within the allotted 60 minutes was recorded. Video recordings were done to verify the live observations.

Barrier Test *– see Figure 3 for detailed diagram*

Seven birds per pen were tested. The barrier was made up of a mesh screen attached to a wood frame which measured 186 cm long X 122 cm high. The screen was clamped to a piece of plywood (81.5 cm wide X 122 cm high) attached to the right side wall 122 cm away from the back wall. There was a 71 cm space between the left side wall and the end of the mesh barrier. The target the birds were to move toward consisted of three pen-mates, "companion birds" (from each individual pen) corralled in a plastic exercise (X) pen designed for use with dogs. The companion birds were placed in the holding pen (80 cm X 90 cm) located in the left corner furthest away from the starting point. Each bird was gently hand-carried into the test area by a familiar handler and placed either in the x-pen if it served as a companion or beneath an upside down silver circular mesh laundry hamper measuring 44 cm in diameter and 50 cm tall if it was a test bird. The companion birds were given a five minute adjustment period once inside the x-pen and each test bird was given a five minute adjustment period when inside the hamper. It was noted after 21 trials that birds were becoming agitated at four minutes under the hamper, so the adjustment time was reduced to three minutes. After the adjustment period, the hamper was slowly lifted and placed behind the plywood barrier (122 cm long X 82 cm high) which housed the second experimenter. When the hamper was raised, testing began and lasted for 5 minutes. Latency of each bird to navigate around the barrier and come within 0.5 meters of the x-pen was recorded. Video recording was done to verify the live observations.

Foraging Test *– See Figure 4 for detailed diagram.*

The hanging feeder from each home pen was removed 12 hours prior to testing. A red feed bowl containing 0.9 kg of feed remained inside the pen. Three hay bales were placed in pre-determined positions within the test room. Nine food caches were placed throughout the test environment (same location for every pen) in the blue dog dishes used for the novel container test. The goal was to have three low value food caches (the birds' regular grain) that were easily reachable, three medium value food caches (popcorn mixed in with grain) which were harder to reach, and three high value food caches (mealworms) in more locations that were more difficult to access as they were placed on top of hay bales throughout the room. The location of the highest value caches was also marked with small, yellow construction mapping flags to assess the birds' ability to use visual cues to locate resources. Additionally, a single 1-gallon plastic jug drinker was placed within the environment. Ten birds per room were tested. Birds were placed inside a plastic x-pen (80 cm X 90 cm) for a two minute adjustment period at which point the x-pen was removed and testing began. Testing lasted 20 minutes. Latency of the first bird to eat, latency of the first bird to drink, number of birds that foraged, and number of caches visited were recorded. The amount of food that was consumed was also recorded. Also, the number of vertical investigations (defined as birds stretching their necks up while looking for high value caches or seeking out other high value caches once on top of a hay bale), and the number and duration of bird clusters during testing, (defined as 4 or more birds grouped together for 3 or more seconds), were video-recorded. Video recording was also done to verify the live observations.

When testing was completed, the birds were maintained in their respective rooms for 27 weeks.

Additional measures

In addition to cognitive tests, some production measures were recorded. The date of first lay was recorded. The number of eggs laid within each room and the weights of individual eggs was recorded for a period of 13 weeks. Nest boxes were added to all rooms to prevent vent pecking during laying. In addition, hay bales were introduced to the enriched rooms to mitigate aggression as per the findings of Huber-Eicher & Wechsler (1998). Aggressive encounters between birds was also recorded via once weekly 20-minute scan samples for the two weeks prior to lay in order to establish a baseline of aggression. When birds reached 90% lay, aggressive encounters were recorded once weekly for three weeks via 20-minute scan sample. Bird weights were also recorded every two months in addition to feather scoring at the last weighing using the methods of Bilčík & Keeling (1999).

Statistical Analysis

All data was analyzed using the statistical program SAS™. An exact Wilcoxon rank sum test was used to analyze the familiar human approach test with regards to the number of birds that approached. An exact Wilcoxon rank sum test was used because the data was non-parametric and this test is robust against small sample size and violations of normality. The latency of the first bird to approach the handler was analyzed using a Kaplan-Meier Estimates of survival function. Both the number of birds to approach the handler and the latency of first bird to approach over each of the three trials was analyzed using a generalized linear model (GLM). The novel human approach test, the familiar and novel human approach test, the novel container test, and the foraging test data were analyzed using an exact Wilcoxon rank sum test. As the barrier test data included "time-outs", it was censored data and required a Kaplan-Meier Estimates of survival function for analysis.

Egg numbers and weights were averaged over one-week periods and analyzed using a repeated measures generalized linear model. The numbers of eggs found in the top tier of the nest box were also analyzed using a generalized linear model and eggs numbers found on the floor and number of those that were broken were analyzed using an exact Wilcoxon rank sum test. Additionally, aggressive encounters over three observation periods were analyzed using a Wilcoxon rank sum test. Finally, bird weights were analyzed using a repeated measure generalized linear model and the distribution of feather scores for each treatment group was analyzed using a chi-square test.

Table 3.1 – Light program for ISA Brown Layers

Date	**Hours of Light**
August 15 – 17	23
August 18 – 21	22
August 22 – 28	20
August 29 – Sept. 4	19
Sept. 5 – 18	18
Sept. 19 – Oct. 2	17
Oct. 3 – 16	16
Oct. 17 – 30	15
Oct. 31 – Nov. 13	14
Nov. 14 – 20	13 ½
Nov. 21 – 27	13
Nov. 28 – Dec 18	12
At 5 % lay	14
At 35 % lay	15
At 60% lay	16

Figure 1 – Photograph of visual enrichment

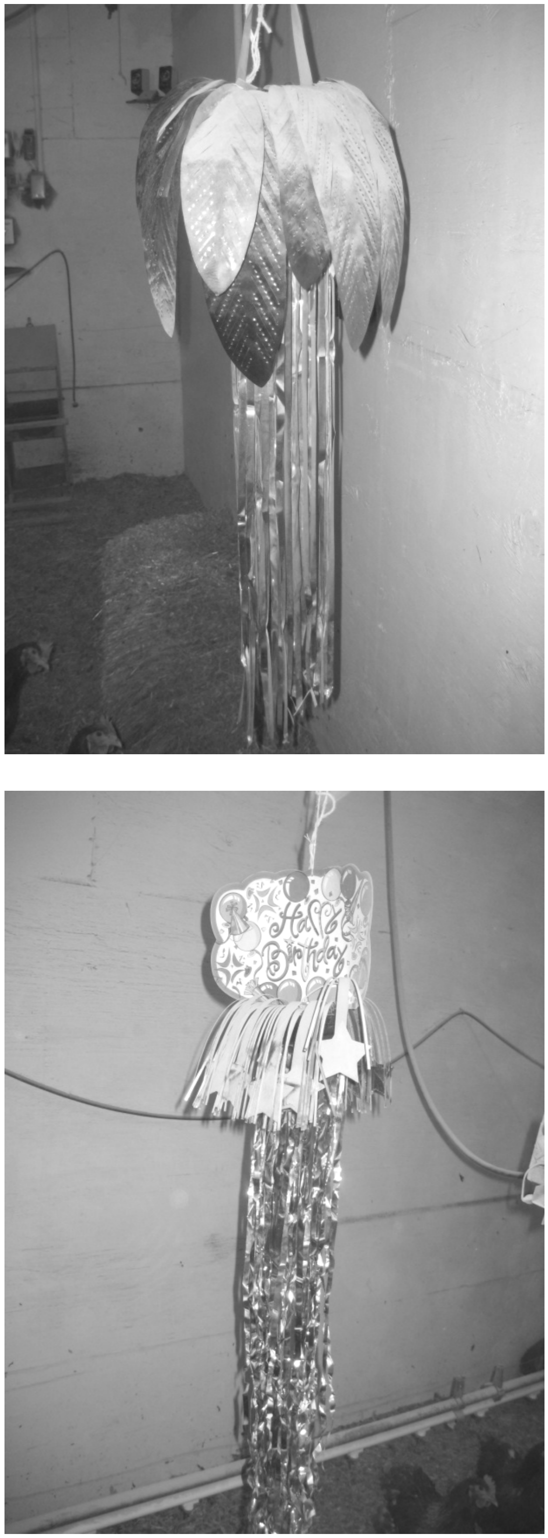


Figure 2 – Diagram and photograph of novel food and water container test set-up

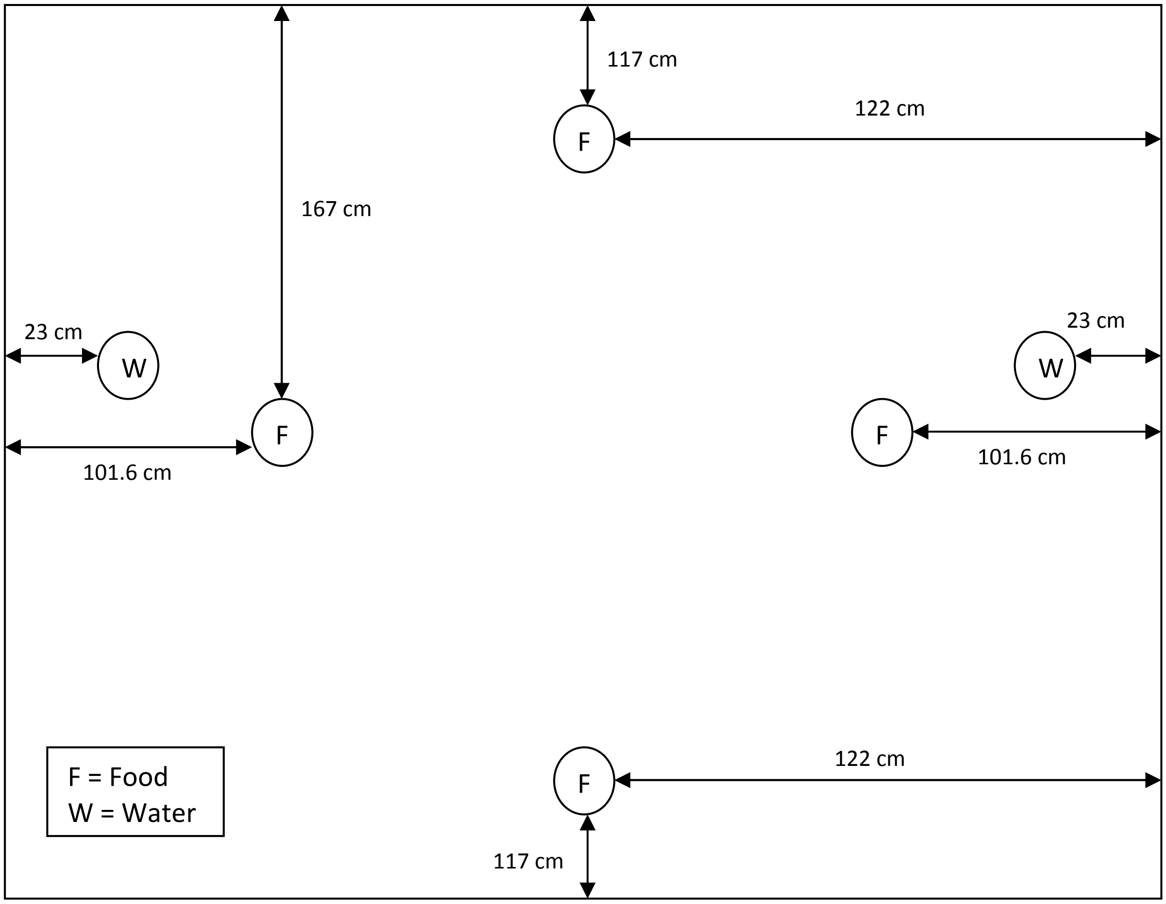


Figure 3 – Diagram of barrier test set-up

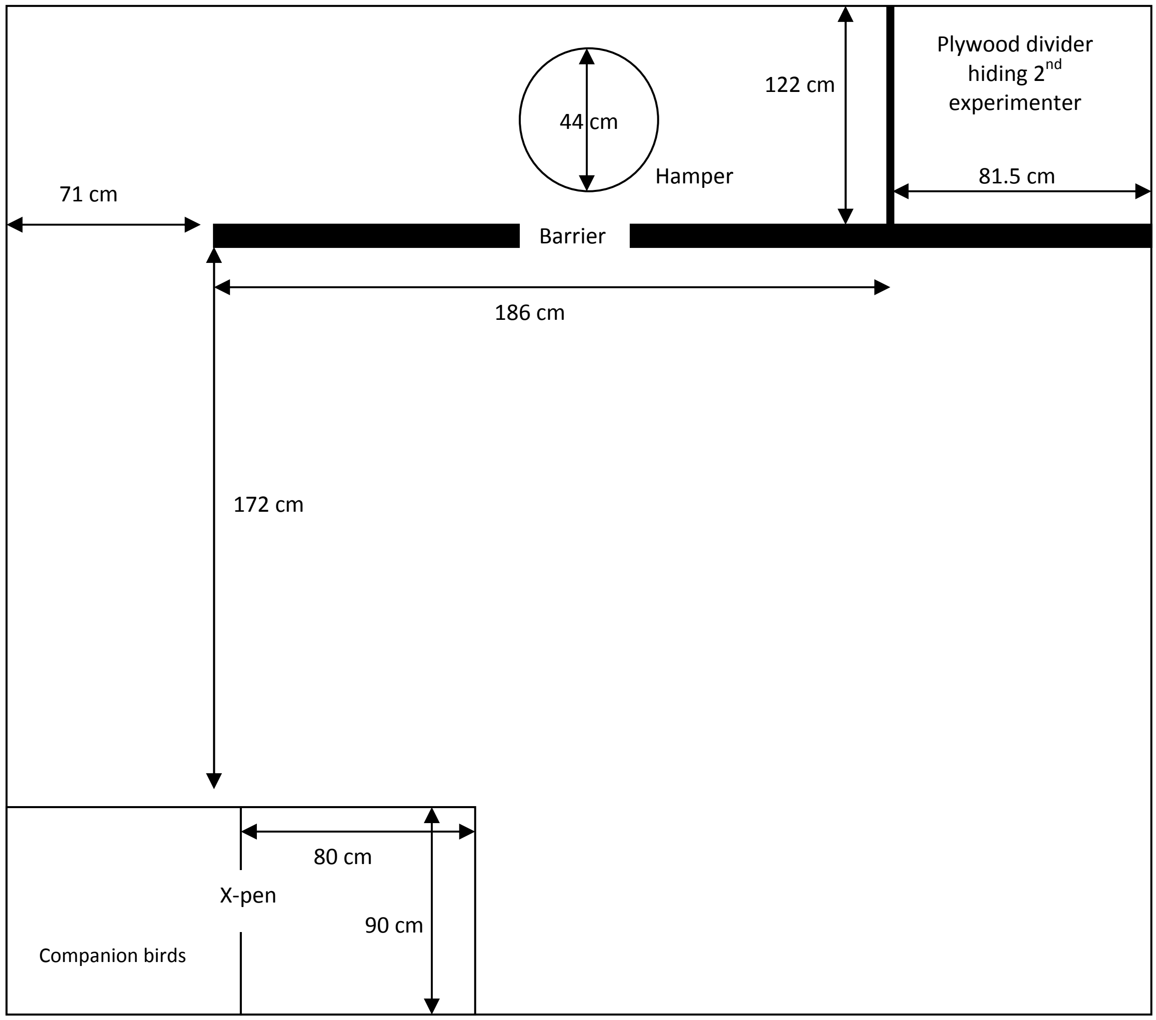
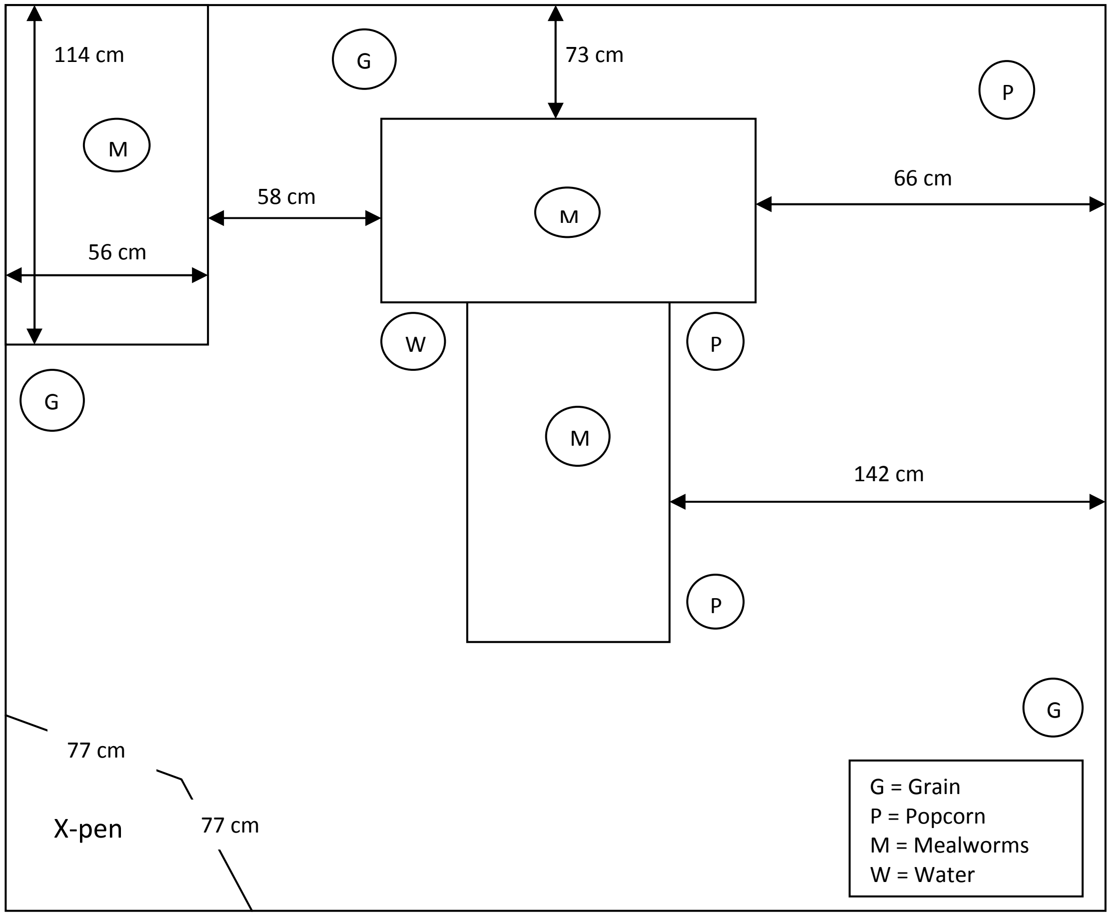


Figure 4 – Diagram and photograph of foraging test set-up



Chapter 4
Results

Familiar Human Approach test in home pen

None of the unenriched birds approached the familiar handler in the first trial at two weeks of age or in the second trial at four weeks of age (Figure 5). There was a significant difference between the enriched and unenriched treatment with regards to the number of birds that approached within 0.5 meters of the familiar experimenter at two weeks (one-sided p-value = 0.05) and at four weeks of age (one-sided p-value = 0.05). At six weeks of age there was no longer a significant difference between treatment groups (one-sided p-value = 0.35).

With regards to the latency to approach the familiar handler, there was a significant difference between treatment groups at two and four weeks (p-value = 0.01 and 0.01) but not six weeks of age (one-sided p-value 0.1). The enriched birds were faster to approach the familiar handler in the first and second trials when compared to the unenriched birds. However, there was no difference between the enriched and unenriched birds in the third trial (Figure 6).

Additionally, there was a significant effect of treatment over the three trials with regards to the number of birds to approach (p-value = 0.01). There was also a significant effect of treatment with regards to the latency of first bird to approach (p-value = 0.0057).

Novel human approach test in home pen

There was no significant difference between the enriched and unenriched treatment with regards to the number of birds that approached the unfamiliar handler in trial 1 (one-sided p-value = 0.15). There was also no significant difference between the enriched and unenriched groups with regards to latency of the first bird to approach the unfamiliar handler (one-sided p-value = 0.35), with regards to closest distance to approach (p-value = 1.0), or furthest distance to approach (one-sided p-value = 0.5). Additionally, fifteen percent of unenriched birds explored whereas 22% enriched birds explored and this difference approached significance (p-value = 0.09). Similarly, in trial two, there was no significant difference between treatment groups with regards to number of birds to approach (one-sided p-value = 0.4), closest distance to approach (one-sided p-value = 1.0) and furthest distance (one-sided p-value = 1.0). There was, however, a significant difference between the enriched and unenriched birds with regards to latency of first bird to approach the unfamiliar handler (one-sided p-value = 0.05). The unenriched birds were faster to approach the unfamiliar handler than the enriched birds (Table 4.1).

Novel and familiar human approach test in novel pen

There was a marginally significant difference between treatment groups with regards to the closest distance at which the birds approached (one-sided p-value = 0.06) but not between the two handlers (one-sided p-value = 0.42) (Table 4.2). The enriched birds approached at closer distances for both the familiar and unfamiliar handler when compared to the unenriched birds. There was no significant difference between treatment groups with regards to the number of birds that approached (one-sided p-value = 0.26) or the latency of first bird to approach (one-sided p-value = 0.23). There was also no significant difference in the number of birds that approached or the latency of first bird to approach between the different handlers (one-sided p-value = 0.21 and 0.51 respectively).

Novel food and water container test

The enriched birds were no faster to drink or eat from the novel containers than the unenriched birds (Figure 7). There was no significant difference between the unenriched and enriched birds in the latency to eat (p-value = 0.3), latency to drink (p-value = 0.5), number of birds to eat (p-value = 0.5), or the number of birds to drink (p-value = 0.3). In fact, one group of enriched birds never drank from the novel drinker in the allotted sixty minutes (Table 4.3).

Barrier test

There was no significant difference between treatment groups in how quickly the birds navigated a barrier to reach the goal object (p-value = 0.47).

Foraging test

There was a significant difference in the number of patches visited (one-sided p-value = 0.05) and in the number of vertical investigations (one-sided p-value = 0.05). The enriched birds visited more patches (Figure 8) and showed more vertical investigations than the unenriched birds (Figure 9). However, there was no significant difference between treatment groups in the latency to eat (one-sided p-value = 0.25) or in the latency to drink (one-sided p-value = 0.2). There was no significant difference between the enriched and unenriched birds with regards to frequency of clusters (p-value = 0.15) or in the longest duration of clustering between treatment groups (one-sided p-value = 0.15).

Additional measures

There was a significant difference between treatments in the number of eggs that were broken (p-value = 0.05) and the enriched birds broke more eggs than the unenriched birds (Figure 10). There was a marginally significant difference between the enriched and unenriched treatments with regards to the number of eggs laid in the top tier of the net box (p-value = 0.058) (Figure 11). Additionally, there was a significant difference between treatment groups with regards to bird weights (p-value = 0.005). The enriched birds weighed more than the unenriched birds (Figure 12).

There was no significant difference between treatment groups with regards to the number of eggs laid over the 13-week period or the weights of eggs (p-value = 0.682 and 0.948 respectively). There was no significant difference in the number of eggs that were laid on the floor (one-sided p-value = 0.40) even though there was a large numerical difference between treatments (Table 4.4). There was a significant difference in the number of feather pecks between the enriched and unenriched treatment groups in the first observation period only (p-value = 0.05). The unenriched birds feather pecked more than the enriched birds. There were no differences in the second and third observation period (p-value = 0.25 and 0.15 respectively). There was a significant difference in the distribution of feather scores between the two treatments

(p-value < 0.0001) with the enriched birds having better feather condition than the unenriched birds (Figure 13).

Figure 5 – Effect of rearing birds in enriched (n=58) versus unenriched (n=57) pens on the number of birds to approach the familiar handler within 0.5 meters in the familiar human approach test. There was a significant difference between treatments in trial 1 ($p=0.05$) and trial 2 ($p=0.05$) but not in trial 3 ($p=0.35$) with more enriched birds approaching the handler than the unenriched birds. The effect of treatment over time was also significant ($p=0.01$).

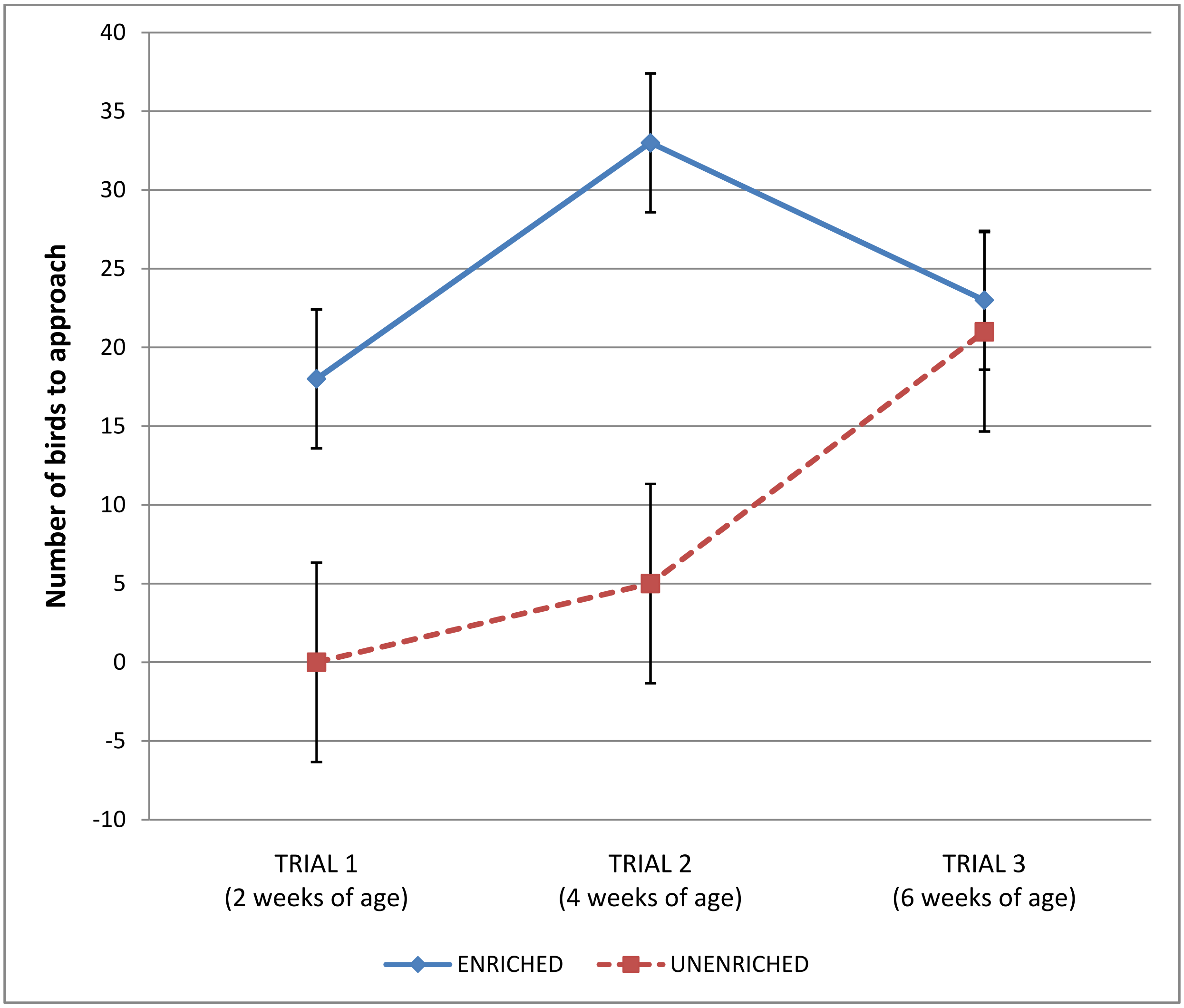


Figure 6 – Effect of rearing birds in enriched versus unenriched pens on the latency of the first bird to approach the familiar handler within 0.5 meters in the familiar human approach test. There was a significant difference between treatments in trial 1 ($p=0.01$) and trial 2 ($p=0.01$) but not in trial 3 ($p=0.1$), with the enriched birds ($n=58$) approaching faster than the unenriched birds ($n=57$). There was also a significant effect of treatment over time ($p=0.006$).

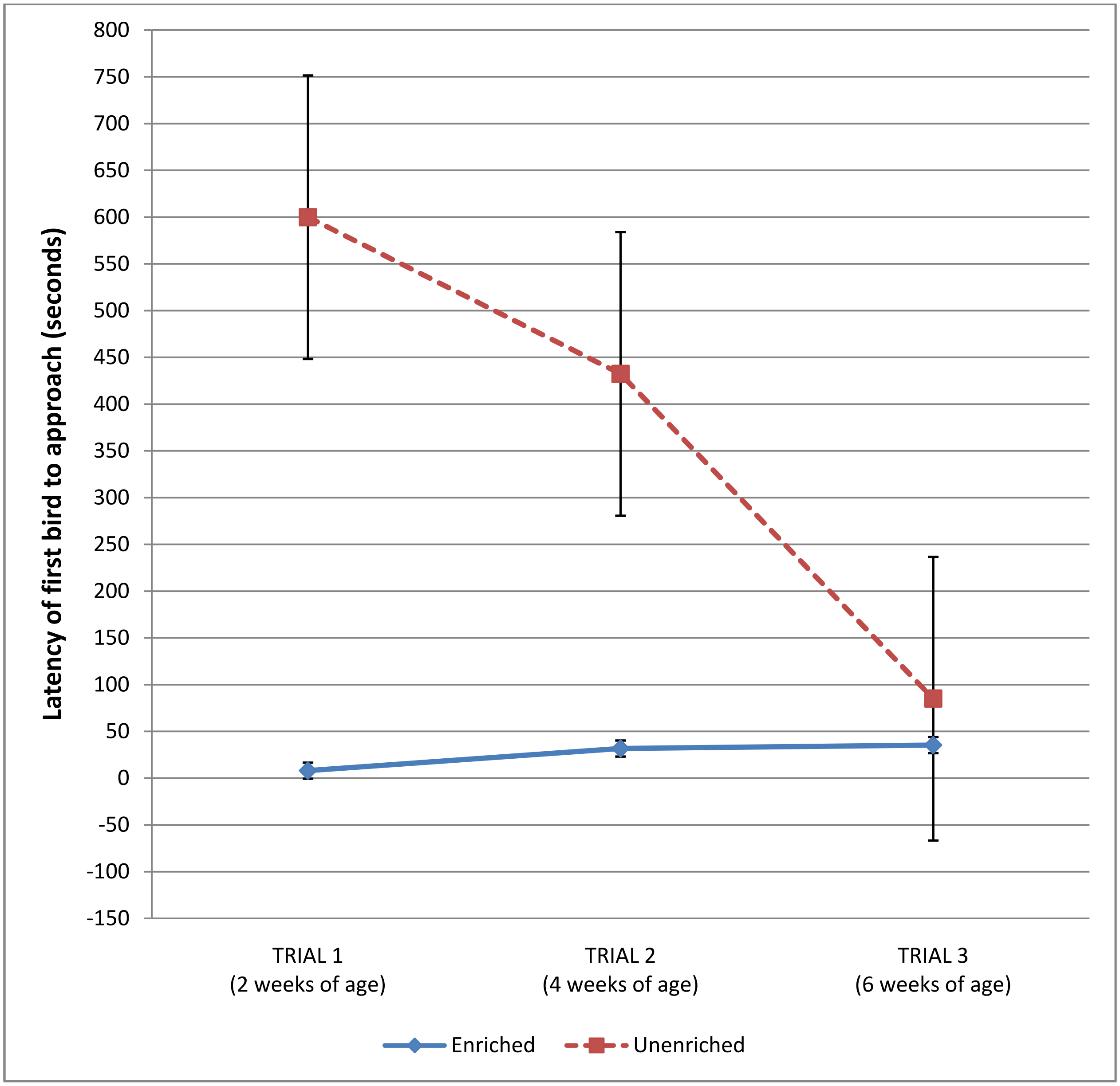


Table 4.1 – Effect of rearing environment on latency to approach an unfamiliar handler in trial two of the novel human approach test in home pen. There was a significant difference between the enriched (n=58) and unenriched (n=57) birds (p=0.05) with the unenriched birds approach the novel handler faster than the enriched birds.

Pen Type	# of birds	Latency to approach (seconds)			$\overline{X}$
Enriched	58	18	14	40	24
Unenriched	57	11	8	2	7

Table 4.2 – Effect of raising birds in enriched versus unenriched pens on average closest distance of approach per handler in the familiar and novel human approach test in novel pen. There was a marginally significant effect of treatment on the average closest distance of approach (p=0.06) with the enriched birds approaching closer to both handlers than the unenriched birds.

	Average closest distance of approach (meters)			
Pen Type	Familiar Handler		Unfamiliar Hander	
Enriched	0.57 m	n=28	0.67 m	n=30
Unenriched	1.17 m	n=27	1.17 m	n=30

Table 4.3 – Effect of raising birds in enriched (n=58) versus unenriched (n=57) pens on the latency of the first bird to drink from the novel drinker in the novel Container Test. There was no significant difference between treatment groups (p=0.5).

Pen	Latency to drink (seconds)			$\overline{X}$
Enriched	727.2	752.4	3600	1693.2
Unenriched	3081.6	1166.4	553.2	1600.4

Figure 7 – Effect of rearing birds in enriched (n=58) versus unenriched (n=57) pens on the latency of the first bird to eat and drink from novel containers in the novel food and water container test. There was no significant difference between treatment groups (eat – p=0.3; drink – p=0.5).

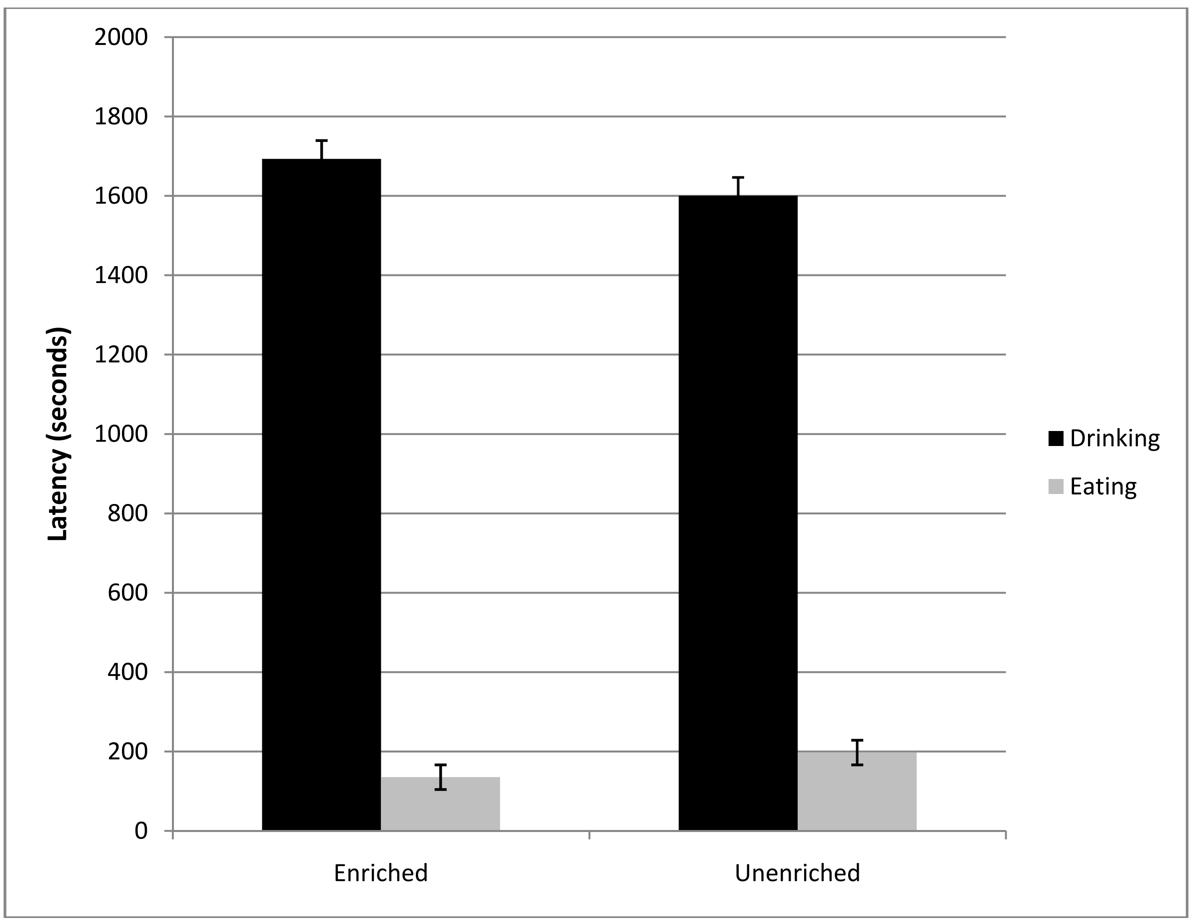


Figure 8 – Effect of keeping birds in enriched (n=30) versus unenriched (n=30) pens on the average number of food caches visited during the foraging test. There was a significant effect of treatment (p=0.05).

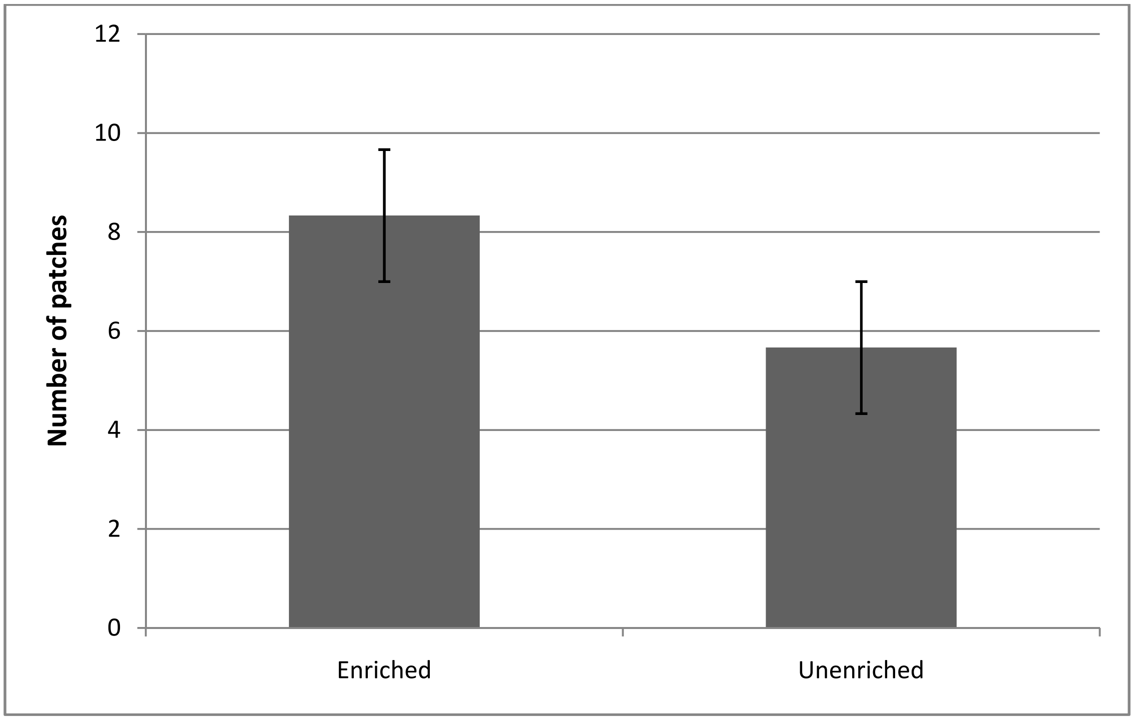


Figure 9 – Effect of raising birds in enriched (n=30) versus unenriched (n=30) pens on the total number of vertical investigations made in the foraging test. There was a significant difference between treatment (p=0.05).

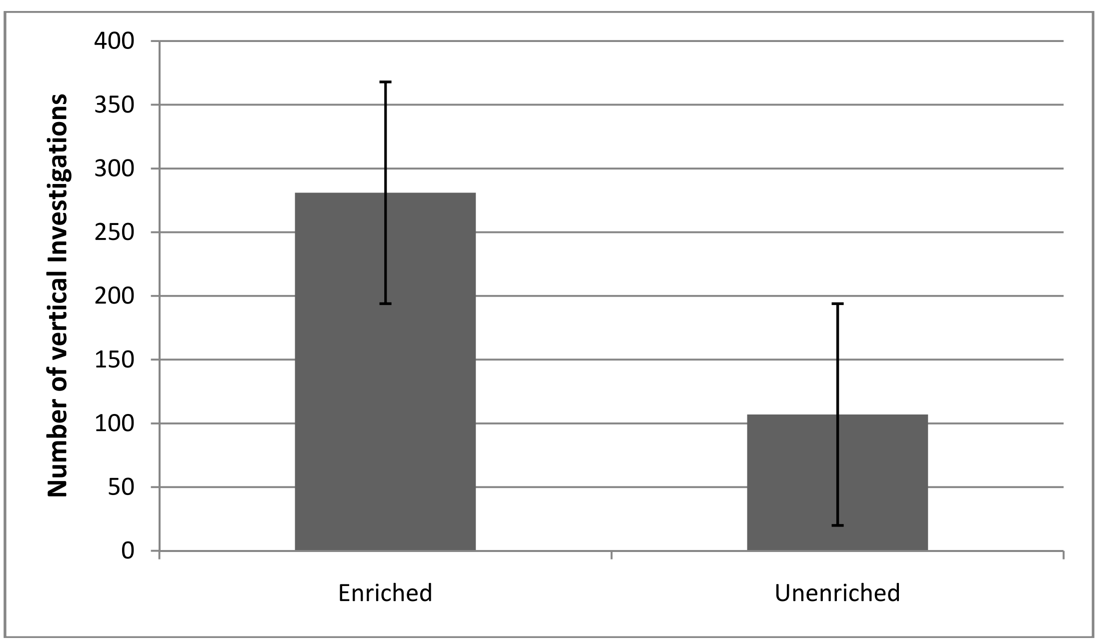


Table 4.4 – Effect of keeping birds in enriched versus unenriched pens on the total number of eggs laid on the floor during 13 weeks. There was no significant effect of treatment on the number of eggs laid on the floor (p=0.40).

Total number of floor eggs								
	Enriched 1	Enriched 2	Enriched 3	$\overline{X}$	Unenriched 1	Unenriched 2	Unenriched 3	$\overline{X}$
TOTAL	11	24	109	15.6	23	24	16	9. 3

Figure 10 – Effect of keeping birds in enriched versus unenriched pens on the number of broken eggs over 13 weeks. There was a significant difference between treatments (p=0.05) with the enriched birds (n=58) breaking more eggs than the unenriched birds (n=57).

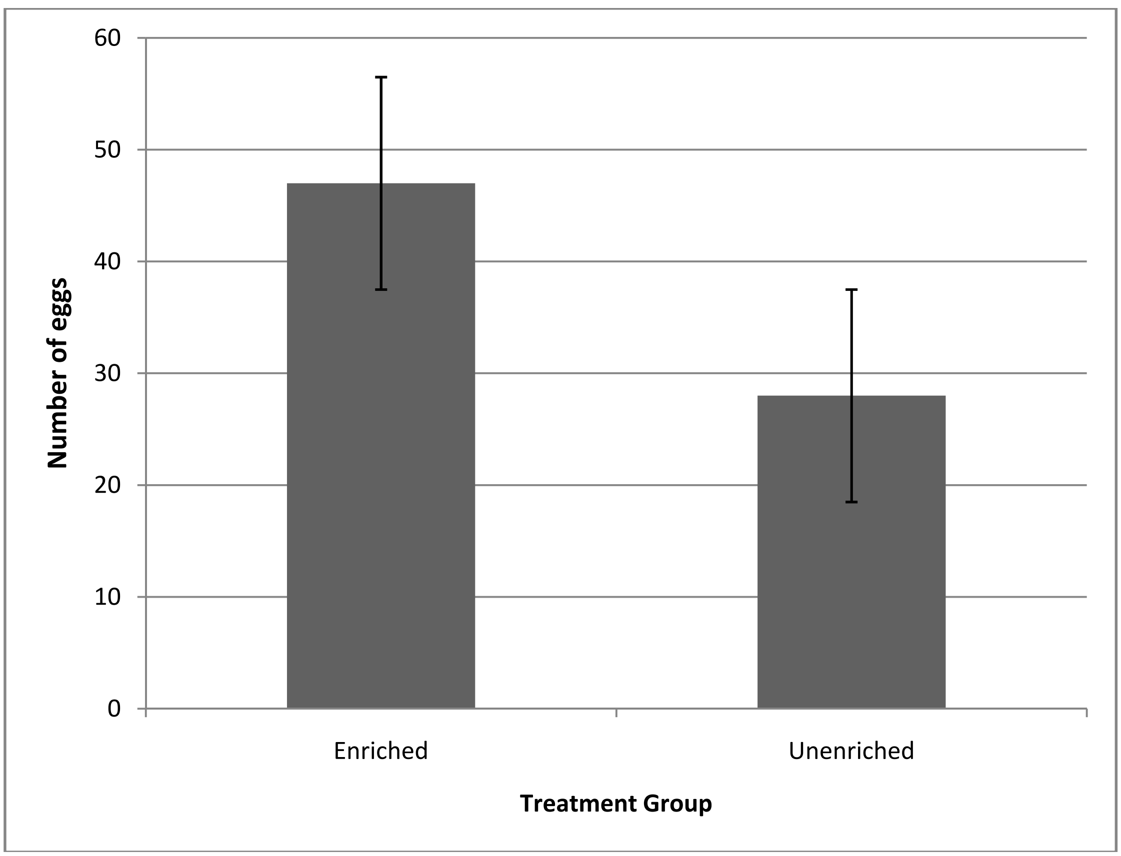


Figure 11 – Effect of age and treatment type on the number of eggs laid in the top tier of the nest box. There was a marginally significant difference between treatments (p=0.058) with the enriched birds laying more in the top tier than the unenriched birds.

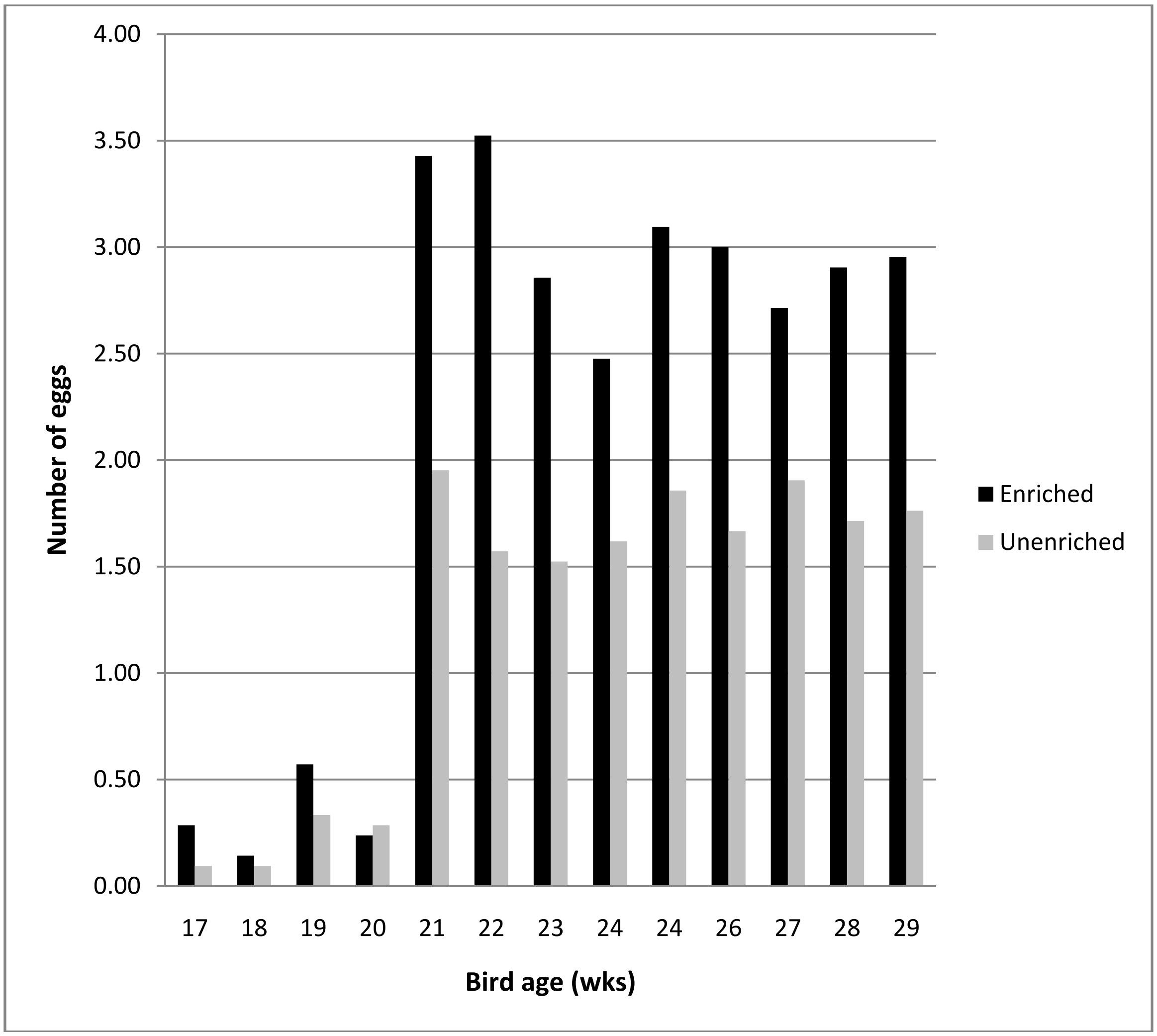


Figure 12 – Effect of treatment on average bird weight (grams). There was a significant difference between treatment groups over time (p=0.005) with the enriched birds (n=58) consistently weighing more than the unenriched (n=57).

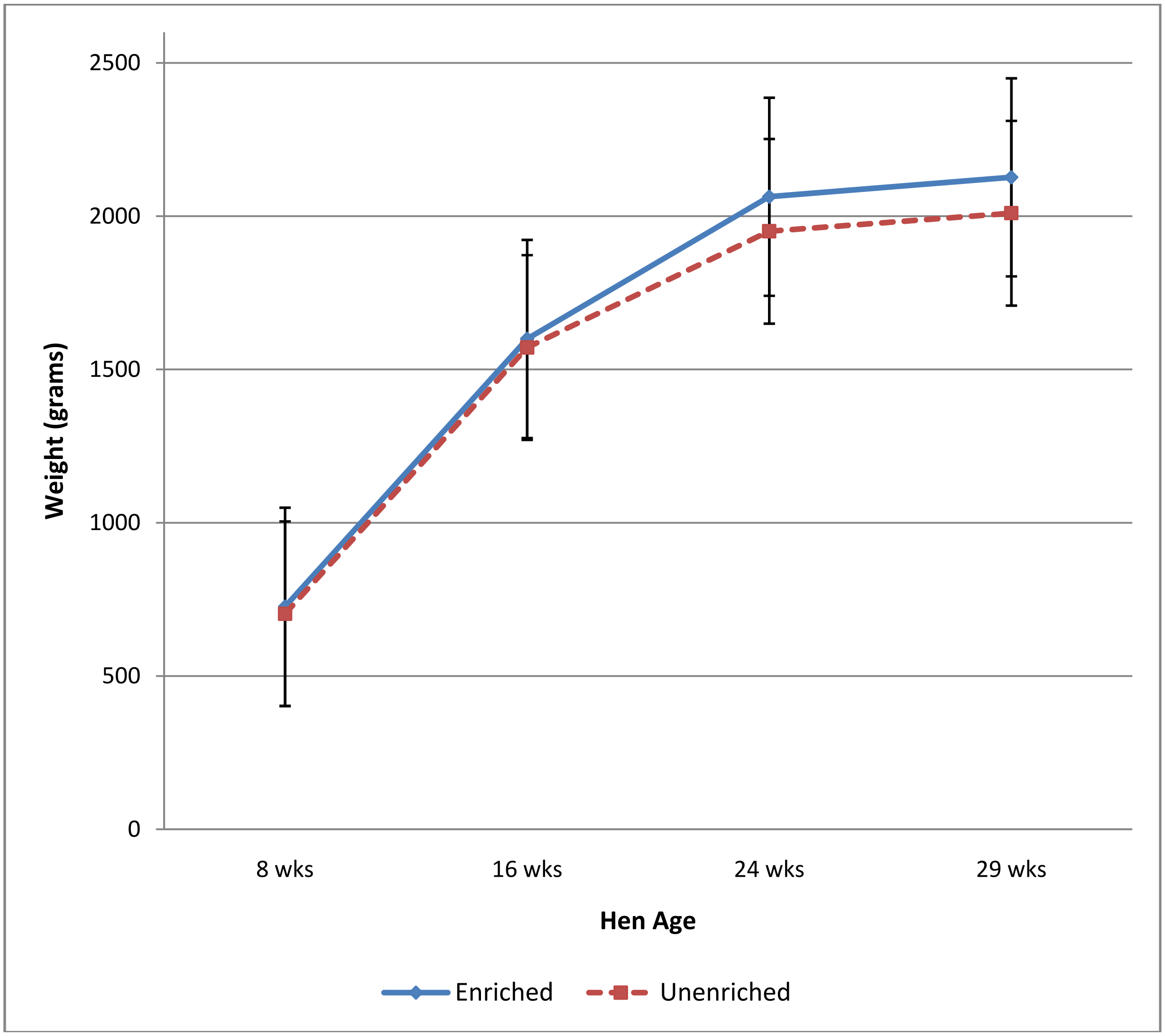
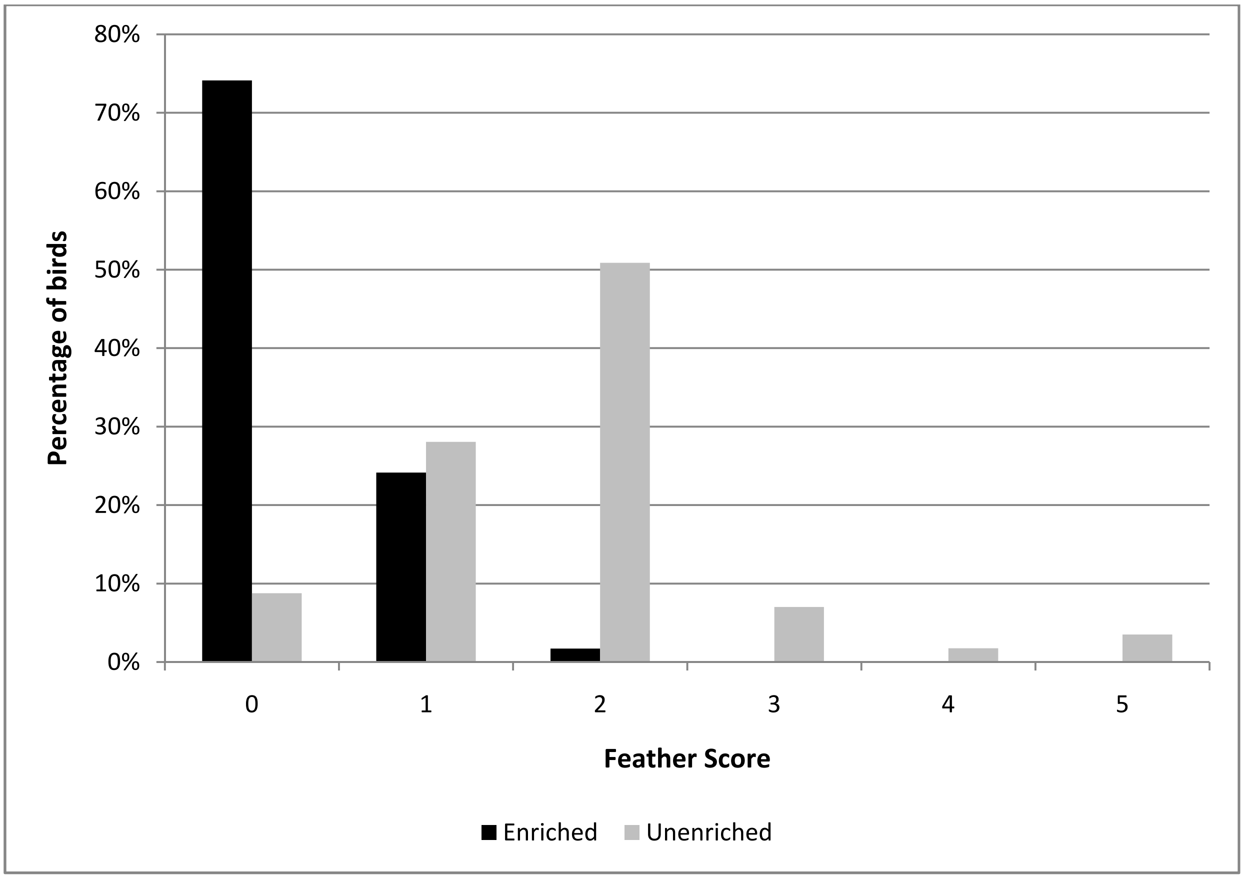


Figure 13 – Percentage of birds with each feather score (scale 0 best – 5 worst). There was a significant difference in the distribution of feather scores between treatment groups (p<0.0001) with the enriched birds (n=58) having better feather condition than the unenriched birds (n=57).



Chapter 5
Discussion

The hypothesis that enriched birds would perform better on cognitive tasks and show more desirable behavior and performance levels was partially met. The hens in the enriched treatment performed better on many of the behavior tests, as well as on some aspects of performance. However, only marginal differences were observed between the two groups in the learning tasks.

Familiar Human Approach Test in home pen

More enriched birds approached the familiar human and were faster to approach in all three trials even though the difference between the two treatment groups was only significant for the first and second trials. The approach test theoretically is a measure of the fear response of the birds, and as the enriched birds had fifteen minutes of gentle, daily human contact with the familiar handler, it is not surprising that they were initially less fearful of the handler entering their pens. However, it was surprising to find an increase in the latency of the first bird to approach in the enriched treatment with successive trials. This finding disagrees with previous studies in chickens and pigs (Jones & Waddington, 1992; Hemsworth *et al*., 1994). One explanation for this finding may be that the enriched birds simply habituated to the presence of the familiar handler and that there was a waning response to human enrichment. It should also be noted that the unenriched birds also appeared to become less fearful of the familiar handler over the course of the three trials, and by six weeks of age, the difference in the number of birds to approach between treatments was not significant. This result may have been due to repeated daily exposure to the familiar handler during routine husbandry practices such as feeding and health checks, as well as habituation to the test experience over time. This result is consistent with those of Jones & Waddington (1992), Hemsworth *et al*. (1994), Hemsworth *et al*. (1996), Hemsworth & Barnett (1992), and Gonyou *et al*. (1986) who similarly found that repeated exposure to humans can decrease fear responses in chickens, pigs and cattle. Additionally, there was a qualitative difference in the behavior of the birds. The unenriched birds were observed to freeze and watch the handler during test sessions, whereas the enriched birds, especially by the third trial, paid noticeably less attention to the presence of the handler and instead engaged in normal behaviors such as eating, perching, foraging, and dustbathing.

Novel Human Approach Test in home pen

The novel human approach tests were conducted to determine whether enrichment or lack of it impacted the fear responses of the birds to unfamiliar people. The first novel human approach test was conducted at eight weeks of age and there was no significant difference between treatment groups in any of the measures recorded. One hundred percent of the enriched birds and 93% of the unenriched birds approached the novel handler. This indicates decreased fear of being approached of birds in both treatment groups, which may reflect that their experience with the familiar handler had generalized to other people. This would be similar to Hemsworth *et al*. (1996) who found that pigs and cattle with prior human exposure were faster to approach and spent more time close to a novel experimenter than those with minimal exposure to humans. There was also a qualitative difference in the behavior of the enriched versus unenriched birds relative to their behavior during the novel human approach test. The unenriched birds spent more time frozen while watching the handler, whereas the enriched birds quickly lost interest in the handler and were more willing to move away and continue engaging in other behaviors, such as foraging or eating from their feeders. Some enriched birds also perched and continued to dustbathe while the novel handler was present, suggesting a lack of fear towards the handler.

The second novel human approach test was conducted at 10 weeks of age. The only difference observed between the treatment groups was in the latency of the first bird to approach with the unenriched birds approaching the handler faster. As in the first trial, there was a qualitative difference in the behavior of the birds, with the enriched birds exhibiting more exploration and other behaviors, such as feeding, perching, and sleeping, than the unenriched birds. Twenty-four percent of the enriched birds explored versus 20% unenriched birds. This difference, however, was not statistically significant. It should be noted that fewer (88%) enriched birds approached the novel human than did unenriched birds (98%), and the unenriched birds approached the novel human more quickly than the enriched birds. This may have been due to the unenriched birds being aroused by the presence of a novel human, but unafraid to investigate him, while the enriched birds may simply have been uninterested in an approaching human due to their repeated exposure to the familiar handler. This result is different from Hemsworth *et al*. (1996) and is encouraging because of the implications for poultry management, namely that just fifteen minutes of neutral daily exposure to a human can reduce the fear responses of birds.

Novel and Familiar Human Approach Test in novel pen

The only significant result of the novel and familiar approach test was the difference between treatment groups with regards to the closest distance relative to the handler that the birds approached. The enriched birds came closer to both the familiar and unfamiliar handler when compared to the unenriched birds. More enriched birds approached the familiar handler than unenriched birds, although this difference was not significant. There was a slight difference in the number of enriched and unenriched birds to approach the unfamiliar handler. More unenriched birds approached the unfamiliar handler than the familiar handler and more enriched birds approached the familiar handler than the unfamiliar handler. Both enriched and unenriched birds foraged and investigated the novel room rather than exploring the novel or familiar handler. These findings suggest that birds in both treatment groups were attracted to novelty, particularly to new people as well as to the new room. This is inconsistent with Jones & Waddington (1992), Grigor *et al.* (1995) and Hemsworth *et al*. (1996) who observed that only enriched birds and pigs were attracted to new people and novel environments.

Novel Food and Water Container Test

The novel food and water container test was conducted when the birds were eight weeks old to allow for appropriate time between testing. There was no significant difference between treatments in any of the measures recorded. All birds from each treatment group ate from the novel containers within the allotted sixty minutes. As the food was easily visible in the novel food container, it is not very surprising that locating this resource was not difficult for either treatment group. Perhaps if the food had been presented in such a way that it looked different from their regular grain, there may have been a different result.

As the novel drinker required the birds to adapt to a very different presentation of water from its normal presentation via a nipple line, this could explain the difficulty some birds had in locating the resource. Surprisingly, one bird from an unenriched room was the fastest to drink from the novel drinker (553.2 seconds) while one entire room of enriched birds failed to drink from the novel water container and therefore "timed out" of the test. If this group was excluded, the average latency to drink for the enriched group would have been 739 seconds compared to 1600 seconds for the unenriched treatment. It would therefore be interesting to know how long it would have taken the outlying enriched room to drink from the novel drinkers. In future studies, it might be wise to allow the birds a longer period of time (under supervision and with appropriate intervention as needed to protect the birds' well-being) to determine how long it might take for them to finally drink.

Although not measured quantitatively, it was observed that more enriched birds investigated the drinker but never drank from it than the unenriched birds. It should also be noted that very few birds from either treatment group (11 out of 58 enriched birds and 7 out of 57 unenriched birds) drank. Perhaps if the test had been longer, more birds would have drunk from the novel drinkers. It may be interesting to note, however, that all birds were quickly transitioned to jug drinkers in the week prior to re-homing at 28 weeks of age.

Barrier Test

There was no significant difference between the enriched and unenriched birds with regards to the time it took each bird to navigate the barrier. This may have been due to the small sample size and the similar number of birds that "timed out" per treatment. It should be noted that of the five enriched birds that timed out, two never moved past the starting point. The other three enriched birds that timed out foraged behind the barrier but never came within 0.5 meters of the companion birds. This suggests that the birds were not fearful of the equipment or environment, because birds usually will not explore or forage (Grigor *et al*., 1995). Three of the six unenriched birds that timed out never moved past the starting point whereas one unenriched bird moved within 1m of the companion birds but never crossed the exit point.

Some of these results may have occurred because of the cumulative effect of the stress of being handled, temporarily confined and isolated from their peers and novelty of the testing apparatus. This explanation would be in agreement with Mendl *et al*. (1997) who noted that pigs that underwent disturbances, such as social isolation or novel spatial environments, showed impaired ability to navigate and locate resources in a foraging test and Laughlin & Zanella (2003) obtained similar results with distressed pigs during a Morris water maze test.

Foraging Test

There was a significant difference in the number of food patches visited with the enriched birds visiting 92% of the food patches compared to 62% in the unenriched birds. There was also a significant difference in the number of vertical investigations. The enriched birds looked up at the hay bales more often than the unenriched birds (93 versus 35 investigations respectively) suggesting not only an awareness of, but also a desire to use their vertical space. These differences suggest an inability to use vertical space by birds that were not reared with enrichment. This is in agreement with Gunnarsson *et al*. (2000) who showed that enrichment that encouraged birds to use, interact with, and process stimuli presented in vertical space had positive effects on spatial learning ability.

There was no significant difference in the number of birds to eat or drink or the latency of the first bird to eat or drink for either treatment group. However, the unenriched birds were faster to eat and drink than the enriched group. Unenriched birds had a reduced desire to investigate the novel room, perhaps due to fear of the novel layout and the unfamiliarity of the hay bales. Additionally, although there were minor differences between treatment groups in the frequency and duration of clustering (defined as 4 or more birds grouped together for 3 or more seconds), these differences were not significant. The unenriched birds did spend more time in groups than the enriched birds even though the enriched birds clustered more frequently. Clustering is a sign of fear and/or stress as birds that are fearful are less likely to explore their novel surroundings (Jones, 1997). As one of the advantages of social life is protection and cooperative resource location (Keeling & Gonyou, 2001), it is not surprising that both enriched and unenriched birds clustered. If birds were fearful of the environment they would be less likely to explore individually and it would seem that clustering may have functioned to give individual birds more protection.

Production Measures

There was no significant effect of treatment on the number of eggs laid or the average egg weight over the 13 week laying period. Since ISA brown layers are a commercial strain selected for egg production, it is not very surprising that enrichment did not have an effect on egg production. Additionally, the first two birds to come into lay at 17 weeks of age were from an enriched and an unenriched room. These were also the heaviest birds from both treatment groups, so this result is unsurprising given that the onset of lay is determined by the bird weight and light cycle. Each room within each treatment also had very similar laying patterns. Additionally, the number of eggs laid per hen per day and the average weight of each egg were all in line with industry standards so it does not appear that there was an effect of enrichment used on egg production.

Interestingly, there was a significant difference between treatment groups in the number of eggs broken. The enriched birds broke 47 eggs compared to 28 in the unenriched birds over the 13-week collection period. This was not however, related to the number of eggs laid on the floor as there was no significant difference between treatment groups in that measure. The higher incidence of broken eggs could be due to the fact that the enriched birds weighed more and with moving around differently and perching, they may have crushed and broken more eggs. This is supported by

Lundberg & Keeling (1999) who note that the risk of an egg being broken and eaten is related to the number of eggs already in that location and the number of birds that walk over them. It should also be noted that one enriched bird was seen breaking into her own egg suggesting intentional breaking of eggs by this particular bird or the development of egg eating behavior.

One enriched group laid 109 eggs on the floor over the 13-week collection period. However, at least one egg per day was laid in the dispersed hay adjacent to the nest box. It would seem that the hay nest constructed by a bird was the preferred location to lay for as many as two birds. It is unlikely that this was due to a lack of nest box space at the time of lay as over the entire laying period, there was never full use of all individual nest boxes in this room. It could, however, be due to an individual bird preference for laying in hay or unavailability of preferred nest boxes at the time of lay, as some nest locations were more popular than others. Interestingly, none of the eggs laid in the hay were ever broken. This result suggests that it might have been useful to furnish the nest boxes with hay or artificial turf to encourage birds with a preference for nesting material to use them. The results of Huber *et al*. (1985) and Duncan & Kite (1989) have demonstrated that laying hens have preferences for different nesting materials.

All other floor eggs laid by the other birds appeared to be randomly distributed throughout the room. It is likely that these other floor eggs were due to lack of nest box space or lack of preferred nest boxes. It could also be due to disturbances by other birds displacing a hen from her chosen nest site and causing her to lay wherever she was. It should be noted that there was a very low frequency of floor eggs in all other groups, except for one enriched group. The low incidence of floor eggs could be due to the introduction of nest boxes three weeks prior, at 15 weeks of age, to anticipated lay at 18 weeks of age. By introducing the nest boxes before the onset of lay, birds could investigate and familiarize themselves with the boxes, which may have encouraged them to use them. This is further supported by the findings of Lundberg & Keeling (1999) who showed that provision of nest boxes after the onset of lay did not reduce the number of eggs laid on the floor and in fact, the nest boxes were rarely used. Additionally, there is a correlation between the proportion of floor eggs and the age of the birds when they are offered nest boxes (Sherwin & Nicol, 1993); the older the birds are when the boxes are introduced, the higher the proportion of floor eggs.

There was a marginally significant difference in the number of eggs laid in the top tier of the nest box over the 13-week period. The enriched birds laid more eggs in the top tier than the unenriched birds, suggesting a better use of their vertical space which is in agreement with the results of the foraging test. It would seem that early experience with vertical enrichment such as perches, and then, later, hay bales, may have been partly responsible for the higher incidence of top tier eggs. This should be investigated in future studies.

Additional Measures

There was a significant effect of treatment on bird weights with the enriched birds weighing more than the unenriched birds. The difference in weights could be due to the increased protein from mealworms fed to the enriched group or from the hay or from both. As the enriched birds broke more eggs than the unenriched birds, it is possible that the extra nutrients gained by consuming eggs had an effect on bird weight. The difference in weights could alternatively be due to bone strength and therefore bone weight. With access to perches, the enriched groups could have increased bone strength which would have added to their overall weight. This would agree with studies showing that providing barriers or perches to broilers increases tibia strength and reduces leg problems (Bizeray *et al.*, 2002).

Enrichment appears to also have had beneficial effects on hen aggression and feather condition. Studies have shown that providing birds with hay bales can reduce aggression (Huber-Eicher & Wechsler, 1998). Although there was no difference between treatment groups with regards to frequency of feather pecking in the second and third observation period, there was a numerical difference in the total frequency of feather pecks between treatments. The unenriched birds pecked each other more over the three periods than the enriched birds (53 versus 21 pecks respectively) and this is also seen in the distribution of feather scores. Feather pecking is thought to be re-directed foraging behavior (Blokhuis, 1986) and the hay bales provided the enriched birds with an alternative substrate to forage on. The enriched birds also had avenues of escape from each other in the form of perches and hay bales that they could use to elevate themselves or move around.

It is thought that the differences in feather pecking may have contributed to the differences in feather score at 29 weeks of age. There was a significant difference in the distribution of feather scores between treatments. The scale used was the same as that of Bilčík & Keeling (1999) where a feather score of zero indicated that all feather were intact. A feather score of two meant that more than three feathers were missing but there were no nude areas and a feather score of five included birds with a completely denuded area greater than 5cm in diameter. There were more enriched birds with feather scores of zero (74%) than unenriched birds (8%) and most of the unenriched birds had feather scores of two (50%). Additionally, there were no enriched birds with feather scores higher than two whereas 11% of the unenriched birds had feather scores higher than two.

It is important to note that none of the birds used in this experiment were beak trimmed and as mentioned earlier, it would seem that providing enrichment, specifically alternative foraging substrates, may have helped to reduce feather pecking and improve feather condition. Most poultry producers beak trim their birds to prevent feather pecking and cannibalism which is quite prevalent in floor grown birds and caged hens of certain strains. However, this experiment shows that at smaller stocking densities and with the provision of enrichment, feather pecking in ISA Brown hens can be reduced, and cannibalism avoided. In fact, none of the birds in this experiment were culled as a result of feather pecking injuries.

Implications

Several key observations were made as a result of this experiment. The type of enrichment used did not impact certain aspects of learning, but did impact fearfulness of humans, inter-bird aggression, spatial navigation, particularly willingness to explore, and use of vertical space. Also, enrichment did not have a negative effect on productivity.

However, further questions are raised. First, the effect of sample size on the results is unclear. If this experiment were to be repeated, the first change to be made should be increasing the number of bird rooms and therefore the number of replicates of treatment groups to determine if larger bird numbers would lead to more significant differences in the test results. Additionally, testing all birds from all groups in the barrier and foraging tests might address the significance issues associated with those specific tests.

Additional changes in the test methodology should also be considered. For example, the increase in latency by enriched birds to approach the familiar handler in their home pens could be due to the fact that enriched birds were initially rewarded with mealworms for approaching the handler. By two weeks of age, even when such rewards had stopped, the hens still anticipated receiving mealworms from the handler. If this test were to be repeated, birds should not be rewarded for approaching in the early rearing phase, and the total number of approach tests should be significantly reduced. Reducing the number of approach tests could help control for the effects of repeated testing and handling. It would still be interesting to explore how the fear response towards humans of enriched and unenriched birds might change over time and to see if this response would generalize to other people. In this case, the familiar human approach test could be conducted once during the early rearing phase. Then a single novel human approach test should be conducted in the home pen and one novel human approach test in a novel environment. It would also be interesting to conduct a startle test and record hen recovery time to test whether enriched birds would recover faster than unenriched birds as has been suggested by Jones & Waddington (1992).

Additionally, it would also be interesting to investigate how long might take to drink from the novel drinkers instead of setting a maximum test time. There is disagreement between behaviorists with regards to “time outs” as they do not accurately indicate whether or how long it would have taken the subject animal to complete the task, and can therefore skew the test results. However, a maximum test time must be assigned in cases where bird welfare might be negatively affected otherwise.

There could also be changes made to the set up of the rooms themselves. As routine husbandry practices and repeated testing appear to have been enough exposure to humans to decrease fear in the unenriched treatment, it would be interesting to repeat the experiment with automatic feeders to reduce even neutral handler-bird interactions. In regards to the enrichment used, it might be interesting to study the effects of introducing hay bales on day 1. Hay bales were not included until after the foraging test so as to avoid skewing the foraging test results by allowing the enriched to gain experience with hay bales. Additionally, larger sand boxes should be used, because when the birds matured, the sand box could only accommodate one hen at a time and a larger box would reduce competition for this resource.

Overall, the results of this experiment reiterate that enrichment reduces fear of humans and novel environments and that this effect may generalize across many different situations. Fear of humans can be a considerable problem with floor-reared birds and can lead to trampling and suffocation (Jones, 1997). Enrichment, as shown in other studies (Ginsburg *et al.,* 1974; Hughes & Black, 1976; Jones & Faure, 1981; Gross & Siegel, 1982), can reduce this occurrence. Additionally, birds reared without enrichment show interest in novel humans and environments perhaps suggesting that their environments fail to engage them (Newberry, 1999). This study shows that even routine husbandry practices such as daily feeding can give birds enough positive exposure to humans to reduce fearfulness of humans and provide them with at least some mental stimulation. It should be noted, however, that all interactions with and handling of birds in this study were positive and gentle. If enrichment is used in production it is important to ensure that human contact with the birds is positive or at least neutral in order to effectively reduce fear and increase adaptability to novelty.

Enrichment appears to increase adaptability to different situations and help birds make better use of their vertical space which would be important in the design of alternative housing systems, especially if resources were located off the ground, such as in an aviary. It would also seem that the provision of perches can improve spatial ability, as shown in other studies (Gunnarsson *et al*., 2000; Wichman *et al*., 2007). Both enriched and unenriched birds perched on equipment in their environments, such as the water line and the hanging feeder, which further emphasizes that perching is a highly motivated behavior. In fact, the enriched birds started to perch at three days of age, earlier than that reported in any other study reviewed (Gunnarsson *et al*., 2000; Heikkila *et al*., 2006; Wichman *et al*., 2007). Providing birds with the opportunity to perch is probably important enough to them that it should be implemented into hen housing wherever feasible, and at an early age to facilitate their use of vertical space, as well as increase their bone strength (Bizeray *et al*., 2002), reduce bird susceptibility to bone breakage and provide them with the opportunity to escape aggressive conspecifics.

Many producers are unwilling to keep layers on the floor due to the high incidence of floor eggs usually seen. This increases the time it takes to collect eggs and as a result costs producers more money. This study has shown that if nest boxes are provided three weeks prior to the expected start of lay, the number of floor eggs can be relatively low. Perhaps providing additional nest boxes or adding hay (or AstroTurf ® as suggested by Hughes (1993)) to the nest box itself might have decreased the incidence of floor eggs in this experiment. The incidence of broken eggs was also very low so the type of enrichment used here does not seem to negatively impact the number of "sellable" eggs.

Producers ultimately must control their costs of production, so it is important to consider the cost of implementing enrichment. As the individual effects of each enrichment device cannot be determined, it would seem impractical for producers to play music, feed mealworms, use visual enrichment, and provide dustbathing boxes, plants and hay. However, given our results relating to the improved use of vertical space, reduced fear, and lower feather pecking and cannibalism, it would seem reasonable to suggest that the provision of perches, hay, nest boxes and daily positive human contact could be effective at improving laying hen behavior, performance, and overall well-being. The perches used in this experiment were inexpensive to make and were frequently used by the birds, which suggests that they could be inexpensively produced and effective for producers. Similarly, low quality hay might be used as an alternative foraging device and if used in conjunction with perches, might help to reduce feather pecking. This type of enrichment is relatively inexpensive and the producer could simply provide hay bales as these would not only provide perching and roosting opportunities but also provide nest building materials.

In conclusion, the results of this study suggest that enrichment may have beneficial effects on hen behavior in that it reduces fear of humans and novel environments, reduces feather pecking and other inter-bird aggression, increases and improves the use of vertical space and ability to locate resources in the vertical plane, and does not impair productivity which is in agreement with those of Jones & Waddington (1992), Gunnarsson *et al*. (2000), Bizeray *et al*. (2002), Jones (1996), Huber-Eicher & Sebo (2001), Johnsen *et al*. (1998), and McAdie *et al*. (2005). Enrichment may improve hen welfare by providing opportunities to satisfy behavioral needs, allowing greater behavioral repertoires, providing mental stimulation and improving adaptability to challenges (such as novel environments or aversive situations) and use of space. The effects of enrichment or lack there of, are also pronounced during the rearing phase and as a result, enrichment should be implemented as early as possible. The enrichment used in the current study is inexpensive and offers an economically feasible addition to poultry production systems. It is therefore suggested that enrichment should be considered in the development or modification of poultry housing systems.

Chapter 6
Conclusion

Rearing and housing systems can have substantial effects on the behavior and physiology of domestic animals, such as a broader behavioral repertoire, more complex neuronal brain structures (van Praag *et al*., 2000; Kempermann *et al*., 1997; Patel *et al*., 1997), better learning performance (Leggio *et al*., 2005; Sneddon *et al*., 2000), less fearfulness and more exploration behavior towards novel stimuli (Beattie *et al*., 1995; Jones, 1996).

As expected based on the existing literature, the enrichment used in this study had some effects on laying hen behavior. First, it appeared to reduce fearfulness of birds towards humans and novelty as demonstrated by quicker latencies to approach experimenters and novel containers. This agrees with studies showing that enrichment can reduce the fear responses of chickens towards humans (Ginsburg *et al*., 1974; Jones & Waddington, 1992) and helps make the case that it is important to enrich the environment of laying hens. Enrichment has also been shown to improve cognitive ability in rodents and pigs when presented with various spatial memory or operant tasks (Sneddon *et al*., 2000; Kempermann *et al*., 1997). The marginal differences seen between birds of different treatment groups in the barrier test and the novel human approach tests suggest that enrichment may have an effect and therefore warrant further investigation.

Likewise, our foraging test results demonstrated that the enriched birds were better able to use their vertical space and to navigate a novel environment and locate more of its resources. This finding is similar to that of Gunnarsson *et al*., (2000) who showed that rearing without early access to perches impairs the spatial ability of laying hens.

Moreover, the enrichment used may have modified the birds' behavior, resulting in reduced aggression and feather pecking as evidenced by the superior feather condition of the enriched birds at the end of the 29 weeks. Additionally, the provision of straw to the pens of 7 week old chicks in a study done by Huber-Eicher & Wechsler (1997) markedly reduced feather pecking and is in agreement with the present findings.

In regards to hen performance, enrichment seemed to impact the number of broken eggs and the number of eggs laid in the top tiers of the nest boxes which is similar to the findings of Lundberg & Keeling (1999). Bird weights were also affected by enrichment in that enriched birds weighed more than unenriched birds. This differs from Gvaryahu *et al*. (1989) who saw no differences in body weight as a result of imprinting enrichment and music (IEM). Body weight gain similar to that in the present study was seen by Jones *et al*. (1980) with the addition of novel objects to the environment of both broiler and layer chicks. Jones *et al*. (1980) suggest that environmental enrichment has a growth-stimulating effect.

These results have implications for the welfare of laying hens and for decision-making about their housing and management. For instance, as legislation continues to be proposed to ban the use of conventional battery cages, it is important to understand how birds may or may not adapt to alternative housing systems. An understanding of how chickens navigate, interact with and utilize their environment and its resources, and what management interventions, such as enrichment, may facilitate their well-being and performance is required to identify suitable housing methods. Understanding how the hens' behavior may be altered by adding enrichment may provide insight into aspects of the environment that are most important to her and help predict how hen behavior in response to environment changes.

There are several questions that are raised as a result of this study which warrant further investigation. First, for commercial laying hen producers, it is important to know at what stocking densities feather pecking might be significantly reduced as a consequence of enrichment. This is an important question given that it would not be practical for a producer to house birds in groups of 20, and therefore such information could help determine appropriate stocking densities to reduce aggression and feather pecking with the provision of enrichment. Additionally, to what extent does enrichment modify the need for beak-trimming? Birds in this study were not beak trimmed and it becomes important to understand whether enrichment might negate the need for beak-trimming in group-reared hens, especially in strains that have a relatively low propensity for aggression to begin with. Genetics strongly influences feather pecking, which makes it important to determine the effectiveness of enrichment on the behavior of hens of different genetic lines.

Additionally, the question is raised about which cognitive tests are best used to determine the effects of enrichment on learning and memory. Would operant tasks be more suited to show any differences in hen learning ability as a function of enrichment? There is relatively little literature on poultry cognition, and it remains important to understand how chickens learn to predict how well they may adapt to and cope with changing environments. Although certain aspects of learning ability were not dramatically improved with the use of enrichment in this study, more research must still be done to investigate the areas of poultry cognition involving spatial learning and adaptability. Similarly, the role that novelty plays in adaptability should be further investigated as anecdotal evidence obtained when the birds were re-homed suggests that unenriched birds are not as adaptable to novel environments and perhaps the novelty used in this study was not novel enough to show differences between treatment groups.

Birds that are repeatedly handled, moved around, and presented with sometimes aversive and novel stimuli must be able to adapt to changing environments and situations. This study showed that the behavior of chickens can be positively affected by the addition of enrichment, and that specific behavioral needs of chickens, such as perching, social interaction, dust-bathing, nest-building, and foraging opportunities, can be met with simple forms of enrichment such as perches, nest boxes, straw, litter and other dust-bathing substrates. Provision of enrichment has enough benefits for hen welfare that it should be strongly considered in the design of alternative housing systems. Although certain aspects of learning ability were not dramatically improved with the use of enrichment in this study, more research must still be done to investigate the areas of poultry cognition involving spatial learning and adaptability.

References

Allen, C. (1998). Assessing animal cognition: Ethological and philosophical perspectives. *Journal of Animal Science*, *76*, 42-47.

Appleby, M.C. & Duncan, I.J.H (1989). Development of perching in hens. *Biology of Behavior, 14*, 157-168.

Appleby, M.C. & Hughes, B.O. (1991). Welfare of laying hens in cages and alternative systems: environmental, physical and behavioral aspects. *World's Poultry Science Journal*, *47*, 109-128.

Appleby, M.C. & Hughes, B.O. (Eds.). (1997). *Animal Welfare* Oxfordshire, UK: CABI Publishing.

Appleby, M.C., Hughes, B.O. & Elson, H.A. (1992). *Poultry Production Systems: Behavior, Management and Welfare*. Oxfordshire, UK: CAB International.

Appleby, M.C., Mench, J.A., & Hughes, B.O. (2004). *Poultry behavior and welfare.* Oxfordshire, UK: CABI Publishing.

Arey, D.S. & Franklin, M.F. (1995). Effects of straw and unfamiliarity on fighting between newly mixed growing pigs. *Applied Animal Behavior Science, 45*, 23-30.

Arey, D.S., Petchey, A.M & Fowler, V.R. (1991). The preparturient behavior of sows in enriched pens and the effect of pre-formed nests. *Applied Animal Behavior Science, 31*, 61-68.

Banks, E.M. (1982). Behavioral research to answer questions about animal welfare. *Journal of Animal Science,* 54, 434-436.

Barnard, C.J. & Hurst, J.L. (1996). Welfare by design: The natural selection of welfare criteria. *Animal Welfare*, *5*, 405-433.

Baxter, M.R. (1983). Ethology in environmental design. *Applied Animal Ethology,* 9, 207-220.

Beattie, V.E., Walker, N., & Sneddon, I.A. (1995). Effects of environmental enrichment on behavior and productivity of growing pigs. *Animal Welfare, 4*, 207-220.

Blakemore, C. & Mitchell, E.D. (1973). Environmental modification of the visual cortex and the neural basis of learning and memory. *Nature, 241*, 467-468.

Blokhuis, H.J. (1986). Feather-pecking in poultry: its relation with ground-pecking. *Applied Animal Behavior Science, 16*, 63-67.

Bilčík, B. & Keeling, L.J. (1999). Changes in feather condition in relation to feather pecking and aggressive behavior in laying hens. *British Poultry Science, 40*, 444-451.

Bizeray, D., Estevez, I., Leterrier, C., & Faure, J.M. (2002). Influence of increased environmental complexity on leg condition, performance, and level of fearfulness in broilers. *Poultry Science*, *81*, 767-773.

Brake, J., Keeley, T.P. & Jones, R.B. (1994). Effect of age and presence of perches during rearing on tonic immobility fear reactions of broiler breeder pullets. *Poultry Science, 73*, 1470-1474.

Brambell Committee (1965). *Report of the technical committee to inquire into the welfare of animals kept under intensive livestock husbandry systems*. Command Report 2836. London: Her Majesty's Stationary Office.

Broadhurst, P.L. (1960). Abnormal animal behavior. In H.J. Eysenck (Ed.), *Handbook of abnormal psychology*. (pp. 726-763). London, UK: Pitman.

Broom, D.M. (1969). Effects of visual complexity during rearing on chicks' reactions to environmental change. *Animal Behavior, 17*, 773-780.

Broom, D.M. (1980). Factors affecting responses of chicks to a novel environmental change. *Applied Animal Ethology, 6*, 385-386.

Broom, D.M. (1986). Indicators of poor welfare. *British Veterinary journal,* 142, 524-526.

Brouns, F., Edwards, S.A. & English, P.R. (1994). Effect of dietary fibre and feeding system on activity and oral behavior of group housed sows. *Applied Animal Behavior Science, 39*, 329-337.

Candland, D.K., Nagy, A.M. & Conklyn, D.H. (1963). Emotional behavior in the domestic chicken (White Leghorn) as a function of age and developmental environment. *Journal of Comparative and Physiological Psychology, 56*, 1069-1073.

Carlstead, K. (1996). Effects of captivity on the behavior of wild mammals. In D.G. Kleiman, M.E. Allen, K.V. Thompson, & S. Lumpkin (Eds.), *Wild mammals in captivity: Principles and techniques*. (pp. 317-333). Chicago: Chicago University Press..

Carlstead, K., Seidensticker, J. & Baldwin, R. (1991). Environmental enrichment for zoo bears. *Zoo Biology, 11,* 165-176.

Carpenter, E. (1980). *Animal and ethics*. London: Watkins.

Carughi, A., Carpenter, K.J. & Diamond, M.C. (1989) Effect of environmental enrichment during nutritional rehabilitation on body growth, blood parameters and cerebral cortex development in rats. *Journal of Nutrition, 119*, 2005-2016.

Chamove, A.S., Anderson, J.R., Morgan-Jones, M.C. & Jones, S.P. (1982). Deep woodchip litter: hygiene, feeding, and behavioral enhancement in eight primate species. *International Journal for the Study of Animal Problems, 3,* 308-318.

Collins, J.W. & Siegel, P.B. (1987). Human handling, flock size and responses to an *E. coli* challenge in young chickens. *Applied Animal Behavior Science, 19,* 183-188.

Cornetto, T. & Estevez, I. (2001). Influence of vertical panels on use of space by domestic fowl. *Applied Animal Behavior Science*, *71*, 141-153.

Cornetto, T., Estevez, I., & Douglass, L.W. (2002). Using artificial cover to reduce aggression and disturbances in domestic fowl. *Applied Animal Behavior Science*, *75*, 325-336.

Craig, J.V. (1981). *Domestic animal behavior.* Englewood Cliffs: Prentice-Hall Inc.

Croney, C. (1999). Cognitive abilities of domestic pigs (*Sus scrofa*). Dissertation, The Pennsylvania State University, University Park, Pennsylvania.

Dahlqvist, P.M., Johansson, B.B., Risedal, A. (2000). NGF1-A and NGF1-B mRNA expression correlates with improved functional recovery induced by environmental enrichment after middle cerebral artery occlusion in rats. *Stroke, 31*, 338.

Dawkins, M.S. (1980). *Animal suffering: The science of animal* welfare. London, UK: Chapman and Hall.

Dawkins, M.S. (1981). Priorities in the cage size and flooring preferences of domestic hens. *British Poultry Science, 22*, 255-263.

Dawkins, M.S. (1988). Behavioral deprivation: a central problem to animal welfare. *Applied Animal Behavior* Science, 20, 209-225.

Dawkins, M.S. (1990). From an animal's point of view: motivation, fitness, and animal welfare. *Behavioral and Brain Sciences,* 13, 1-9 and 54-61.

Day, J.E.L., Van de Weerd, H.A., & Edwards, S.A. (2008). The effect of varying lengths of straw bedding on the behavior of growing pigs. *Applied Animal Behavior Science, 109*, 249-260.

de Jong, I.C., Bokkers, E.A.M., Schouten, W.G.P. & Helmond, F.A. (1996). Rearing piglets in a poor environment: developmental aspects of social stress in pigs. *Physiology and Behavior, 60*, 389-396.

de Jong, I.C., Ekkel, E.D., Van de Burgwal, J.A., Lambooij, E., Korte, S.M., Ruis, M.A.W., Koolhaas, J.M., & Blokhuis, H.J. (1998). Effects of strawbedding on physiological responses to stressors and behavior in growing pigs. *Physiology and Behavior, 64*, 303-310.

de Jong, I.C., Prelle, T., van de Burgwal, J.A., Lambooij, E., Blokhuis, H.J. & Koolhaas, J.M. (2000). Effects of environmental enrichment on behavioral responses to novelty, learning, and memory, and the circadian rhythm in cortisol in growing pigs. *Physiology and Behavior, 68*, 571-578.

de Passillé, A.M.B., Christopherson, R.J. & Rushen, J. (1993). Nonnutritive sucking and postprandial secretion of insulin, CCK and gastrin by the calf. *Physiology & Behavior, 54*, 1069-1073.

de Wilt, J.G. (1985). Behavior and welfare of veal calves in relation to husbandry systems. PhD thesis, The Agricultural University, Wageningen, The Netherlands.

Duffy, S.N., Craddock, K.J. & Nguyen, P.V. (2001). Environmental enrichment modifies the PKA-dependence of hippocampal LTP and improves hippocampus-dependent memory. *Learning and Memory, 8*, 26-34.

Duncan, I.J.H. (1987). The welfare of farm animals: an ethological approach. *Science Progress, Oxford,* 71, 317-326.

Duncan, I.J.H. (1998) Behavior and behavioral needs. *Poultry Science*, *77*, 1766-1772.

Duncan, I.J.H. (2001). The pros and cons of cages. *World's Poultry Science Journal, 57*, 381-390.

Duncan, I.J.H. (2004). Welfare problems of poultry. In G.J. Benson & B.E. Rollin, *The Well-Being of Farm Animals: Challenges and Solutions*. (pp. 307-324). Iowa: Blackwell Publishing.

Duncan, I.J.H. & Dawkins, M.S. (1983). The problem of assessing 'well-being' and 'suffering' in farm animals. In D. Smidt (Ed.), *Indicators relevant to farm animal welfare*. (pp. 13-24). The Hague, the Netherlands: Martinus Nijhoff.

Duncan, I.J.H. & Fraser, D. (1997). Understanding Animal Welfare. In M.C. Appleby & B.O. Hughes (Eds.), *Animal Welfare* (pp. 19 – 31). Oxfordshire, UK: CABI Publishing.

Duncan, I.J.H. & Hughes, B.O. (1972). Free and operant feeding in domestic fowls. *Animal Behavior, 20*, 775-777.

Duncan, I.J.H. & Kite, V.G. (1989). Nest site selection and nest-building behavior in the domestic fowl. *Animal Behavior, 37*, 215-231.

Duncan. I.J.H. & Petherick, J.C. (1991). The implication of cognitive processes for animal welfare. *Journal of Animal Science*, *69*, 5017-5022.

Duncan, I.J.H. & Wood-Gush, D.G.M. (1972a). Thwarting of feeding behavior in the domestic fowl. *Animal Behavior, 20,* 444-451.

Elton, C. (1939). On the nature of cover. *Journal of Wildlife Management, 3(4)*, 332-338.

Escorihuela, R.M., Tobena, A. & Fernandez-Teruel, A. (1994). Environmental enrichment reverses the detrimental action of early inconsistent stimulation and increases the beneficial effects of postnatal handling on shuttlebox learning in adult rats. *Behavioral Brain Research, 61*, 169-173.

Estep, D.Q. & Baker, S.C. (1991). The effects of temporary cover on the behavior of socially housed stump-tailed macaques (*Macaca arctoides*). *Zoo Biology, 10*, 465-472.

Estevez, I., Newberry, R.C. & Faure, J.M. (1998). Complexity and aggression in Label Rouge chickens. In I. Veissier & A. Boissy (Eds.). *Proceedings of the 32nd Congress of the International Society of Applied Ethology*. (pp. 147). Clermont-Ferrand, France.

Fagen, R. (1982). Evolutionary issues in the development of behavioral flexibility. In P.P.G. Bateson & P.H. Klopfer (Eds.), *Perspectives in Ethology*, Vol. 5. New York: Plenum Press.

Farrell, R., Evans, S. & Corbett, D. (2001). Environmental enrichment enhances recovery of function but exacerbates ischemic cell death. *Neuroscience, 107*, 585-592.

Fernandez-Teruel, A., Escorihuela, R.M., Castellano, B., Gonzalez, B. & Tobena, A. (1997). Neonatal handling and environmental enrichment effects on emotionality, novelty/reward seeking, and age-related cognitive and hippocampal impairments: focus on the Roman rat lines. *Behavior Genetics, 27*, 513-526.

Fickenwirth, A., Folsch, D.W. & Dolf, C. (1985). San shortens the claws and beaks of hens – prevents injuries: In R.M. Wegner (Ed.), *Proceedings of second symposium on poultry welfare*. (pp. 288-290). Celle: WPSA.

Fraser, A.F. (1968). Behavior disorders in domestic animals. In M.W. Fox (Ed.), *Abnormal behavior in animals.* (pp.179-187). Philadelphia: Saunders.

Fraser, D. (1975). The effect of straw on the behavior of sows in tether stalls. *Animal Production, 21*, 59-68.

Fraser, D. (1993). Assessing animal well-being: common sense, uncommon science. In B. Baumgardt & H.G. Grey (Eds.), *Food animal well-being* (pp. 37-54). West Lafayette, Indiana: Purdue University.

Fraser, D. & Broom, D.M. (1996). *Farm animal behavior and welfare*. London, UK: CABI Publishing. (Original work published 1990).

Fraser, D., Phillips, P.A., & Thompson, B.K. (1986). A test of a free-access two-level pen for fattening pigs. *Animal Production, 42*, 269-274.

Fox, M.W. (1968). Introduction: the concepts of normal and abnormal behavior. In M.W. Fox (Ed.), *Abnormal behavior in animals.* (pp.1-5). Philadelphia: Saunders.

Fox, R.A. & Millam, J.R. (2004). The effect of early environment on neophobia in orange-winged Amazon parrots (*Amazona amazonica*). *Applied Animal Behavior Science, 89*, 117-129.

Gilloux, I., Gurnell, J., & Shepherdson, D. (1992). An Enrichment device for great apes. *Animal Welfare, 1*, 279-289.

Ginsberg, H.J., Braud, W.G. & Taylor, R.D. (1974). Inhibition of distress vocalizations in the open field as a function of heightened fear or arousal in domestic fowl (*Gallus gallus*). *Animal Behavior, 22*, 745-749.

Goodwin, D., Davidson, H.P.B., & Harris, P. (2002). Foraging enrichment for stabled horses: effects on behavior and selection. *Equine Veterinary Journal*, *34*(7), 686-691.

Gonyou, H.W., Hemsworth, P.H. & Barnett, J.L. (1986). Effects of frequent interactions with humans on growing pigs. *Applied Animal Behavior Science, 16*, 269-278.

Gray, J.A. (1987). *The Psychology of Fear and Stress*. 2nd edition. Cambridge: Cambridge University Press.

Grayson, L. (2000). *Animals in Research: For and Against*. London: The British Library.

Greenough, W.T. (1976). In Rosenzweig, M.R. & Bennett, E.L. (Eds.), *Neural Mechanisms of learning and Memory*. (pp. 255-278). Cambridge, Massachusetts: MIT Press.

Grigor, P.N., Hughes, B.O., & Appleby, M.C. (1995). Effects of regular handling and exposure to an outside area on subsequent fearfulness and dispersal in domestic hens. *Applied Animal Behavior Science*, *44*, 47-55.

Gross, W.B. & Siegel, P.B. (1982). Socialization as a factor in resistance to infection, feed efficiency, and response to antigen in chickens. *American Journal of Veterinary Research, 43*, 2010-2012.

Gunnarsson, S., Yngvesson, J., Keeling, L., & Forkman, B. (2000). Rearing without early access to perches impairs spatial skills of laying hens. *Applied Animal Behavior Science*, *67*, 217-228.

Guy, J.H., Field, J.C., Slaughter, D. & Rose, S.P. (2001). Preliminary observations on the effect of perches and objects in the feed trough on the behavior and welfare of caged hens. *British Poultry Science, 42*, S71-S72.

Guy, J.H., Rowlinson, P., Chadwick, J.P., & Ellis, M. (2002a). Behavior of two genotypes of growing-finishing pigs in three different housing systems. *Applied Animal Behavior Science, 75*, 193-206.

Gvaryahu, G., Cunningham, D.L., & Van Tienhoven, A. (1989). Filial imprinting, environmental enrichment, and music application effects on behavior and performance of meat strain chicks. *Poultry Science*, *68*, 211-217.

Gvaryahu, G., Ararat, E., Asaf, E., Lev, M., Weller, J.I., Robinzon, B. & Snapir, N. (1994). An enrichment object that reduces aggressiveness and mortality in caged laying hens. *Physiology and Behavior, 55*, 313-316.

Häne, M., Huber-Eicher, B. & Fröhlich, E. (2000). Survey of laying hen husbandry in Switzerland. *World's Poultry Science Journal, 56*, 21-31.

Hannigan, J.H., Berman, R.F. & Zajac, C.S. (1993). Environmental enrichment and the behavioral effects of prenatal exposure to alcohol in rats. *Neurotoxicology and Teratology, 15*, 261-266.

Harrison, R. (1964). *Animal Machines*. London, Vincent Stuart Ltd.

Haskell, M., Wemelsfelder, F., Mendl, M.T., Calvert, S., & Lawrence, A.B. (1996). The effect of substrate-impoverished housing environments on the diversity of behavior in pigs. *Behavior, 113*, 741-761.

Healy, S.D. & Tovée, M.J. (1999). Environmental enrichment and impoverishment: neurophysiological effects. In F. Dollins (Ed.), *Attitudes to Animals*. (pp 54-76). Cambridge: Cambridge University Press.

Heikkila, A., Wichman, A., Gunnarsson, S. & Valros, A. (2006). Development of perching behavior in chicks reared in enriched environment. *Applied Animal Behavior Science, 99*, 145-156.

Hemsworth, P.H. & Barnett, J.L. (1989). Relationships between fear of humans, productivity and cage position of laying hens. *British Poultry Science, 30*, 505-518.

Hemsworth, P.H. & Barnett, J.L. (1992). The effects of early contact with humans on the subsequent level of fear of humans in pigs. *Applied Animal Behavior Science, 35*, 83-90.

Hemsworth, P.H., Coleman, G.J., Cox, M. & Barnett, J.L. (1994). Stimulus generalization: the inability of pigs to discriminate between humans on the basis of their previous handling experience. *Applied Animal Behavior Science, 40*, 129-142.

Hemsworth, P.H., Price, E.O. & Borgwardt, R. (1996). Behavioral responses of domestic pigs and cattle to humans and novel stimuli. *Applied Animal Behavior Science, 50*, 43-56.

Hogan, J.A. (1965). An experimental study of conflict and fear: an analysis of behavior of young chicks towards a mealworm. Part 1. The behavior of chicks which do not eat the mealworm. *Behavior,* 25-26, 45-95.

Hoplight, B.J., Sherman, G.F., Hyde, L.A. & Denenberg, V.H. (2001). Effects of neocortical ectopias and environmental enrichment on Hebb-Williams maze learning in BXSB mice. *Neurobiology of Learning and Memory, 76*, 33-45.

Huber, H., Fölsch, D.W. & Stahli, U. (1985). Influence of various nesting materials on nest-site selection of the domestic hen. *British Poultry Science, 26*, 367-373.

Huber-Eicher, B. A. & Sebo, F. (2001b). Reducing feather pecking when raising laying hen chicks in aviary systems. *Applied Animal Behavior Science, 73*, 59-68.

Huber-Eicher, B. & Wechsler, B. (1997). Feather pecking in domestic chicks: its relation to dustbathing and foraging. *Animal Behavior, 54*, 757-768.

Huber-Eicher, B. & Wechsler, B. (1998). The effect of quality and availability of foraging materials on feather pecking in laying hen chicks. *Animal Behavior, 55*, 861-873.

Hughes, B.O. (1975). The concept of an optimal stocking density and its selection for egg production. In B.M. Freeman & K.N. Boorman (Eds.), *Economic Factors Affecting Egg Production*. (pp. 271-298). Edinburgh, UK: British Poultry Science Ltd.

Hughes, B.O. (1976a). Behavior as an index of welfare. In Proceedings of the fifth European Poultry Conference, (pp. 1005-1018). Malta.

Hughes, B.O. (1978). Behavior in different environments and its implications for welfare. In Y. Sørensen (ed.), *First Danish seminar on poultry welfare in egg-laying cages*. (pp. 21-27). Copenhagen: National committee for poultry and eggs.

Hughes, B.O. (1993). Choice between artificial turf and wire floor as nest sites in individually caged laying hens. *Applied Animal Behavior Science, 36*, 327-335.

Hughes, B.O. & Black, A.J. (1974). The effect of environmental factors on activity, selected behavior patterns and 'fear' of fowls in cages and pens. *British Poultry Science, 15*, 375-380.

Hughes, B.O. & Black, A.J. (1976). The influence of handling on egg production, egg shell quality and avoidance behavior of hens. *British Poultry Science, 17*, 135-144.

Hughes, B.O. & Duncan, I.J.H. (1988). The notion of ethological 'need', models of motivation and animal welfare. *Animal Behavior*, *36*, 1696-1707.

Hughes, B.O., Duncan, I.J.H. & Brown, M.F. (1989). The performance of nest building by domestic hens: is it more important than the construction of a nest? *Animal Behavior, 37*, 210-214.

Ickes, B.R., Pham, T.M., Sanders, L.A., Albeck, D.S., Mohammed, A.H. & Granholm, A.C. (2000). Long term environmental enrichment leads to regional increases in neurotropin levels in rat brain. *Experimental Neurology, 164*, 45-52.

Inglis, I.R. (1975). Enriched sensory experience in adulthood increases subsequent exploratory behavior in the rat. *Animal Behavior, 23*, 932-940.

Inglis, I.R. (1983). Towards a cognitive theory of exploratory behavior. In J. Archer & L.I.A. Birke (Eds.), *Exploration in Animals and Humans*. (pp. 72-117). London, UK: Van Nostrang Reinhold Inc.

Ishiwata, T., Uetake, K., & Tanaka, T. (2002). Use of a box to prevent agonistic behavior after regrouping in isolated and non-isolated pigs. *Animal Science Journal, 73*, 287-292.

Johnsen, P.F., Vestergaard, K.S. & Norgaard-Nielsen, G. (1998). Influence of early rearing conditions on the development of feather pecking and cannibalism in domestic fowl. *Applied Animal Behavior Science, 60*, 25-41.

Jones, R.B. (1982). Effects of early environmental enrichment upon open-field behavior and timidity in the domestic chick. *Developmental Psychobiology, 15*, 105-111.

Jones, R.B. (1986a). Responses of domestic chicks to novel food as a function of sex, strain and previous experience. *Behavior Processes, 12*, 261-271.

Jones, R. B. (1987a). Fear and fear responses: a hypothetical consideration. *Medical Science Research, 15,* 1287-1290.

Jones, R.B. (1989a). Development and alleviation of fear. In J.M. Faure & A.D. Mills (Eds.). *Proceedings of the 3rd European Symposium on Poultry Welfare*. (pp. 123-136). Tours: World Poultry Association.

Jones, R.B. (1996). Fear and adaptability in poultry: insights, implications, and imperatives. *British Poultry Science Journal, 52*, 131-174.

Jones, R.B. (1997). Fear and Distress. In M.C. Appleby & B.O. Hughes (Eds.), *Animal Welfare* (pp. 75 – 87). Oxfordshire, UK: CABI Publishing.

Jones, R.B. (2001). Environmental enrichment for poultry welfare. In C.M. Wathes (Ed.), *Integrated Management Systems for Livestock.* (pp. 125-131). British Society for Animal Sciences. Penicuik, Scotland: Occasional Publication 28.

Jones, R.B. (2004). Environmental enrichment: the need for practical strategies to improve poultry welfare. In G.C. Perry (Ed.), *Welfare of the laying hen* (pp. 215-225). CAB Publishing.

Jones, R.B. & Carmichael, N.L. (1999a). Can 'environmental enrichment' affect domestic chickens' preferences for one half of an otherwise symmetrical home cage? *Animal Welfare, 8*, 159-164.

Jones. R.B., Carmichael, N.L., & Rayner, E. (2000). Pecking preferences and pre-dispositions in domestic chicks: implications for the development of environmental enrichment devices. *Applied Animal Behavior Science*, *69*, 291-312.

Jones, R.B., Carmichael, N.L. & Williams, C. (1998). Social housing and domestic chicks' responses to symbolic video images. *Applied Animal Behavior Science, 56*, 231-243.

Jones, R.B. & Faure, J.M. (1981). The effects of regular handling on fear in the domestic chick. *Behavior Processes, 6*, 135-143.

Jones, R.B., Harvey, S., Hughes, B.O., & Chadwick, A. (1980). Growth and the plasma concentrations of growth hormone and prolactin in chicks: effects of "environmental enrichment", sex and strain. *British Poultry Science*, *21*, 457-462.

Jones, R.B. & Hughes, B.O. (1981). Effects of regular handling on growth in male and female chicks of broiler and layer strains. *British Poultry Science, 22*, 461-465.

Jones, R.B & Hughes, B.O. (1986). Fearfulness and abnormalities in the chicken's eggshell: is there a link? In J. Czatco (Ed.). *Proceedings of the International Symposium on Applied Ethology in Farm Animals*. (pp. 171-175). Budapest: Hungarian Academy of Sciences.

Jones, R.B. & Waddington, D. (1992). Modification of fear in domestic chickens, *Gallus gallus domesticus*, via regular handling and early environmental enrichment. *Animal Behavior*, *43*, 1021-1033.

Kastelein, R.A & Wiepkema, P.R. (1989). A digging trough as occupational therapy for Pacific walruses (*Odobenus rosmarus divergens)* in human care. *Aquatic Mammals, 15,* 9-17.

Keeling, L.K. & Gonyou, H.W. (2001) (Eds.). *Social Behavior in Farm Animals*. (pp. 15-17). Wallingford, UK: CABI Publishing.

Kelly, H.R.C., Bruce, J.M., English, P.R., Fowler, V.R., & Edwards, S.A. (2000). Behavior of 3-week weaned pigs in Straw-Flow, deep straw and flatdeck housing systems. *Applied Animal Behavior Science, 68*, 269-280.

Kempermann, G., Kuhn, H.G. & Gage, F.H. (1997). More hippocampal neurons in adult mice living in an enriched environment. *Nature, 386*, 493-495.

Kendrick, K.M. (1992). Cognition. In C.J.C. Phillips & D. Piggins (Eds.), *Farm animals and their environment*. (pp. 209-231). Wallingford, UK: CAB International.

Krause, E.T., Naguib, M., Trillmich, F., & Scrader, L. (2006). The effects of short term enrichment on learning in chickens from a laying strain (*Gallus gallus domesticus*). *Applied Animal Behavior Science*, *101*, 318-327.

Laughlin, K. & Zanella, A.J. (2003). Influence of weaning age on stress-induced deficits of spatial learning in pigs. In: Proceedings of the 37th International Society for Applied and Ethology (ISAE). (pp. 92). Abano Terme, Italy.

Leggio, M.G., Mandolesi, L., Federico, F., Spirito, F., Ricci, B., Gelfo, F. & Petrosini, L. (2005). Environmental enrichment promotes improved spatial abilities and enhanced dendritic growth in the rat. *Behavioral Brain research, 163*, 78-90.

Leone, E.H. & Estevez, I. (2008). Economic and welfare benefits of environmental enrichment for broiler breeders. *Poultry Science*, *87*, 14-21.

Lundberg, A. & Keeling, L.J. (1999). The impact of social factors on nesting in laying hens (*Gallus gallus domesticus*). *Applied Animal Behavior Science, 64*, 57-69.

Lyons, C.A.P., Bruce, J.K., Fowler, V.R., & English, P.R. (1995). A comparison of productivity and welfare of growing pigs in four intensive systems. *Livestock Production Science, 43*, 265-274.

McAdie, T.M., Keeling, L.J., Blokhuis, H.J., & Jones, R.B. (2005). Reduction in feather pecking and improvement of feather condition with the presentation of a string device to chickens. *Applied Animal Behavior Science*, *93*, 67-80.

McBride, G. (1970). The social control of behavior in fowls. In B.M. Freeman & R.F. Gordon (Eds.). *Aspects of Poultry Behavior*. (pp. 3-13). Edinburgh: British Poultry Science.

McGlone, J.J. & Curtis, S.E. (1985). Behavior and performance of weanling pigs in pens equipped with hide areas. *Journal of Animal Science, 60*, 20-24.

McNamara, R.K. & Skelton, R.W. (1993). The neuropharmacological and neurochemical basis of place learning in the Morris water maze. *Brain Research Review, 18*, 33-49.

Mench, J.A. (1992). The welfare of poultry in modern production systems. *Poultry Science Reviews, 4,* 107-128.

Mench, J.A. (1994). Environmental enrichment and exploration. *Lab Animal, February*, 38-41.

Mench, J.A. (1998). Environmental enrichment and the importance of exploratory behavior. In D.J. Shepherdson, J.D. Mellen & M. Hutchins (Eds.), *Second Nature: Environmental enrichment for captive animals*. (pp. 30-46). Washington: Smithsonian Institution Press.

Mench, J.A. & Mason, G.J. (1997). Behavior. In M.C. Appleby & B.O. Hughes (Eds.), *Animal Welfare* (pp. 127 – 141). Oxfordshire, UK: CABI Publishing.

Mench, J.A. & Tienhoven, van A. (1986). Farm animal welfare. *American Scientist, 74*, 598-603.

Mendl, M.T., Burman, O., Laughlin, K. & Paul, E. (2001). Animal memory and animal welfare. *Animal Welfare, 10*, S141-S159.

Mendl, M.T., Erhard, H.W., Haskell, M., Wemelsfelder, F., & Lawrence, A.B. (1997). Experience in substrate-enriched and substrate-impoverished environments affects behavior in pigs in a T-maze task. *Behavior, 134*, 643-659.

Mendl, M.T., Laughlin, K. & Hitchcock, D. (1997). Pigs in space: spatial memory and its susceptibility to interference. *Animal Behavior, 54*, 1491-1508.

Mills, A.D. & Faure, J.M. (1990). Panic and hysteria in domestic fowl: a review. In R. Zayan & R. Dantzer (Eds.). *Social Stress in Domestic Animals*. (pp. 248-272). Dordrecht: Kluwer Academic Publishers.

Murphy, L.B. & Duncan, I.J.H. (1978). Attempts to modify the responses of domestic fowl towards human beings. II. The effect of the experience. *Applied Animal Ethology, 4*, 5-12.

Newberry, R.C. (1993). The space-time continuum, and its relevance to farm animals. *Etologia, 3*, 219-234.

Newberry, R.C. (1995). Environmental enrichment: Increasing the biological relevance of captive environments. *Applied Animal Behavior Science*, *44*, 229-243.

Newberry, R.C. (1999). Exploratory behavior of young domestic fowl. *Applied Animal Behavior Science*, *63*, 311-321.

Newberry, R.C. & Hall, J.W. (1990). Use of pen space by broiler chickens, effects of age and pen size. *Applied Animal Behavior Science, 25*, 125-136.

Newberry, R.C. & Shackleton, D.M. (1997). Use of visual cover by domestic fowl: a Venetian blind effect? *Animal Behavior, 54*, 387-395.

Nicol, C.J. (1992). Effects of environmental enrichment and gentle handling on behavior and fear responses of transported broilers. *Applied Animal Behavior Science, 33*, 367-380.

Nicol, C.J. (2004). Chicken Cognition. In G.C. Perry (Ed.), *Welfare of the laying hen* (pp. 177-189). CAB Publishing.

Nilsson, M., Perfilieva, E., Johansson, U., Orwar, O. & Eriksson, P.S. (1999). Enriched environment increases neurogenesis in the adult rat dentate gyrus and improves spatial memory. *Journal of Neurobiology, 39*, 569-578.

Orlans, F.B., Beauchamp, T.L., Dresser, R., Morton, D.B., & Gluck, J.P. (1998). *The human use of animals: case studies in ethical choice*. New York: Oxford University Press.

Patel, S.N, Clayton, N.S. & Krebs, J.R. (1997). Spatial learning indices neurogenesis in the avian brain. *Behavioral Brain Research, 89*, 115-128.

Pearce, G.P., Paterson, A.M., & Pearce, A.N. (1989). The influence of pleasant and unpleasant handling and the provision of toys on the growth and behavior of male pigs. *Applied Animal Behavior Science*, *23*, 27-37.

Pelley, M.C., Lirette, A., & Tennessen. T. (1995). Observations on the response of feedlot cattle to attempted environmental enrichment. *Canadian Journal of Animal Science*, *75*, 631-632.

Pereira, G.P., Macedonia, J.M., Haring, D.M. & Simons, E.L. (1989). Maintenance of primates in captivity for research: the need for naturalistic environments. In E. Segal (Ed.), *Housing, Care and Psychological Wellbeing of Captive and Laboratory Primates* (pp. 40-60). Park Ridge, NJ: Noyes Publications.

Petherick, J.C. & Rushen, J. (1997). Behavioral Restriction. In M.C. Appleby & B.O. Hughes (Eds.), *Animal Welfare* (pp. 89 – 105). Oxfordshire, UK: CABI Publishing.

Pham, T.M., Ickes, B., Albeck, D., Soderstrom, S., Granholm, A.C. & Mohammed, A.H. (1999). Changes in brain nerve growth factor levels and nerve growth factor receptors in rats exposed to environmental enrichment for 1 year. *Neuroscience, 94*, 279-86.

Phillips, C.J.C. (1993). *Cattle Behavior*. Ipswich, UK: Farming Press Books.

Price, E.O. (1984). Behavioral aspects of animal domestication. *Quarterly Review of Biology, 59*, 1-32.

Prusky, G.T., Reidel, C. & Douglas, R.M. (2000). Environmental enrichment from birth enhances visual acuity but not place learning in mice. *Behavioral Brain Research, 114*, 11-15.

Reed, H.J., Wilkins, L.J., Austin, S.D. & Gregory, N.G. (1993). The effect of environmental enrichment during rearing on fear reactions and depopulation trauma in adult caged hens. *Applied Animal Behavior Science, 36*, 39-46.

Reinhardt, V. (1994). Caged rhesus macaques voluntarily work for ordinary food. *Primates, 35*, 95-98.

Renner, M.J. & Rosenzweig, M.R. (1987). *Enriched and Impoverished Environments. Effects on Brain and Behavior*. New York: Spinger-Verlag.

Robert, S., Matte, J.J., Farmer, C., Girard, C.L. & Martineau, G.P. (1993). High fibre diets in sows: effects on stereotypies and adjunctive drinking. *Applied Animal Behavior Science, 37,* 297-309.

Rogers, L.J. (1995). *The Development of brain and behavior in the chicken*. Wallingford, UK: CAB International.

Rollin, B.E. (1992). *Animal rights and human morality*. New York: Prometheus Books.

Rollin, B.E. (1993). Animal production and the new social ethic for animals. In B. Baumgardt & H.G. Grey (Eds.), *Food animal well-being* (pp. 3-13). West Lafayette, Indiana: Purdue University.

Rollin, B.E. (1995). *Farm animal welfare*. Iowa: Iowa State University Press.

Rollin, B.E. (1998). The unheeded cry: animal consciousness, animal pain, and science. Iowa: Iowa State University Press.

Rose, S.P., Fielden, M., Foote, W.R. & Grandin, P. (1995). Sequential feeding of whole wheat to growing broiler chickens. *British Poultry Science, 36*, 97-111.

Rosenzweig, M.R. & Bennett, E.L. (1996). Psychobiology of plasticity: effects of training and experience on brain and behavior. *Behavioral Brain Research, 78*, 57-65.

Rushen, J., Lawrence, A.B. & Terlouw, E.M.C. (1993a). The motivational basis of stereotypies. In A.B. Lawrence & J. Rushen (Eds.), *Stereotypic animal behavior: fundamentals and applications to animal welfare* (pp. 41-64). Wallingford, UK: CABI Publishing.

Ruiterkamp, W.A. (1987). The behavior of grower pigs in relation to housing systems. *Netherlands Journal of Agricultural Science, 35*, 67-70.

Schouten, W.G.P. (1986). *Rearing conditions and behavior in pigs.* Netherlands: Wageningen Agricultural University.

Schrott, L.M., Denenberg, V.H., Sherman, G.F., Waters, N.S., Rosen, G.D. & Galaburda, A.M. (1992). Environmental enrichment, neocortical ectopias and behavior in the autoimmune Nzb mouse. *Developmental Brain Research, 67*, 85-93.

Shapiro, L. (2000). *Applied Animal Ethics.* New York: Delmar Thomson Learning.

Shepherdson, D.J. (1998). Tracing the path of environmental enrichment in zoos. In D.J. Shepherdson, J.D. Mellen & M. Hutchins (Eds.), *Second Nature: Environmental enrichment for captive animals*. (pp. 1-12). Washington: Smithsonian Institution Press.

Shepherdson, D.J., Carlstead, K., Mellen, J.D. & Seidensticker, J. (1993). The influence of food presentation on the behavior of small cats in confined environments. *Zoo Biology, 12*, 203-216.

Sherwin, C.M. & Nicol, C.J. (1993). Factors influencing floor-laying by hens in modified cages. *Applied Animal Behavior Science, 36*, 211-222.

Sherwin, C.M., Lewis, P.D. & Perry, G.C. (1999). Effects of environmental enrichment, fluorescent and intermittent lighting on injurious pecking amongst male turkey poults. *British Poultry Science, 40*, 592-598.

Sneddon, I.A., Beattie, V.E., Dunne, L., & Neil, W. (2000). The effect of environmental enrichment on learning in pigs. *Animal Welfare, 9*, 373-383.

Stolba, A., Wood-Gush, D.G.M. (1980). Arousal and exploration in growing pigs in different environments. *Applied Animal Ethology, 6*, 382-383.

Stolba, A. & Wood-Gush, D.G.M. (1984). The identification of behavioral key features and their incorporation into housing design for pigs. *Annales de Recherches Vétérinaires, 15*, 287-298.

Scott, K., Chennells, D.J., Campbell, F.M., Hunt, B., Armstrong, D., Taylor, L., Gill, B.P., & Edwards, S.A. (2006a). The welfare of finishing pigs in two contrasting housing systems: fully slatted versus straw bedded accommodation. *Livestock Science, 103*, 104-115.

Tang, Y.P., Wang, H., Feng, R., Kyin, M. & Tsien, J.Z. (2001). Differential effects of enrichment on learning and memory function in NR2B transgenic mice. *Neuropharmacology, 41*, 779-790.

Tanika, T. & Hurnik, J.F. (1992). Comparison of behavior and performance of laying hens housed in battery cages and an aviary. *Poultry Science, 71*, 235-243.

Tees, R.C. (1999). The influences of sex, rearing environment, and neonatal choline dietary supplementation on spatial and nonspatial learning and memory in adult rats. *Developmental Psychobiology, 35*, 328-342.

Thompson, C. I. (1976). Growth in the Hubbard broiler: increased size following early handling. *Developmental Psychobiology, 9*, 459-464.

Thorne, J.B., Goodwin, D., Kennedy, M.J., Davidson, H.P.B., & Harris, P. (2005). Foraging enrichment for individually house horses: Practicality and effects on behavior. *Applied Animal Behavior Science*, *94*, 149-164.

Torasdotter, M., Metsis, M., Henriksson, B.G., Winblad, B. & Mohammed, A.H. (1998). Environmental enrichment results in higher levels of nerve growth factor mRNA in the rat visual cortex and hippocampus. *Behavioral Brain Research, 93*, 83-90.

Tuyttens, F.A.M. (2005). The importance of straw for pigs and cattle welfare: a review. *Applied Animal Behavior Science, 92*, 261-282.

Van der Beek, E.M., Bolhuis, J.E., Karman, A.G., Van Eerdenburg, F.J.C.M. & Wiegant, V.M. (2000). Housing condition affects the correlation between volume of the dentate gyrus and the cortisol response to stress in pigs. *Abstracts Society for Neuroscience, 26*, part 1. 30th Annual Meeting, New Orleans (abstract).

van de Weerd, H.A., Docking, C.M., Day, J.E.L., & Edwards, S.A. (2005). The development of harmful social behaviors in pigs with intact tails and different enrichment backgrounds in two housing systems. *Animal Science, 80*, 289-298.

Van Praag, H., Kempermann, G. & Gage, F.H. (2000). Neural consequences of environmental enrichment. *Nature Reviews Neuroscience, 1*, 191-198.

Waran, N.K. & Broom, D.M (1993). The influence of a barrier on the behavior and growth of early-weaned piglets. *Animal Production, 56*, 115-119.

Webster, J. (2005). *Animal Welfare: Limping towards Eden.* UFAW Animal Welfare Series: Blackwell Publishing.

Wechsler, B. (1995). Coping and coping strategies: a behavioral view. *Applied Animal Behavior Science, 43*, 123-134.

Wechsler, B. & Lea, S.E.G. (2007). Adaptation by learning: Its significance for farm animal husbandry. *Applied Animal Behavior Science*, *108*, 197-214.

Weiss, J.M. (1971). Effects of coping behavior with and without a feedback signal on stress pathology in rats. *Journal of Comparative and Physiological Psychology, 77,* 22-30.

Wemelsfelder, F., Haskell, M., Mendl, M., Calvert, S., & Lawrence, A.B. (2000). Diversity of behavior during novel object tests is reduced in pigs housed in substrate-impoverished conditions. *Animal Behavior, 60*, 385-394.

Wemelsfelder, F. (1993). The concept of animal boredom and its relationship to stereotyped behavior. In A.B. Lawrence & J. Rushen (Eds.), *Stereotypic animal behavior: fundamentals and applications to animal welfare* (pp. 65-95). Wallingford, UK: CABI Publishing.

Wemelsfelder, F. & Birke, L. (1997). Environmental Challenge. In M.C. Appleby & B.O. Hughes (Eds.), *Animal Welfare* (pp. 35 – 47). Oxfordshire, UK: CABI Publishing.

Westerath, H.S., Laister, S., Winckler, C., & Knierim, U. (2009). Exploration as an indicator of good welfare in beef bulls: An attempt to develop a test for on-farm assessment. *Applied Animal Behavior Science, 116,* 126-133.

Wichman, A., Heikkila, M., Valros, A., Forkman, B. & Keeling, L.J. (2007). Perching behavior in chickens and its relation to spatial ability. *Applied Animal Behavior Science, 105*, 165-179.

Widman, D.R., Abrahamsen, G.C. & Rosellini R.A. (1992). Environmental enrichment: the influences of restricted daily exposure and subsequent exposure to uncontrollable stress. *Physiology and Behavior, 51*, 309-318.

Wiepkema, P.R. (1987). Behavioral aspects of stress. In P.R. Wiepkema & P.W.M. Van Adrichem (Eds.), *Biology of Stress in Farm Animals*: *An integrative Approach.* Boston: M. Nijhoff for the Commission of the European Communities.

Wiepkema, P.R. & Schouten, W.P.G. (1990). Mechanisms of coping in social situations. In R. Zayan & R. Dantzer (Eds.), *Social Stress in Domestic Animals*. (pp. 8-24). Dordrecht: Kluwer Academic Publications.5

Williams, B.M., Luo, Y., Ward, C., Redd, K., Gibson, R., Kuczaj, S.A., McCoy, J.G. (2001). Environmental enrichment: Effects on spatial memory and hippocampal CREB immunoreactivity. *Physiology and Behavior, 73*, 649-658.

Wilson, S.C., Mitlöhner, F.M., Morrow-Tesch, J., Dailey, J.W., & McGlone, J.J. (2002). An assessment of several potential enrichment devices for feedlot cattle. *Applied Animal Behavior Science*, *76*, 259-265.

Woodcock, E.A. & Richardson, R. (2000). Effects of environmental enrichment on rate of contextual processing and discriminative ability in adult rats. *Neurobiology of Learning and Memory, 73*, 1-10.

Wood-Gush, D.G.M. & Gilbert, A.B. (1969). Observations on the laying behavior of hens in battery cages. *British Poultry Science, 10*, 29-36.

Wynne, C.D.L. (2001). *Animal Cognition: the mental lives of animals*. New York, N.Y.: Palgrave MacMillan.

Xerri, C., Coq, J.O., Merzenich, M.M.& Jenkins, W.M. (1996). Experience-induced plasticity of cutaneous maps in the primary somatosensory cortex of adult monkeys and rats. *Journal of Physiology-Paris, 90*, 277-287.

Young, R.J., Carruthers, J. & Lawence, A.B. (1994). The effect of a foraging device (the 'Edinburgh Football') on the behavior of pigs. *Applied Animal Behavior Science, 39,* 237-247.

Young, R.J. (2003). *Environmental enrichment for captive animals*. Oxford, UK: Blackwell Publishing.