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Evaluating Insect Experimentation: Ethical, Scientific and Regulatory Perspective

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ABSTRACT

Animal and insect testing is an essential part of experimentation in the current world. However, what goes unseen is the amount of insect testing, especially cockroaches, due to their undesirable nature. This study examines the scientific limitations of inherent animal and insect testing, reveals insights from studies about the memory and pain receptors of insects, and uncovers ethical backings of animal testing. One problem with animal testing is that there are limitations to model organisms because they are not humans and the reliability of animal testing is off. Which results in animal testing and lives in vain. In addition to this, insects, like cockroaches, have particular learning, memory and nociception pathways which reveal the elevated cognitive capabilities that insects may have. In conclusion, this paper draws attention and scrutinizes the current ethical and regulatory systems in place for insect testing. Although the utilitarian perspective weighs the benefits of medical advancements against the ethical concerns of animal/insect suffering, by embracing other potential alternatives to animal testing, modern-day research can head towards a more humane scientific practice.

Scientific Limitations in Animal Testing

Animal testing is a core process within modern-day research, but there are 3 key ways in which the results of animal testing may not be applicable to the usage of animals. Firstly, the environment within a laboratory is markedly different from the real world. Therefore, the conditions of the laboratory may elicit different neurological, genetic, and nerve effects that would not have been present if the trials had not occurred in a laboratory. Secondly, animal models that test human disease can be faulty, due to the complexity of human diseases and the simplicity of animal models. This is shown through the high failure rate of cancer medication, as animal models cannot replicate human carcinogenesis. Furthermore, a systematic review in 2007 showed that the odds of correctly predicting whether or not a certain treatment would or would not benefit humans was near 50%. Lastly, the differences between animals and humans in their physiology, behavior, pharmacokinetics, and genetics significantly limit the reliability of animal studies. Seen in mice, they have vastly different responses to various inflammatory conditions, and thus are responsible for a high drug failure rate. Efforts to ameliorate this issue such as genetically modifying the mice to have human genes also do not work, for mice express human genes differently than humans do. For example, a human gene meant to create blood sugar-controlling proteins led to mice seeing a loss in their regulation of blood sugar. Even nonhuman primates, animals that have the closest similarity to humans, can show different results in drug results. In the past, potential methods to treat Parkinson's disease, cardiovascular disease, and various viruses have shown promise in nonhuman primates but resulted in disappointing results in humans. Several other notable instances have also occurred in the past, such as hormone replacement therapy to treat cardiovascular disease being successful in nonhuman primates, but leading to an increased risk in women, and repeated failures in creating an HIV vaccine. These repeated instances show that animal experimentation is not always the most successful route (Akhtar, 2015).

Cockroach Learning and Memory

Cockroaches have been subjects of interest in studies related to learning and memory, particularly through classical and operant conditioning paradigms. In the past, cockroaches have been tested under classical and operant conditioning by giving them various tasks. Classical conditioning is a type of learning that allows a neutral stimulus to elicit a response after pairing it with a stimulus that is known to elicit a response. Operant conditioning is a type of learning in which rewards and punishments are used to alter the response from a neutral stimulus (American Psychological Association, 2018). An experiment by Arican et. al investigated the ability to which honeybees and cockroaches were able to express the correct behavior. Research has shown that cockroaches exhibit individuality in learning and memory during both classical and operant conditioning tasks. Studies have demonstrated that cockroaches can express correct behaviors in response to conditioning trials, indicating their ability to form memories and learn. This is further emphasized by how the cockroaches consistently performed the correct behavior after only a single learning trail (Arican et al., 2020).

In addition to learning, studies have been conducted to elucidate the neural mechanisms of learning and memory in cockroaches as well. Ultimately, these studies show that cockroaches can form memories, but to a certain extent. Dopamine and tyrosine hydroxylase-immunoreactive neurons in the cockroach brain have been implicated in aversive memory formation (Hamanaka et al., 2016). This implicates certain neurons, suggesting that there are specific neuronal pathways for memory processing. A comprehensive study discovered the molecular and genetic views of memory consolidation in cockroaches (Pintér, 2005). These studies call to action to investigate short-term, intermediate-term, and long-term memory formation in cockroaches.

Insect Nociception and Pain Perception

Pain in animals is typically assessed through physiological and behavioral changes, allowing researchers to observe and determine whether insects feel pain. However, it is important to note that the conclusions drawn by these observations cannot currently definitively state whether or not the animals, in this case the cockroach, are actually feeling a sensation similar to that of one that humans feel. Commonly observed factors to assess pain include responses such as flexor reflexes, increased blood pressure, tachypnoea, and vocalization. Research by Wigglesworth examined the possibility of insect pain, noting that while high temperature and electric shock can cause pain, most stimuli do not. To fully examine the question, there are three key considerations. First, is the “adaptive role of pain in mammals” and how these roles apply to insects. Secondly, the examination extends to the adaptive role of pain in mammals and its relevance to insect biology, highlighting that insect behavior patterns are largely pre-programmed, although insects can learn to avoid certain stimuli. However, this avoidance is highly situation-specific and often pre-programmed, leading to unreliable signs of pain since noxious stimuli do not always produce strong motor outputs (Eisemann et al., 1984).

The neural basis of nociception and pain perception in mammals differs from that in insects, which have similar yet contrasting behavioral responses to trauma or noxious stimulation. Previous research suggesting insects can't feel pain is based on three main points: insects continue to feed or mate while experiencing noxious damage, they do not respond to noxious injury from parasites, and they do not protect the injury site. However, this evidence does not conclusively prove the absence of a painful mental state in insects, as they can exhibit non-reflexive protective behaviors and may act more injured in front of mates (Gibbons & Sarlak, 2020).

The findings suggest that pain for invertebrates differs from that for vertebrates, with different stimuli eliciting pain responses. Insect nociceptive processing occurs largely in parallel in the mushroom bodies and the central complex of the brain, but there is little evidence of a coordinated pain network integrating these areas (Adamo, 2019). Consequently, the likelihood of insects experiencing pain is low, despite their nociceptive

behaviors and highly situational cognitive conditions. Potential criteria for pain in insects include swift avoidance learning, anxiety, and risk aversion, long-term behavioral changes, trade-offs between avoidance and other motivations, activities directed towards the site of damage, and protection from further damage by limb autotomy (Elwood, 2023).

Nociceptive Pathway in Cockroaches

Nociceptors are responsible for relaying nociceptive information, which involves high-threshold mechanoreceptors, thermal receptors, chemical receptors, and polymodal receptors. These receptors process noxious stimuli through both the central nervous system (CNS) and the peripheral nervous system (PNS), typically activated by tissue injury and extreme temperatures, among other factors (Kendroud & Hanna, 2022). The perception of nociceptive stimuli depends on the frequency of action potentials, the interval between each action potential, and input from higher-order brain centers. Researchers tested the response to noxious stimuli by applying a heat probe to the cuticle of a cockroach, specifically examining neuronal responses and differentiating between tactile sensory axons and other noxious responses while observing the cockroach's behavior.

The probe was either cold or initially cold and then heated, with stimuli categorized as pre-noxious, tactile, or a combination. Noxious stimuli produced a greater escape time than the other types, averaging about five seconds in 27 out of 28 trials. Tactile stimuli evoked a response in the slow motor neuron (Ds) but rarely in the fast motor neuron (Df), whereas tactile-noxious stimuli elicited strong responses from both Df and Ds. Brief noxious and tactile stimuli resulted in similar escape responses, but continuous noxious stimuli caused a much longer escape duration compared to continuous tactile stimuli. This indicates a distinct pathway for processing nociceptive information (Emanuel & Libersat, 2019).

Nociceptive pathways are present in other lower species such as M. sexta and Drosophila, suggesting they might also exist in cockroaches. The cockroach's response to shock was measured through its contraction during three one-minute intervals: no shock, 50V AC every 10 seconds, and no shock again. This study aimed to determine if antistatic foam could be used to investigate insect behavior, with an adaptation period for cockroaches. Results showed significantly increased contractions when shocked, demonstrating a clear response to noxious stimuli different from normal responses. Additionally, the effects of heat on cockroaches and their reactions to various types and doses of drugs were examined (Abramson et al., 2004).

Cockroaches have specific physiological responses to various stimuli and the effectiveness of different drugs in modulating these responses. A study performed by Maliszewska et al. looked into the effects of heat on cockroaches, observing their reactions under different temperature conditions and drug treatments. Cockroaches were subjected to both normal heat, ranging from 10 to 40°C, and noxious heat at 50°C. The effects of drugs such as capsaicin, capsazepine, and camphor were observed. The results were that camphor had the most effect in altering cockroach behavior. Capsazepine required approximately five drops to exhibit efficacy, while capsaicin showed significant effects only in certain aspects, with the others being relatively mild. Thermo-TRP (transient receptor potential) channels of the cockroaches were examined to understand the mechanisms underlying heat sensitivity in cockroaches. Drugged cockroaches exhibited prolonged stays in noxious areas and displayed a preference for hotter normal temperatures, indicating alterations in their nociceptive responses. To account for potential confounding factors, levels of malondialdehyde (MDA) and catalase activity were assessed. Oxidative stress induced by noxious heat was observed only in control and vehicle-treated groups, not in the drugged ones, suggesting a protective effect of the drugs against oxidative damage. Catalase activity remained unaffected across all groups. Despite concerns about desensitization, the experiments were reproducible across multiple trials, indicating the robustness of the findings. Moreover, the efficacy of drug effects was found to be dose-dependent, highlighting the importance of dosage in modulating nociceptive pathways in cockroaches (Justyna Maliszewska et al., 2018).

Regulatory Framework and Ethical Guidelines

International ethical comparisons on the regulatory approach reveal significant differences between countries such as the UK, which relies heavily on state regulation, and Japan, which favors self-regulation. Current laws establish standards for the humane treatment and housing of animals in laboratories, encouraging the limitation and seeking of alternatives when consistent with scientific goals. However, if the justification for using animals is strong enough, including the use of great apes and other primates, it is permitted based on the assumption that advancing medical progress is more important. These laws focus heavily on housing and care during research but do not adequately address three key issues: suffering from poorly justified research protocols, the lack of concrete objective standards due to reliance on overseers' judgment, and unnecessary suffering when not strictly required by the experiment (Latham, 2012).

The principles of Reduce, Replace, and Refine are subjective, potentially leading to less harmful alternatives being overlooked. Additional suffering can occur due to inappropriate handling, housing, and feeding practices both during and after research. Disagreements among regulatory bodies, such as the Animal Welfare Association and Institutional Animal Care and Use Committees (IACUC), are common, with 79% of research protocols reviewed resulting in different conclusions between committees. These committees can mandate changes to experimental protocols and review potential research, but they do not always agree on basic standards of care or consistently produce high-quality work (Bass, 2012).

The NIH's Guide for the Care and Use of Laboratory Animals, mandatory for federal fund recipients, has existed since 1963 and covers all vertebrates, allowing judgment in applying general standards to specific species or protocols. The Animal Welfare Act of 1966, originally aimed at controlling pet breeding and sale practices, now regulates experimentation on warm-blooded animals but excludes lab rats, mice (since 1970), and birds (since 2002). This act requires adherence to the 3Rs but involves minimal review of scientific merit or research protocols.

Disadvantages of the current system include a lack of transparency and accountability, anonymous and unelected positions, and regulations that mostly amount to recommendations. Federal guidelines apply primarily to labs receiving federal funding, resulting in inconsistent decision-making and quality of research oversight. There is a perception that the U.S. government is too deferential to local IACUCs and does not audit labs rigorously. Improved funding and training are necessary. However, the current system does permit oversight by knowledgeable local researchers, allowing for the development of specialized knowledge (Latham, 2012).

Utilitarian Perspective on Insect and Animal Testing

Played in a variety of fields, including moral philosophy, and utilitarianism, which prioritizes actions based on their consequences and generating the greatest good for the greatest number, contributes heavily to ethical decision-making concerning animal experimentation. The utilitarian position on insect and animal experimentation is intricately connected to the mixed role of emotional reactions and rational deliberation. Research conducted by Greene et al. (2008) suggests that emotional blunting commonly gives rise to non-utilitarian judgments, revealing an intertwined relationship between an individual's emotions and his or her utilitarian moral reasoning.

The utilitarian argument for animal testing hinges on a balance of benefits and harms, with both proponents and opponents presenting compelling points. Proponents emphasize the significant medical advances and cures that animal testing has made possible, arguing that the benefits to human health and well-being far outweigh the harms to animals. They point out that without animal testing, many critical treatments might never have been discovered. On the other hand, opponents highlight the guaranteed suffering animals endure, often without corresponding guaranteed benefits. They raise concerns about opportunity costs, suggesting that funds

allocated to animal testing could be redirected to other beneficial causes. Opponents also argue for the consideration of viable alternatives to animal testing, questioning whether certain cures could have been achieved through different means. They identify four key harms: promising treatments failing in clinical trials, missed opportunities for human benefits, dangers specific to animals but not humans, and safety in animals that don't translate to humans. Furthermore, a key consideration is the fact that harming an animal is a guaranteed outcome. The debate often pivots on the perceived legitimacy and value of animal suffering, with figures like Peter Singer arguing that all suffering, regardless of species, should be given equal moral consideration, condemning the disregard for animal suffering as speciesism (Bass, 2012).

Within the realm of utilitarianism, liberal utilitarianism offers nuanced considerations for evaluating animal testing practices. The 6 principles of liberal utilitarianism are (1) the greatest need satisfaction, (2) hierarchical needs, (3) overriding need satisfaction, (4) necessary and contingent ends, (5) awareness and (6) autonomy. It emphasizes the distinction between basic human needs and non-human animal welfare, demanding a separate assessment when human needs conflict with or do not involve non-human ones. Furthermore, it unequivocally denounces certain forms of animal testing, particularly those outside the realm of scientific necessity, such as cosmetic testing (HÄYRY, 2021).

Therefore, the utilitarian perspective extends beyond traditional ethical frameworks, as evidenced by its application in diverse fields such as consumer behavior. For instance, Legendre & Baker (2021) examine how utilitarian and hedonic messages influence consumers' willingness to try edible insect food, emphasizing the importance of understanding consumer psychology from a utilitarian standpoint.

Conclusion

In conclusion, the examination of scientific constraints in animal and insect experimentation exposes the intricacies and improbabilities that intimate the application of animal results to humans. The variation between controlled environments and natural habitats, together with foundational physiological, psychological, and genetic contrasts, has shaken the credibility and plausibility of animal experiments. Redefining procedures and models, such as the inclusion of primates or the alteration of an organism's genetic makeup, whether the argument, yet provisos like counter inferences and impromptu outcomes reflect the counter-productivity of animal testing. Though limited, the study of insects such as cockroaches has provided some priceless clues to learning, nociception, memory, and pain perception. In the case of learning and memory, cockroach research indicates the possibility of individuality in the learning and memory process and the presence of neural mechanisms involved in the formation of long-term memory. The nociceptive pathway in cockroaches provides a unique representation of insect pain perception by allowing us to appreciate the way these animals respond to noxious stimuli.

With the knowledge that cockroaches do feel pain, the regulatory and ethical systems in place for animal testing should be adjusted. Although existing regulations seek to ensure the humane treatment of animals and minimize unnecessary suffering, there are inconsistencies in oversight and interpretation for insect testing. Therefore, the use of insect testing must be scrutinized due to the moral and ethical dilemmas associated with attempts to balance real or potential human health benefits and animal suffering. Researchers should be looking into alternatives for insect and animal testing such as robotic testing or adjust their methodologies for conducting insect testing. By marrying progress in technology, neuroscience, and ethics, researchers can strive toward a more effective and ethical scientific world.

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