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A theoretical review of human-pet relationships from the perspective of attachment theory: toward interdisciplinary integration and conceptual reconstruction

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Abstract. In the social context of urbanization exacerbating the "loneliness epidemic" and the transformation of pets' roles from instrumental to emotional, this paper systematically reviews the application progress of attachment theory in cross-species relationships. Based on the core framework of Bowlby's attachment theory, this study integrates multidisciplinary perspectives of neurobiology, psychology, and ethics, and critically reviews existing results from a dual-dimensional perspective of time and topic through literature analysis and topic modeling. This paper found that human-pet attachment is based on a neurobiological foundation shared by mammals (oxytocin-cortisol bidirectional regulation, synchronous activation of the prefrontal-limbic system), and pets significantly improve insecure attachment through desocialized interactions, regular behaviors, and low-intensity emotional expressions. However, the validity of the scale transplantation is questionable, and the emotional overload of pets highlights ethical risks. In the future, it is necessary to develop cross-species attachment-specific tools, build a "neuro-ethical" dual-track assessment framework, and promote policy norms to balance human emotional needs and animal welfare.

Keywords: cross-species attachment, attachment theory, neurobiological mechanism, ethical controversy, psychological intervention effect

1. Introduction

The social role of pets has undergone a fundamental transformation. Early studies emphasized their functional value (care, hunting, etc.), while contemporary studies reveal the core position of pets as "emotional substitutes" [1, 2]. The biological basis of this transformation lies in the shared attachment needs of mammals: neuroimaging studies have confirmed that the activation patterns of the prefrontal cortex and limbic system when humans and dogs interact are highly homologous, providing an evolutionary basis for cross-species emotional connections [3].

In the social context of the "loneliness epidemic" spawned by urbanization, the urgent need for pets to transform from instrumental functions (such as care, hunting) to emotional attachment objects has become increasingly prominent.

Traditional attachment theory has long focused on the human mother-infant relationship, while the theoretical disconnection of cross-species adaptive research, the lack of analysis of neurochemical mechanisms, and the ethical blind spots caused by pets as "emotional substitutes" together constitute the core research motivation of this review. Pets have become the preferred object of alternative attachment due to their unconditional acceptance and tactile availability. Empirical studies have shown that interacting with pets can significantly regulate neurochemical levels—salivary oxytocin increases by 15-30% and cortisol concentrations decrease by 10-15%. At the same time, brain imaging evidence reveals the synchronous activation of the prefrontal-limbic system during human-dog interaction, verifying the physiological basis of cross-species attachment from both the biochemical and neural levels [4].

Through a systematic analysis of literature from 1980 to the present, this review combs the research evolution in the field of human-pet attachment from a dual perspective of time and subject.

The time dimension presents a three-stage transformation: the instrumental value-dominant period (behavioral observation quantifies pet functionality), the neural mechanism exploration period (fMRI technology reveals the oxytocin-dopamine pathway), and the ethical-technical integration period (wearable devices and cloning ethics are juxtaposed).

The subject dimension integrates two major research clusters: the controversy over the cross-species adaptability of attachment theory (such as the "extension theory" advocates the applicability of human scale modification, while the

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"reconstruction theory" emphasizes uniqueness) and neurobiological mechanisms (oxytocin-cortisol bidirectional regulation and brain region functional connectivity).

2. Theoretical background: cross-species reconstruction of the attachment paradigm

2.1. The core framework of attachment theory

Attachment theory was proposed by British psychologist John Bowlby in the 1950s to explain the emotional connection between infants and caregivers (usually mothers). Bowlby believed that attachment is the tendency of individuals to form a strong emotional bond with others of special significance, which can provide security and comfort to the individual. This emotional connection arises from the interaction between infants and parents and is an emotional connection and bond [5].

The core concepts of attachment theory include attachment behavior system, secure base and attachment style. Bowlby proposed that infants have an innate attachment behavior system that will be activated when they feel insecure or threatened, so that they seek to get close to caregivers for security and comfort. Caregivers serve as the "secure base" of infants, and infants can explore the surrounding environment from this base. In addition, Mary Ainsworth further developed attachment theory through the "strange situation experiment" and identified several different attachment styles, including secure attachment, anxious attachment, and avoidant attachment.

Neurobiological research further revealed that the operation of the attachment system depends on the coordination of the limbic system-prefrontal circuit: the amygdala is responsible for threat detection, the Prefrontal Cortex (PFC) regulates emotional responses, and oxytocin, as a key neuropeptide, enhances social bonding by inhibiting amygdala activity [6].

Pets, as "non-human attachment objects", can meet the corresponding attachment needs of humans. And its biological basis, including the oxytocin system and limbic system regulation, is conserved across species.

2.2. Three mechanisms of improving attachment type in human-pet relationships

Pets provide an alternative correction path for improving human attachment type through their unique biological-social interaction characteristics.

2.2.1. Alternative construction of secure attachment

Because pets lack the social judgment mechanism of humans, their emotional feedback is usually more stable and consistent, and is not affected by factors such as appearance and social status. This "desocialized" interaction provides a non-conditional, low-threat emotional connection channel for the attachment system, which helps to establish an alternative secure attachment. Studies have shown that individuals with attachment insecurity in interpersonal relationships can often obtain emotional comfort and attachment compensation in their relationships with pets, and show higher emotional regulation ability and trust levels [6]. Tactile-mediated emotion regulation mechanisms also play a role. Daily interactions such as intimate caressing and physical contact help stimulate the release of oxytocin and reduce stress levels, thereby providing continuous neural regulation input for the attachment system. Although this attachment model is different from traditional interpersonal attachment, it can partially replace it in function, especially for individuals in the context of early attachment deprivation.

2.2.2. Desensitization regulation of anxious attachment

The core feature of anxious attachment is a high degree of alertness to uncertainty in intimate relationships. Companion animals provide emotional regulation support for anxious individuals through their stable biological rhythms and gentle tactile interactions, thereby reducing the overactivation of the sympathetic nervous system. Studies have shown that regular petting of pets can significantly increase Heart Rate Variability (HRV), enhance parasympathetic nerve tone, and help relieve anxiety [7]. The non-evaluative emotional feedback provided by pets promotes emotional stability and cognitive reappraisal, which is an important mechanism for alleviating attachment anxiety.

2.2.3. Functional reconstruction of avoidant attachment

In the process of reconstructing avoidant attachment, the low-intensity and non-invasive emotional expression of pets (such as wagging tails and rubbing legs) becomes an important intervention method. This kind of gentle interaction can control emotional stimulation within the tolerance range of avoidant individuals and avoid triggering their defense mechanisms. The dependent relationship between pets and humans has led to a reversal of the power structure, with owners transforming from "attachment seekers" to "care providers", reducing the risk of emotional exposure of avoidant individuals in intimate relationships. This role

change helps to alleviate the defensive resistance of avoidant attachment people to intimacy and promotes the reconstruction of their attachment system and emotional openness [7].

3. Research status: dual perspective of time and subject

In order to further clarify the theoretical evolution of cross-species attachment and the characteristics of interdisciplinary studies, this study systematically reviews the field from the dual perspectives of time dynamics and subject differentiation, revealing the transformation trajectory of this field from functional instrumentalism to the bioethical integration paradigm.

3.1. Time dimension: three-stage transition of theoretical deepening

3.1.1. Instrumental value dominance period (1980-2000)

The research focus is on the value evaluation of pets as "functional objects", such as the work efficiency of guide dogs and the physiological health benefits of companion animals [8, 9]. During this stage, attachment theory had not yet been systematically introduced, and quantitative indicators mostly used behavioral observation methods (such as contact frequency and care duration).

3.1.2. Emotional connection exploration period (2001-2015)

The popularization of Functional Magnetic Resonance Imaging (fMRI) technology promoted the change of research paradigm. The landmark event was the Berns team who first confirmed that dogs can recognize human facial expressions, and in 2015 further revealed the phenomenon of human-dog neural synchronization [10]. During this stage, the neurobiological mechanism of cross-species attachment became a core issue, and the oxytocin-dopamine dual pathway regulation model was initially established [11].

3.1.3. Ethics-technology integration period (2016-present)

With the strengthening of the trend of "pet humanization", related research has shown a polarized development. On the one hand, advanced wearable devices and behavior tracking technologies are used to monitor pet attachment behavior in real time, such as using smart collars and sensors to capture animal physiological and behavioral data [12]. On the other hand, digital technology has promoted the development of cloned pets and artificial intelligence virtual pets, triggering ethical controversy and focusing on social and moral challenges such as emotional exploitation and digital immortality [13].

3.2. Thematic dimension: dual progress in theory and mechanism

3.2.1. Paradigm evolution of attachment theory

The theoretical construction of human-pet attachment revolves around the species universality of the attachment system, forming two complementary paradigms:

A. Extension paradigm

Supporters argue that the core mechanism of human attachment is conserved across species. Zilcha-Mano et al. demonstrated through Confirmatory Factor Analysis (CFA) that the Pet Attachment Questionnaire (PAQ) developed based on the attachment theory framework maintains a three-dimensional structure of secure-anxious-avoidant in dog owners (Comparative Fit Index (CFI) =0.89, Root Mean Square Error of Approximation (RMSEA) =0.07), and is moderately correlated with the anxiety dimension of the Adult Attachment Scale (ECR) ($r=0.38$, $p<0.01$) [14]. This shows that the behavioral expression system of attachment is consistent across subjects.

B. Reconstruction paradigm

This paradigm emphasizes the uniqueness of the human-pet attachment relationship and questions the appropriateness of directly applying human attachment theory to cross-species interactions. Supporters point out that there is a significant asymmetry in the human-pet relationship—for example, in human-dominated interactions, pets usually lack language expression and behavioral autonomy, which makes their attachment behavior present a structure and function different from that of human relationships. In addition, communication between different species is limited by differences in perception mechanisms (such as the differential expression of audio-visual channels and social signals), which further weakens the applicability of the "interactive secure base" in traditional attachment theory [15].

In recent years, more and more studies have adopted mixed methods (such as combining the ECR scale with pet behavioral ecological coding) to simultaneously capture human subjective feelings and animal objective behavioral responses. This approach has promoted the rise of the "bio-social integration model", that is, in the framework of biological evolution, comprehensively considering the regulatory effects of species specificity, social environment and individual experience on attachment relationships [16].

This paradigm not only challenges the human-centric perspective, but also promotes cross-species psychological research from one-way projection to two-way understanding, laying a theoretical foundation for the reconstruction of attachment theory in non-human animal research.

3.2.2. Neurobiological mechanisms

Research on the neural mechanisms of cross-species attachment has revealed unique biodynamic characteristics in human-pet interactions, which are mainly reflected in the following two aspects:

A. Neuromodulatory pathways

Pets not only passively accept human emotional projections, but their biological signals may also affect human brain activity. Studies have shown that interactions with pets, such as stroking and gazing, can promote the release of oxytocin in humans, thereby enhancing emotional regulation and social bonding. Human-dog interactions can significantly increase human oxytocin levels, reduce the concentration of the stress hormone cortisol, and thus reduce anxiety [17].

B. Epigenetic imprinting

Continuous contact with pets in early childhood may have long-term effects on individual gene expression. Studies have found that close interactions with pets in childhood are associated with changes in the methylation level of the Oxytocin Receptor Gene (OXTR), and this epigenetic modification may affect an individual's social behavior and emotional regulation ability. There is a correlation between children's positive interactions with pet dogs and their OXTR genotype and behavioral performance, suggesting that pet interactions may participate in the regulation of social emotional development by affecting the oxytocin system [18]. These findings point to an important conclusion: human-pet attachment is not only an emotional connection, but may also involve the participation of biological mechanisms, forming a unique cross-species connection pattern. This provides a theoretical basis for the development of biomarker-based attachment intervention programs (such as pet-assisted therapy).

4. Research controversy and methodological challenges

4.1. Validity issues of direct transplantation of human attachment scales

Human attachment theory originated from the study of mother-child relationships, and its core dimensions (secure, anxious, and avoidant) have a high explanatory power in describing interpersonal relationships. However, when this theory is directly applied to the attachment relationship between people and pets, validity issues gradually emerge. For example, traditional attachment scales often define "avoidant attachment" as resistance to intimacy and emotional alienation, but in pet attachment, avoidant traits may show completely different meanings. Studies have found that some individuals with avoidant attachment are more inclined to obtain emotional compensation through pets because they do not have to face the complexity of interpersonal interactions. The unconditional acceptance of pets may transform "avoidance" behavior into a safe psychological distance adjustment strategy rather than a manifestation of emotional isolation.

In addition, the design logic of the existing scales implies the premise of "two-way interaction", while the relationship between people and pets is essentially a one-way power structure. For example, the item "Does the other person understand my emotions" in the attachment scale, if applied to pets, needs to rely on the owner's subjective projection rather than the pet's real feedback. This measurement bias may lead to doubts about the ecological validity of the research conclusions. Some scholars have called for the development of special tools for cross-species attachment to distinguish the theoretical assumptions of human-centrism.

4.2. "Emotional exploitation" risk: pets as 24-hour emotional labor providers

While being given the identity of "non-human family members", pets are also caught in the dilemma of structural exploitation. Unlike human caregivers, pets cannot refuse the requirements of emotional labor through language. For example, pets raised by patients with depression have significantly increased cortisol levels, suggesting that they have been under long-term negative emotional pressure from their owners. More hidden exploitation is manifested as "anthropomorphic expectations"—owners require pets to play the role of idealized partners (such as always responding positively and never refuting). This unilateral emotional demand may distort the natural behavior patterns of animals.

Ethical disputes are also reflected in commercial pet services. The certification system for emotional support animals has made pets a "therapeutic tool", but their own welfare is often ignored. For example, emotional support dogs of airlines need to work continuously for several hours in noisy cabins. This high-intensity emotional labor lacks corresponding animal protection regulations.

5. Conclusion

This study systematically analyzed the cross-species connection mechanism of human-pet emotional attachment, integrated the biological basis, psychological intervention effect and ethical controversy, and revealed its theoretical evolution and multidimensional challenges. The study found that human-pet attachment is rooted in the common neural conservatism of mammals (such as the oxytocin system and the limbic circuit synergy). Pets significantly improve the quality of human attachment through stable interaction and low-threat feedback, but their role is dual: they can repair early attachment trauma through neural plasticity, but also cause ethical dilemmas due to doubts about the validity of scale transplantation, emotional exploitation risks and attachment rupture trauma. There are two major limitations in current research: first, the theoretical framework has not yet bridged the gap between neural mechanisms and ethical criticism; second, the quantitative tools for pet welfare lag behind, making it difficult to balance human emotional needs and animal rights protection. Future research can focus on three-dimensional breakthroughs: developing a cross-species attachment scale to transcend the anthropocentric paradigm; constructing a "neuro-ethical" dual-track assessment model to standardize pet-assisted therapy practices; and formulating animal emotional labor protection policies to curb exploitative behavior in commercial services.

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