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ARAŞTIRMA MAKALESİ RESEARCH PAPER

# Developing An Effective Training Protocol For Biodetector Rats: A Preliminary Study

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**Abstract:** Rats have increasingly been employed as biodetector animals due to their keen olfactory capabilities, similar to dogs, for tasks including disease diagnosis, search-and-rescue operations, and detecting hazardous substances such as explosives and prohibited materials. This preliminary study aimed to develop a reliable and efficient training protocol for biodetector rats by integrating classical and operant conditioning methods. Ten female Sprague Dawley rats were trained using classical and operant conditioning paradigms within a specially modified Skinner box. The animal was expected to ring the bell in the odor chamber, then was rewarded. Following the socialization phase, a training procedure was prepared including a clicker as a conditioned stimulus at each stage and reward food which functioned as an unconditioned stimulus and later served as a positive reinforcer. Training sessions were conducted for 15 minutes daily, five days per week, with rats receiving a 60% reduction in their food intake 24 hours prior to training to increase motivation. The frequency of target behaviors and non-target behaviors was recorded, showing a significant increase in target behavior realization by 628 % and an increase in non-target behaviors by 98 %. These findings demonstrate that integrating classical and operant conditioning is an effective and practical approach for training biodetector rats. Future studies are planned to incorporate advanced technology such as machine learning and artificial intelligence to further refine training methodologies and enhance outcomes.

**Keywords**: Biodetector, rats, biodetector training, skinner box.

# Biyodedektör Sıçanlar İçin Etkili Bir Eğitim Protokolünün Geliştirilmesi: Bir Ön Çalışma

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**Öz:** Sıçanlar, köpeklerde olduğu gibi üstün koku alma yetenekleri nedeniyle hastalık teşhisi, arama-kurtarma operasyonları ve patlayıcı veya yasak maddelerin tespiti gibi çeşitli görevlerde biyodedektör hayvan olarak giderek daha fazla kullanılmaktadır. Bu ön çalışmada, klasik ve operant koşullanma yöntemlerini entegre ederek biyodedektör sıçanlar için güvenilir ve verimli bir eğitim protokolü geliştirmek amaçlanmıştır. On adet dişi Sprague Dawley sıçanı, özel olarak modifiye edilmiş bir Skinner kutusu içinde klasik ve operant koşullanma paradigmaları kullanılarak eğitilmiştir. Hayvanın koku odasındaki zili çalması beklenmiş ve ardından ödüllendirilmiştir. Her eğitim aşamasında koşullu uyarıcı olarak tıklayıcı kullanılırken, yiyecek ödülleri başlangıçta koşulsuz uyarıcı işlevi görmüş ve ardından istenilen davranışın pozitif pekiştiricisi olarak görev yapmıştır. Eğitim seansları haftada beş gün, her sıçan için günde 15 dakika olarak uygulanmış ve sıçanların motivasyonu artırmak amacıyla seanslardan 24 saat önce gıda alımları %60 oranında azaltılmıştır. Eğitim prosedürü, zili her iki pençeyle çalma davranışını hedefledi. Hedef davranışların ve hedef dışı davranışların gerçekleşme sıklıkları kaydedilmiş; hedef davranışların gerçekleşmesinde %628, hedef dışı davranışlarda ise %98 oranında artış görülmüştür. Elde edilen bulgular, klasik ve operant koşullanma yöntemlerinin biyodedektör sıçanların eğitimi için etkili ve pratik bir yaklaşım olduğunu göstermektedir. Gelecekte yapılacak çalışmalarda, eğitim yöntemlerini daha da geliştirmek ve sonuçları iyileştirmek amacıyla makine öğrenmesi ve yapay zekâ gibi ileri teknolojilerin kullanılması planlanmaktadır.

**Anahtar kelimeler:** Biyodedektör, sıçanlar, biyodedektör eğitimi, skinner kutusu

## INTRODUCTION

Throughout rat training processes, animals acquire novel skills and behaviors required to perform detection tasks in response to specific targets, as documented in previous studies. To effectively address research questions, understanding learning and memory mechanisms during the training process is critical. Learning and memory are the major issues in neuroscience (Mayes & Roberts, 2001). Learning is defined as the acquisition of knowledge and skills, and it is also considered a change in behavior resulting from experiences. Memory can be classified according to motivational context as reward-based or punishment-based memory. Furthermore, memory is divided into relational and non-relational categories based on its structural characteristics. Relational memory involves the experiencer organizing and controlling relationships and responses between stimuli, while non-relational memory pertains to creating conditions conducive to specific responses. Classical and operant conditioning paradigms, commonly observed in behavioral research, fall within the non-relational memory category (Quillfeldt, 2006).

Commonly employed training methodologies include the open field habituation test, passive avoidance test, contextual fear conditioning, two-way active avoidance test, maze tests, and novel object recognition tests (More et al., 2016; Quillfeldt, 2006; Tanila, 2018). Pavlov's classical conditioning studies primarily focused on involuntary responses elicited by known stimuli. In contrast, Skinner's operant conditioning research concentrated on voluntary behaviors and their associations with consequences, where stimuli may be less explicit (Skinner, 1938). Operant conditioning involves establishing associations between behaviors and subsequent outcomes. The Skinner box, developed by Skinner, is a pivotal experimental apparatus for observing operant conditioning processes (Skinner, 1938). Operant conditioning comprises repeated trials where behavior frequency is either increased or decreased based on the outcomes. Positive reinforcement, involving pleasant stimuli, increases behavior probability, while negative or aversive stimuli can temporarily suppress behaviors. While pleasant stimuli or effects are positive reinforcements for the behavior, unpleasant stimuli have a meaning as punishment and can stop the behavior for a certain period of time. According to studies focused on memory and operant conditioning, training experimental animals significantly enhances research validity (Dalkiran et al., 2022).

Skinner advocated for the incorporation of auditory stimuli in behavioral training, citing their perceptibility across various distances and contexts, a distinct advantage over visual stimuli (Skinner, 1961). Presently, training methods that employ clickers or auditory cues are acknowledged as efficacious techniques in animal training within the realm of behavioral psychology. These methods are particularly noted for their effectiveness in marking and reinforcing desired behaviors (Feng et al., 2016). A standard clicker is usually a small plastic apparatus containing a metal piece that emits a brief, sharp, dual-tone click when pressed. This auditory signal typically precedes the immediate provision of food reinforcement. Research examining the correlation between clicker cues and food intake remains limited; while some studies find no substantial differences when compared to exclusive food reinforcement, others have noted improved response rates (Pfaller-Sadovsk et al., 2020; Martin & Friedman, 2020).

In recent years, there has been a growing interest in biomaterials and engineering technologies aimed at enhancing system quality while simultaneously reducing operational costs. Among these, biosensors represent a particularly promising avenue for the analysis of both biological and non-biological systems. Biosensors are analytical devices that translate biological signals into quantifiable outputs, such as volatile organic compounds (VOCs). These VOCs, also referred to as odorant molecules, are distinct chemical entities produced by biological systems. Various types of chemical and biological analyzers have been developed to detect and interpret these molecules. Several studies have highlighted the potential applications of biosensors in applied sciences and medical diagnostics (Oh et al., 2015). Nevertheless, analytical instruments currently in use are reported to have significant limitations, including high costs, slow response times, operational complexity, substantial power requirements, and the need for extensive optimization (Oh et al., 2015; Tomsic & Musevic 2013; D'Amico et al., 2010). Given these constraints, there is a need for alternative and innovative sensory tools—particularly those involving biodetector animals. Animals such as dogs, rats, insects, and honeybees, which possess exceptionally sensitive olfactory systems, have been employed for biodetection purposes in recent years. Notably, the olfactory sensitivity of dogs and rats has been shown to exceed that of humans by up to several hundred thousand times (Berg et al., 2024).

Rats have long been utilized as model organisms in scientific research; however, their olfactory capabilities have remained relatively underexplored. Recent studies have begun to investigate their potential as biodetector animals in a wide array of applications, including the diagnosis of diseases and pathological conditions, search and rescue operations, and the detection of flammable, explosive, or prohibited substances—similar to the roles traditionally assigned to dogs (Poling et al., 2011; Schoenberg et al., 2019; Leidinger et al., 2017). To effectively employ an animal as a biodetector, the implementation of an appropriate behavioral training protocol is essential. In this context, behavioral modeling conducted in conjunction with structured training programs plays a critical role. Biodetector rats, in particular, must be capable of executing a series of task-specific behaviors acquired through such training. The present study aimed to develop a refined training model using a modified Skinner box, integrating classical and operant conditioning paradigms to assess and address gaps in behavioral training. Furthermore, the study sought to construct optimized behavioral models for biodetector training by systematically identifying and correcting deficiencies encountered during the training process. Ultimately, this research also serves as a preliminary investigation into the feasibility of utilizing rats as biodetector animals.

## MATERIAL AND METHOD

***Animals and housing:*** In the study, 10 female Sprague Dawley rats, 1-2 months old, 150-250 g live weight, were used as experimental animals. The rats were housed in Bursa Uludag University Experimental Animal Application and Research Center. All necessary approvals were obtained from the University Experimental Animals Local Ethics Committee (Ethics Committee Decision No: 2024-06/03).

The animals were kept for 1 week to get used to the environment before the experiment. Each rat was housed individually in boxes measuring 20×30×55 cm. The cages were outfitted with enrichment materials, including tunnels, ladders, running wheels, and platforms constructed from wood and metal, to promote physical and mental stimulation for the animals. Additionally, compact cotton material was provided to facilitate nesting behaviors (Figure 1). The rats were kept under standard lighting (12 hours light / 12 hours dark) and room temperature (22-23 $^{0}$C) conditions during the study. Sufficient standard pellet food and water were available *ad libitum*.

***Skinner training box:*** A Skinner box was modified and designed for the experiment. The box was rectangular prisms measuring 30×30×40 cm, crafted from transparent materials to allow for unobstructed observation of the interior by the operator. There was a bell, a bait and an odor chamber inside the box. The chain with the bell attached hangs from the top of the odor chamber. The bell was used as a discriminative stimulus that the subjects interacted with during the operant conditioning phase. The bait and the odor chamber were in a location that is accessible from the outside (Figure 2).

**Figure 1.** Rats house with housing materials.

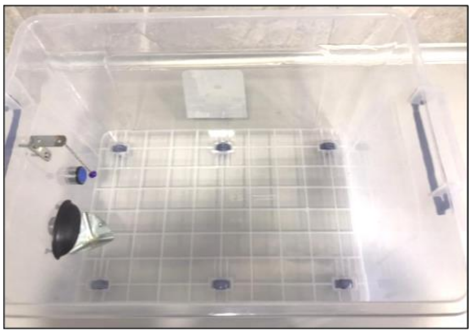

**Figure 2.** Modified skinner box

***Reward food:*** Solid biscuit pieces were given as a reward food. This reward food served as a reinforcer for the rats when they successfully performed the target behavior in the study.

***Clicker:*** A standard commercial model clicker was used. It was held in a plastic or metal housing, had a piece that was depressed at one end, returned to alignment when released, and maked a sharp "click" sounded each time it was depressed.

***Test procedure:*** The overall procedure for training rats consisted of two phase: (i) a socialization phase, followed by (ii) a continuous training phase, in which reward was delivered via classical and operant conditioning paradigms.

*Socialization phase:* The initial phase encompassed the adaptation and socialization process. This phase was designed to help the rats acclimate to the experimental environment, enhance their confidence in interacting with humans, and promote their effective participation in the experimental procedures. To achieve this, a 7-day socialization protocol was implemented for the rats. Throughout this process, no food restrictions were imposed on the animals. Following the adaptation and socialization phase, the rats' food intake was reduced by 60%, while water intake remained unrestricted for 24 hours before the training sessions.

*Training phase:* The training schedule involved one session per animal per day, conducted five days a week, with each session limited to 15 minutes. The training protocol was meticulously developed by integrating and adapting the core principles of classical and operant conditioning paradigms.

Target and non-target behaviors were recorded across all training stages. Additionally, the percentage changes in the frequency of these behaviors were calculated and analyzed. The observed behaviors during the training sessions included: circling the cage, waiting in the reward chamber, inspecting a corner of the cage unconsciously touching the bell, unintentionally touching the bell, and ringing the bell with both forepaws that modified by literatures (Rautio et al., 2024; Figure 3-7). In the study, "ringing the bell with both forepaws" behavior was targeted for the training procedure. Non-target behaviors were defined as any actions that deviated from the specified target behavior. Furthermore, to monitor the welfare of the rats throughout the training process, indicators of anxiety-specifically spontaneous urination, defecation, and vocalization-were systematically recorded.

*a. First stage:* In the initial phase of the training procedure, the odor chamber was physically separated from the section designated for reward delivery using a partition. During this stage, the rats were subjected to classical conditioning, wherein a commercial clicker was employed as a conditioned stimulus. The food reward was administered immediately following the click sound to establish the association between the auditory cue and reinforcement.

*b. Second stage:* In the second and subsequent stages, the partition separating the odor chamber from the reward area was removed. When the animal made contact with the bell—using a paw, its nose, or another part of the body—the clicker was activated, and the food reward was immediately delivered. Through repeated trials, the rats began to form an association between bell activation, the clicker sound, and the subsequent reward. At this stage, however, there was no odor awareness.

*c. Third stage:* During this stage, the rats were reinforced for touching the bell with either one or both forepaws. The aim was for rat to learn to lift its body. The partition remained removed during this stage to maintain environmental continuity and facilitate learning.

*d. Fourth stage:* In this final stage, the rats were required to assume an upright posture with their noses oriented toward the odor chamber and ring the bell using both forepaws. Upon successful execution of this specific behavior, the clicker was sounded and the food reward was delivered. This stage represented the complete acquisition of the target behavior in the context of the training apparatus.

**Figure 3.** Circling the cage behavior.

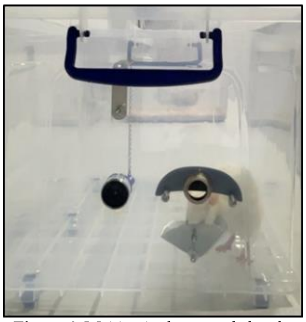

**Figure 4.** Waiting in the reward chamber.

**Figure 5.** Inspecting a corner of the cage unconsciously touching the bell.

**Figure 6.** Unintentionally touching the bell.

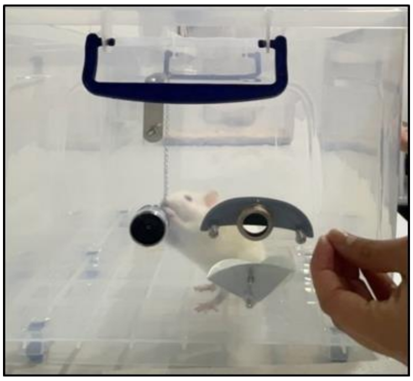

**Figure 7.** Ringing the bell with both forepaws.

***Statistical analysis:*** Statistical analyses were conducted using GraphPad Prism version 5. Analysis of variance (ANOVA) will be used to determine the effects of operant conditioning protocols on the number of shaping trials, and the frequency of target and non-target behaviors. Response rates will be calculated with the application of the conditioned stimulus. Parameters were grouped and means and standard errors were calculated.

Prior to hypothesis testing, the Kolmogorov–Smirnov and Shapiro–Wilk tests were applied to evaluate the normality of data distribution. For data exhibiting normal distribution, Levene's test was used to assess homogeneity of variances. Depending on the outcomes of these preliminary tests, either parametric methods—including ANOVA and the paired samples t-test—or non-parametric methods—such as the Kruskal–Wallis test and Mann–Whitney U test—were used for group comparisons. A p-value of less than 0.05 was considered statistically significant.

## RESULTS

Target behaviors were successfully performed, and non-target behaviors were recorded throughout all stages of the training phases (Figure 8). Percentage changes in behavior frequencies were calculated by comparing data from the beginning and end of the study (Figure 9). No statistically significant difference was observed between the overall frequencies of target and non-target behaviors across all rats (p:0.209; 41.29±6.71 ve 24.57±9.61). However, the target behavior realization rate increased markedly by 628%, while the frequency of non-target behaviors showed a more moderate increase of 98%.

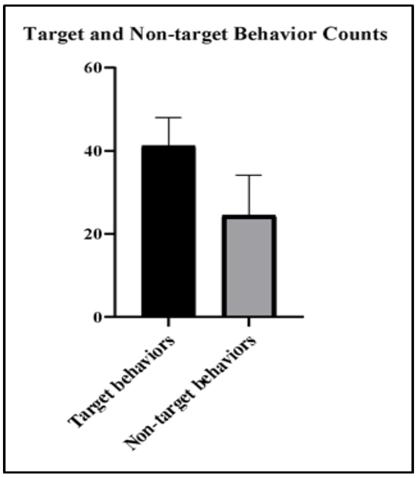


**Figure 8.** The counts of target and non-target behaviors during traning (p>0.005; Mean ± S.E; n=10).

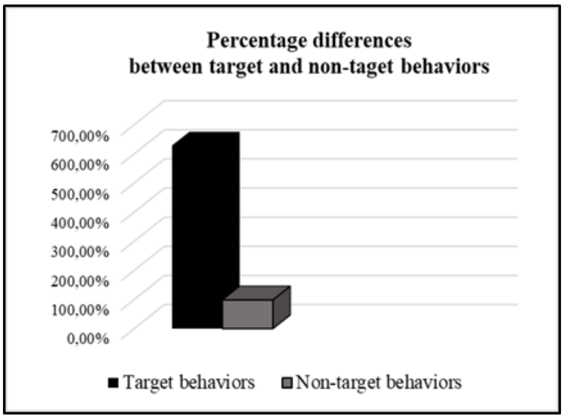


**Figure 9.** The percentage differences between target and non-target behaviors during traning (p>0.005; Mean ± S.E; n=10).

Following the socialization phase, initial training (Stage 1) began, during which the association between the clicker sound and food reward was established. Some rats successfully learned this association by Day 3, while others required up to Day 6. Although each stage was structured to occur over one training day, rest intervals were incorporated between stages. As a result, Stage 1 training was conducted between Days 6 and 12.

Stage 2 commenced on Day 12, at which point rats were introduced to the bell. On Days 12 and 13, food rewards were given when the rats rang the bell unintentionally. By Day 14, however, the animals had begun to associate bell-ringing—whether performed with a paw, the nose, or another part of the body—with the clicker sound and the subsequent reward.

On Day 15 (Stage 3), the rats began receiving rewards only when they touched the bell with either one or both forepaws. By Day 18 (Stage 4), all animals were able to perform the full target behavior—ringing the bell with both forepaws in response to the odor stimulus—followed by the clicker sound and reward delivery.

Throughout the training process, no signs of distress, such as urination, defecation, or vocalization, were observed in any of the rats, with the exception of one instance of urination on Day 1 by a single animal.

## DISCUSSION AND CONCLUSION

In this study, we demonstrated a fundamental training approach in which rats successfully learned to perform a sequence of novel behaviors involving bell ringing, auditory cues (clicker), and food reinforcement. The animals observed high performance and learning success during the study. Previous studies have reported that the effects of clicker training with several species, including dogs and horses. Early research on clicker-based methodologies was firmly grounded in behavioral analysis, particularly in the context of reinforcement learning. However, it has been noted that key terms commonly used in clicker training—such as cueing, bridging, and conditioned reinforcement—are often interpreted inconsistently across different studies, which complicates the analysis of behavioral outcomes. The earliest device resembling a modern clicker—a buzzer—was developed by McCall and Burgin (2002), who found that bell training paired with food rewards was more effective in horses than providing food alone. Similarly, a study by Thorn et al. (2006) investigated whether a clicker paired with food was more effective than verbal praise in dog training. Their findings suggested that verbal praise elicited higher levels of sustained response than the clicker. In contrast, Chiandetti et al. (2016) found no significant difference between clicker-plus-food, verbal praise-plus-food, and food-only conditions, highlighting ongoing inconsistencies in the literature. Given the limited but growing body of research exploring the association between clicker cues and food reinforcement (Pfaller-Sadovsky et al., 2020; Martin & Friedman, 2020), one of the most notable findings in the present study is that training success was achieved across all individual rats, reinforcing the utility and reproducibility of this conditioning model in a rodent population.

In the present study, the initial and most critical step involved training the rats to associate the clicker sound with the subsequent food reward—a key phase representing the completion of classical conditioning. The success of this association was found to be influenced by the individual rats' engagement and responsiveness to training. Despite the incorporation of rest periods between training stages, most rats were able to establish the clicker–reward connection between the 3rd and 6th training days.

In subsequent stages, particularly Stage 2—when the partition was removed—rats began to unintentionally contact the bell using various parts of their bodies. Upon doing so, they received both the clicker sound and the food reward. This phase represented the second major milestone of the study, as it marked the beginning of the operant conditioning process. Repeated reinforcement led the rats to gradually associate the act of bell-ringing with the reward mechanism.

By Day 12, although inconsistently, rats began to actively ring the bell. By Day 14, most animals had learned to associate the clicker sound and food reward with physical contact with the bell, whether through one or both forepaws, their nose, or other body parts. From Day 15 onward, food rewards were only administered when the bell was touched using one or both forepaws. Notably, by Day 18, the animals consistently performed the complete target behavior—ringing the bell using both forepaws—successfully linking it to the clicker cue and the ensuing reward.

The behavior of "ringing the bell with both forepaws" represented the most critical component of the training process, as it served as the primary action through which a clear association between the behavior and the reinforcement could be established. It was observed that rats acquired this target behavior relatively quickly, regardless of the trainer's level of experience. Notably, efficient training outcomes were achieved even under the guidance of less experienced trainers.

Previous studies have reported common errors in clicker training, such as reinforcing inappropriate behaviors or failing to present the food reward promptly following the clicker cue (Leidinger et al., 2017). In the present study, similar mistakes were identified during the early training stages—particularly the initial failure of some rats to respond to the clicker before the association was learned. However, these issues were progressively resolved as the training advanced.

The individual temperament of rats constitutes an uncontrollable variable in the training process. Although all animals in the present study were born and raised under identical environmental conditions, they nonetheless exhibited a wide range of behavioral characteristics. Previous research has highlighted such variability, noting differences in taste preferences, appetite, and exploratory behavior among individual rodents (Crawley, 2007; Loos et al., 2015; Leidinger et al., 2017).

Based on the current findings, the type of food reward emerged as another critical factor influencing training outcomes. Although solid food rewards were employed in this study, training effectiveness appeared to be affected by individual differences in taste preference and feeding behavior. Moreover, the use of solid rewards was found to reduce motivation in some animals, likely due to the longer time required for consumption. Therefore, it is proposed that utilizing liquid food rewards may enhance the acquisition of target behaviors and improve overall training efficiency.

A key limitation of this study is that it was conducted using only one rat strain. Considering that behavioral traits such as learning ability, stress response, and reward sensitivity can differ significantly between strains, future studies should include additional strains to enhance the generalizability of the findings (Loos et al., 2015; Leidinger et al., 2017). Moreover, further research is warranted to evaluate the broader behavioral repertoire and physiological stress responses associated with the training process, in order to better understand both performance and animal welfare outcomes.

In conclusion, this study demonstrated that the application of a clicker-based operant conditioning protocol in female Sprague Dawley rats is both practical and effective. Despite certain limitations, including a modest sample size and individual learning variability, the findings offer a clear proof of principle for training paradigms based on observational and operant learning in rodents. The high success rate observed across the majority of subjects highlights the reliability of the model. Looking ahead, future studies will aim to refine the behavioral framework further and explore the integration of automated systems, including machine learning and artificial intelligence, to enhance precision, efficiency, and scalability in biodetector training protocols.

**Conflict of interest statement:** None of the authors have any conflicts of interest to disclose.

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**REFERENCES**

**Berg, P., Mappes, T., & Kujala, M.V. (2024).** Olfaction in the canine cognitive and emotional processes:

From behavioral and neural viewpoints to measurement possibilities. *Neurosci Biobehav Rev.*, ***157***, 105527. DOI: 10.1016/j.neubiorev.2023.105527

**Chiandetti, C., Avella, S., Fongaro, E., & Cerri, F. (2016).** Can clicker training facilitate conditioning in dogs? *Applied Animal Behaviour Science*, ***184***, 109-116. DOI: 10.1016/j.applanim.2016.08.006

**Crawley, J.N. (2007).** *What's wrong with my mouse? Behavioral phenotyping of transgenic and knockout mice*, 2nd ed., John Wiley & Sons Inc. DOI: 10.1002/0470119055

**D'Amico, A., Pennazza, G., Santonico, M., Martinelli, E., Roscioni, C., Galluccio, G., Paolesse, R., & Di Natale, C. (2010).** An investigation on electronic nose diagnosis of lung cancer. *Lung Cancer*, ***68***(2), 170-6. DOI: 10.1016/j.lungcan.2009.11.003

**Dalkiran, B., Acikgoz, B., & Dayi, A. (2022).** Behavioral Tests Used in the Evaluation of Learning and Memory in Experimental Animals. *Journal of Basic and Clinical Health Sciences*, ***6***, 938-945. DOI: 10.30621/jbachs.1017172

**Feng, L.C., Howell, T.J., & Bennet, P.C. (2016).** How clicker training works: Comparing Reinforcing, Marking, and Bridging Hypotheses. *Applied Animal Behavior Sci.*, ***181***, 34-40. DOI: 10.1016/j.applanim.2016.05.012

**Leidinger, C., Herrmann, F., Thöne-Reineke, C., Baumgart, N., & Baumgart, J. (2017)** Introducing Clicker Training as a Cognitive Enrichment for Laboratory Mice. *Journal of Visualized Experiments*, ***121***, e55415, DOI: 10.3791/55415

**Loos, M., Koopmans, B., Aarts, E., Maroteaux, G., & van der Sluis, S. (2015).** Neuro-BSIK Mouse Phenomics Consortium; Verhage M, Smit AB. Within-strain variation in behavior differs consistently between common inbred strains of mice. *Mammalian Genome*, ***26***(7-8), 348-54. DOI: 10.1007/s00335-015-9578-7

**Martin, S., & Friedman, S.G. (2020).** *Blazing clickers.* Available online: http://www.behaviorworks.org/files/journals/Blazing%20Clickers.pdf (accessed on 23 September 2020).

**Mayes, A.R., & Roberts. N. (2001).** Theories of episodic memory. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, ***356***(1413), 1395-1408. DOI: 10.1098/rstb.2001.0941

**McCall, C.A., & Burgin, S.E. (2002).** Equine utilization of secondary reinforcement during response extinction and acquisition. *Applied Animal Behaviour Science*, ***78***, 253-262. DOI: 10.1016/S0168-1591(02)00109-0

**More, S.V., Kumar, H., Cho, D.Y., Yun, Y.S., & Choi, D.K. (2016).** Toxin-induced experimental models of learning and memory impairment. *International Journal of Molecular Sciences*, ***17***, 1447. DOI: 10.3390/ijms17091447

**Oh, Y., Lee, Y., Heath, J., & Kim, M. (2015).** Applications of Animal Biosensors: A Review. *IEEE Sensors Journal*, ***15***, 637-645. DOI: 10.1109/JSEN.2014.2358261

**Pfaller-Sadovsky, N., Hurtado-Parrado, C., Cardillo, D., Medina, L.G., & Friedman, S.G. (2020).** What's in a Click? The Efficacy of Conditioned Reinforcement in Applied Animal Training: A Systematic Review and Meta-Analysis. *Animals*, ***10***, 1757. DOI: 10.3390/ani10101757

**Poling, A., Weetjens, B., Cox, C., Beyene, N. W., Bach, H., & Sully, A. (2011).** Using trained pouched rats to detect land mines: Another victory for operant conditioning. *Journal of Applied Behavior Analysis*, ***44***(2), 351-355. DOI: 10.1901/jaba.2011.44-351

**Rautio, I.V., Holmberg, E.H., Kurup, D., Dunn, B.A., & Whitlock, J.R. (2024).** A novel paradigm for observational learning in rats. *Cognitive Neurodynamics*, ***18***(2), 757-767. DOI: 10.1007/s11571-023-10022-8

**Quillfeldt, J.A. (2006).** Behavioral methods to study learning and memory in rats. İçinde M.L. Andersen ve S. Tufik (Ed.), *Rodent Models as Tools in Ethical Biomedical Research, eBook*, 341-383p, Springer, Switzerland.

**Schoenberg, H.L., Sola, E.X., Seyller, E., Kelberman, M., & Toufexis, D.J. (2019).** Female rats express habitual behavior earlier in operant training than males. *Behavioral Neuroscience*, ***133***(1), 110-120. DOI: 10.1037/bne0000282

**Skinner, B.F. (1938).** *The behavior of organisms: an experimental analysis.* Appleton-Century, Skinner Foundation: Cambridge, MA, USA,

**Skinner, B.F. (1961).** How to teach animals. In Skinner, B.F. (Ed.), *Cumulative record, Enlarged ed.*, 412-419p, Appleton-Century-Crofts. DOI: 10.1037/11324-031

**Tanila, H. (2018).** Testing cognitive functions in rodent disease models: present pitfalls and future perspectives. *Behavioural Brain Research*, ***352***, 23-27. DOI: 10.1016/j.bbr.2017.05.040

**Thorn, J.M., Templeton, J.J., Van Winkle, K.M.M., & Castillo, R.R. (2006).** Conditioning shelter dogs to sit. *Journal of Applied Animal Welfare Science*, ***9***, 25-39. DOI: 10.1207/s15327604jaws0901_3

**Tomši˘c, U., & Mušević˘c, I. (2013).** *Detection of explosives: Dogs vs. CMOS capacitive sensors*. Faculty of Mathematics and Physics, Univ. Ljubljana, Ljubljana, Slovenia, Tech. Rep., SEMINAR 1a 1st year, 2nd cycle, 2013.