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A Novel Avoidance Test Setup: Device and Exemplary Tasks

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Abstract. This paper presents a novel rodent avoidance test. We have developed a specialized device and procedures that expand the possibilities for exploration of the processes of learning and memory in a psychophysiological experiment. The device consists of a current stimulating electrode-platform and custom software that allows to control and record real-time experimental protocols as well as reconstructs animal movement paths. The device can be used to carry out typical footshock-avoidance tests, such as passive, active, modified active and pedal-press avoidance tasks. It can also be utilized in the studies of prosocial behavior, including cooperation, competition, emotional contagion and empathy. This novel footshock-avoidance test procedure allows flexible current-stimulating settings. In our work, we have used slow-rising current. A test animal can choose between the current rise and time-out intervals as a signal for action in footshock avoidable tasks. This represents a choice between escape and avoidance. This method can be used to explore individual differences in decision-making and choice of avoidance strategies. It has been shown previously that a behavioral act, for example, pedal-pressing is ensured by motivation-dependent brain activity (avoidance or approach). We have created an experimental design based on tasks of instrumental learning: pedal-pressing in an operant box results in a reward, which is either a piece of food in a feeder (food-acquisition behavior) or an escape-platform (footshock-avoidance behavior). Data recording and analysis were performed using custom software, the open source Accord.NET Framework was used for real-time object detection and tracking.

Keywords: Engineering · Learning · Footshock · Avoidance task · Appetitive task · Approach/Withdrawal · Behavioral analysis

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1 Introduction

Animal models are used by researchers all over the world. Rodent passive/active avoidance tests are the typical models not only in experimental psychology but also in clinical psychology, psychiatry and behavioral neuroscience. Recent years have brought rapid advances in our understanding of the brain processes involved in the avoidance-learning, along with their clinical implications for anxiety disorders, PTSD etc. [7, 10]. Avoidance behavior in rodents has predominantly been studied using lever-press signaled avoidance task, which requires animals to press a tool upon presentation of a warning signal in order to prevent or escape punishment [10]. The development of new techniques capable of modeling multidimensional cognitive activity could be a valuable contribution to psychophysiological studies. The system organization of human and animal behavior, including the processes of systemogenesis, can be studied in a variety of situations, such as learning and performing behavioral tasks, acute/chronic stress, psychotrauma, alcohol intoxication, etc. This paper presents a novel rodent avoidance test designed to expand the possibilities for exploration of learning and memory processes.

2 Device

The device we developed consists of a current stimulating electrode-platform and custom software that allows to control and record the real-time behavioral protocol, which can be used to reconstruct trajectories of the animal's movement. The size and amount of the electrodes provide a stable contact with animal skin (see Fig. 1e). The device can be used for the typical footshock-avoidance tests, including passive, active and modified active (see Fig. 1a–c). This is achieved by combining separate sectors of electrodes (Patent RU2675174C1, Fig. 1). The device is completed with partitions and sound/light signals, which provide possibilities to implement a broad range of behavioral tasks in various situations and conditions, such as learning, helplessness, stress in the studies of anxiety, stress disorders and memory, etc.

Finally, the device can be used to study prosocial behavior in rodents, including cooperation, competition, willingness to help a conspecific, emotional contagion and empathy. For instance, we have used a previously established model of emotional contagion [4, 6] in which an animal observes a conspecific experience painful electroshocks. This model is illustrated in Fig. 1d.

It is known that the electrical resistance of rodent skin depends on such factors as age, sex and weight. Indeed, experiments revealed wide differences in the skin resistance of animals [5, 8]. In addition, our study showed that skin resistance in rats decreases after 5-min of electrostimulation. Therefore, we have applied electrical circuit of the voltage-controlled current source to compensate for this change in the operation of the device.

A user can apply automatic settings for task-dependent stimulation or control stimulation manually, including both, AC (alternating current) and DC (direct current). Slow-growing stimulation can be regulated by a microcontroller. Impulse noise (artifacts) elimination is provided by the alternating current.

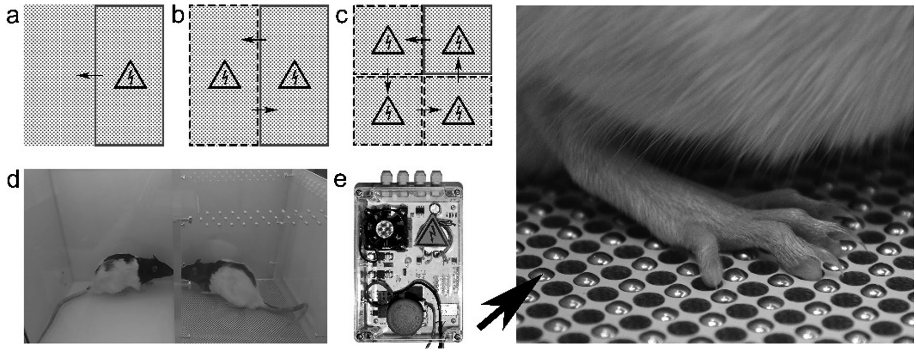

Fig. 1. Typical footshock-avoidance tests: (a) passive, (b) active, (c) modified active, (d) “emotional contagion” - observer (left) and pain-demonstrator (right). (e) Device controller (left) and a photograph illustrating the stable contact between electrodes (the arrow indicates one of the electrodes) and animal’s skin.

3 A Novel Avoidance Test Procedure

A novel footshock-avoidance test procedure allows flexible current-stimulating settings with variable times of trials, currents (from 0 to 3 mA) and time between trials. In our work we have used slow-rising current. A typical trial consists of three intervals: (1) current rise; (2) maximum value; (3) time-out (pause between trials). In order to avoid footshock, a test animal learns to press a pedal during either the current rise period, or time-out period. This experimental procedure allows to explore individual differences in decision-making and choice avoidance strategies, when an animal makes a choice between escape and avoidance.

Figure 2 illustrates the “learned helplessness” experiment, when unavoidable high-intensity footshock is applied to an animal.

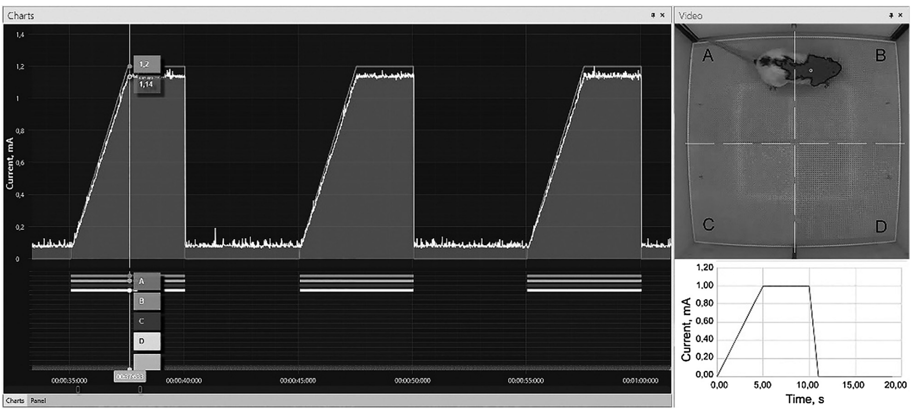

Fig. 2. An example of real-time protocol of footshock-avoidance behavior. Footshock is applied in all 4 sectors (A, B, C, D). Three trials are illustrated here. The rat is given a current of 0 to 1 mA, interval settings: current rise from 0 to 5 s, followed by the maximum value from 5 to 10 s, and current stops after 10 s (bottom, right). The next trial begins. Top right corner shows the real-time video recording.

4 Exemplary Tasks of Instrumental Learning

4.1 Approach/Withdrawal Paradigm

The most general division of behavior is considered to be approach and withdrawal. Studies demonstrated motivation-dependent brain activity (avoidance- or approach-goal) during behavioral acts, such as pedal pressing [1–3, 9]. A typical model of approach behavior is a food-acquisition task, while the typical model of withdrawal behaviour is an avoidance task.

We have created an experimental design based on tasks of instrumental learning. Operant box is equipped with automated feeders, escape-platform and pedal bars located in the opposite corners of the box. Pedal-pressing results in a reward, which is either a piece of food in a feeder (food-acquisition behavior, see Fig. 3b), or an escape-platform (footshock-avoidance behavior, see Fig. 3a). The action of pedal-pressing is the same in both cases, but its result is variable: escape-platform or feeder.

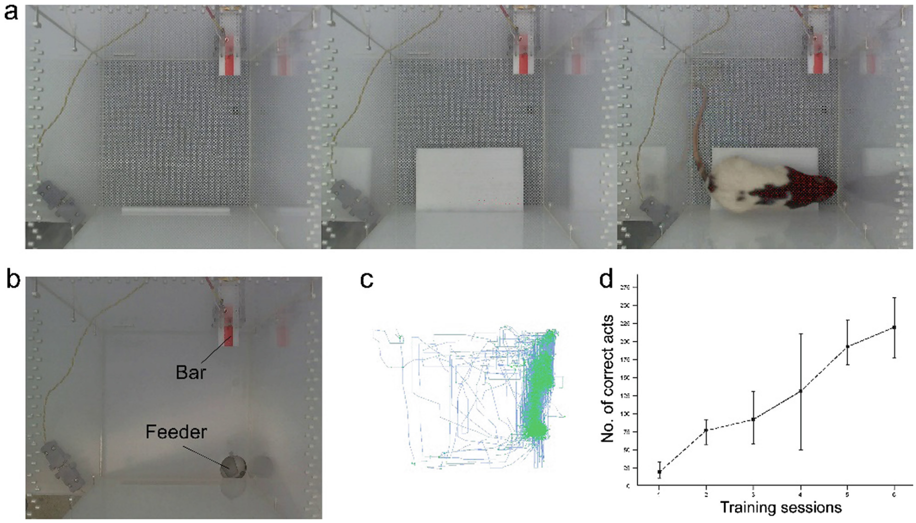

Fig. 3. (a) Instrumental footshock-avoidance behavior. (b) Instrumental food-acquisition behavior. (c) Movement paths of a representative rat. (d) Exemplary learning curve during appetitive bar-pressing behavior.

4.2 Behavioral Data Recording and Analysis

Data recording and analysis were performed using custom software developed by Volkov S.V. Fig. 4 shows exemplary real-time protocol for behavioral analysis (provided by the device).

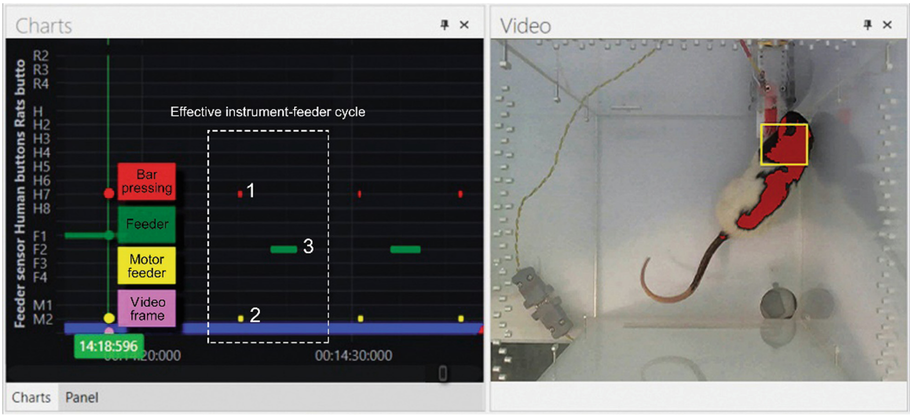

Fig. 4. Exemplary real-time protocol for behavioral analysis (food-acquisition task). The behavioral cycle: 1 - pedal (bar) pressing; 2 - start of the feeder motor; 3 - lowering rat head and taking food from the feeder. Frame from the actual video recording during operant food-acquisition behavior (right). The object is identified (rectangle), coordinates are recorded in PC.

The food-acquisition behavioral cycle was divided into several acts (Fig. 4 left): pedal (bar) pressing (mechanosensor); moving to pedal corner; lowering head (photosensor) and taking food from the feeder. The moving object is identified (Fig. 4 right, rectangle) by custom software using the open source Accord.NET Framework [11]. The signal-coordinates are recorded into PC. Animals' movement paths are restored by coordinates (see Fig. 3c).

The Accord.NET Framework is a .NET machine learning framework combined with audio and image processing libraries completely written in C#. Real-time object detection and tracking, as well as general methods for detecting and tracking. Convenient open source.

5 Conclusion

We have compiled and debugged a novel rodent avoidance task procedure that allows to obtain new type of data about individual differences in decision-making and choice of avoidance strategies. For example, experiments in active non-instrumental avoidance test (see Fig. 1b) showed, that female rats choose to minimize the risks and avoid shock during low-voltage current (a signal for avoidance), while male rats do it during the pause (between trials), which allows to avoid the shock completely but with a risk of high-voltage shock in rare occasions.

We have created an experimental design based on tasks of instrumental learning that allows to explore motivation-dependent brain activity (avoidance or approach). The novel rodent avoidance test that we developed expands the possibilities for exploration of learning and memory processes.

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References

1. Alexandrov, Y.I., Sams, M.: Emotion and consciousness: ends of a continuity. Cogn. Brain Res. **25**, 387–405 (2005)
2. Bulava, A.I., Grinchenko, Y.V.: Patterns of hippocampal activity during appetitive and aversive learning. Biomed. Radioelectron. **2**, 5–8 (2017)
3. Bulava, A.I., Svarnik, O.E., Alexandrov, Y.I.: Reconsolidation of the previous memory: decreased cortical activity during acquisition of an active avoidance task as compared to an instrumental operant food-acquisition task. In: 10th FENS Forum of Neuroscience, Abstracts P044609, p. 3493 (2016)
4. Carrillo, M., Han, Y., Migliorati, F., Liu, M., Gazzola, V., Keysers, C.: Emotional mirror neurons in the rat's anterior cingulate cortex. Curr. Biol. **29**(8), 1301–1312 (2019)
5. Cheng, N., Van Hoof, H., Bockx, E., Hoogmartens, M.J., et al.: The effects of electric currents on ATP generation, protein synthesis, and membrane transport in rat skin. Clin. Orthop. **171**, 264–272 (1982)
6. Keum, S., Shin, H.-S.: Rodent models for studying empathy. Neurobiol. Learn. Mem. **135**, 22–26 (2016)
7. Krypotos, A.-M., Effting, M., Kindt, M., Beckers, T.: Avoidance learning: a review of theoretical models and recent developments. Front. Behav. Neurosci. **9**, 189 (2015)
8. Muenzinger, K.F., Mize, R.H.: The sensitivity of the white rat to electric shock: threshold and skin resistance. J. Comp. Psychol. **15**(1), 139–148 (1933)
9. Shvyrkova, N.A., Shvyrkov, V.B.: Visual cortical unit activity during feeding and avoidance behavior. Neurophysiology **7**, 82–83 (1975)
10. Urcelay, G.P., Prevel, A.: Extinction of instrumental avoidance. Curr. Opin. Behav. Sci. **26**, 165–171 (2019)
11. Accord.NET Framework. http://accord-framework.net/index.html. Accessed 14 May 2019