

Review Article

Using Machine Learning To Integrate Ethology And Comparative Psychology Techniques To Advance Social Behavioral Neuroscience.

Joeri Bordes, Lucak Miranda, Bertram Müller-Myhsok b, Mathiak V. Schmidl

Research Group Neurobiology of Stress Resilience, Max Planck Institute of Psychiatry, Kraepelinstr. 2-10, 80804 Munich, Germany.

Abstract

Vertebrate animals naturally exhibit social behavior, which has a significant evolutionary component and is essential to an individual's healthy development and long-term survival. Several significant approaches to social behavioral phenotyping have been observed in behavioral neuroscience. The comparative psychology approach was created using standardized and univariate social behavioral assessments, but the ethological research approach has thoroughly examined social behavior in natural environments. The creation of sophisticated and accurate Recently, a new behavioral phenotyping technique that combines the advantages of both approaches has been made possible by tracking technologies and post-tracking analysis packages. In addition to being advantageous for basic social behavioral research, the application of such techniques will allow for a better comprehension of the various elements that can affect social behavior, including stress exposure. Additionally, In order to better understand the biological underpinnings of social behavior and inform intervention strategies for behavioral abnormalities in psychiatric disorders, future research will expand the number of data modalities, including sensory, physiological, and neuronal activity data.

INTRODUCTION

Since behavior plays a major role in both human and animal existence and interactions with the environment, it is imperative that we understand it (Heimlich and Ardoin, 2008; Bolhuis et al., 2021). However, behavioral disorders are the main cause of severe and extremely

common mental health conditions. In particular, social functioning impairment is a significant symptom of a wide range of mental illnesses, including schizophrenia, depression, autism, and post-traumatic stress disorder (PTSD). (Peleh et al., 2019a; Dodell-Feder et al., 2015; Katz et al., 2011; Nietlisbach and Maercker, 2009; American Psychiatric Association, 2013). Since behavior plays a major role in both human and animal existence and interactions with the environment, it is imperative that we understand it (Heimlich and Ardoin, 2008; Bolhuis et al., 2021). However, behavioral disorders are the main cause of severe and extremely common mental health conditions. In particular, social functioning impairment is a significant symptom of a wide range of mental illnesses, including schizophrenia, depression, autism, and post-traumatic stress disorder (PTSD). (Peleh et al., 2019a; Dodell-

Feder et al., 2015; Katz et al., 2011; Nietlisbach and Maercker, 2009; American Psychiatric Association, 2013)

Animal behavior's history

The behavioral response is ultimately driven by a unique pattern of cellular reactions in the brain that are triggered by exposure to external stimuli. Traditionally, observational research—in which animals are watched in their natural habitat without interference—has been used to establish fundamental principles of behavior. Charles Darwin conducted one of the first and most significant studies on animal behavior in the 1800s (Thierry, 2010). Based on his observations of animal differences, Darwin came to the conclusion that species were descended from one another (Darwin, 1859). The discipline of ethology, which focused on the evolutionary underpinnings of animal behavior and mostly employed observational methods, emerged as a result of this kind of behavioral research. The research of Tinbergen and associates, who noted that young birds can differentiate between the shapes of a hawk and a goose and alter their behavior based on the perceived shape, is a significant example of exceptional ethological work

***Corresponding Author:** Mathiak V. Schmidl, Research Group Neurobiology of Stress Resilience, Max Planck Institute of Psychiatry, Kraepelinstr. 2-10, 80804 Munich, Germany.

Received: 01-Feb-2025, ; **Editor Assigned:** 02-Feb-2025 ; **Reviewed:** 19-Feb-2025, ; **Published:** 28-Feb-2025.

Citation: Mathiak V. Schmidl. Using machine learning to integrate ethology and comparative psychology techniques to advance social behavioral neuroscience. *Advances in Behavioral Neuroscience*. 2025 February; 1(1).

Copyright © 2025 Mathiak V. Schmidl. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

(Tinbergen, 1939). Furthermore, Lorenz and associates' research revealed an intriguing occurrence in young domestic chicks: after early exposure, young animals focus their social preference towards an object, usually their parent (Bolhuis and Giraldeau, 2005; Sulloway, 1982). Although observational research and the discipline of ethology have produced amazing research discoveries, the study design has significant drawbacks as well. Because observational studies depend on the researcher's ability to evaluate behavior, there may be misunderstandings and, as a result, variations in how different researchers interpret the behaviors they observe. Furthermore, because of the high degree of variability among the experimental circumstances, the lack of environmental control restricts the throughput and the research topic that can be evaluated, which may result in results that cannot be replicated.

The discipline of comparative psychology was created in reaction to these constraints, with the goal of using well regulated environmental settings to study and comprehend behavior. Here, the emphasis was on simplifying the behavior and limiting the dimensions in which conduct can be conveyed through exact laboratory settings in order to break the behavioral construct down into easily recognized and quantifiable syllables. These lab tasks necessitate hypothesis-driven research questions since they are distinguished by a standardized set of behavioral read-outs and a high degree of environmental control. Thorndike, Skinner, and numerous more exceptional researchers demonstrated the strength and uniqueness of this field.

By observing that animals got more adept at escaping an apparatus and receiving their reward after more trials, Thorndike illustrated the concept of trial-and-error learning (Thorndike, 1898). Later, Skinner created the operant conditioning chamber, one of the earliest and most well-liked behavioral laboratory exercises (Skinner, 1948). The task's superiority is demonstrated by the fact that it can be used for both positive and negative reinforcement learning and is still being employed in research worldwide.

Morris, 1981), and continues to this day. Unquestionably, behavioral science laboratory activities are of the highest caliber, particularly when it comes to examining how external stimuli—like the stress response system—and interventions—like pharmaceutical ones—affect behavioral output (Hånell and Marklund, 2014). Furthermore, the investigation of certain target genes' effects on behavior has been made possible by the previously unheard-of possibilities for employing several genetic mice models. There are certain issues with laboratory tasks that must be addressed, and regrettably, no behavioral task is perfect. Many behavioral disciplines benefit from the reductionistic approach used in laboratory tasks, but behavioral constructs that depend on a wide range of behavioral outputs and call for more naturalistic settings—

which make them more difficult to evaluate—may find this approach problematic (Blumstein, 2010). In these situations, the repeatability rate is frequently lowered by laboratory activities that oversimplify behavior, which may result in an inaccurate or insufficient assessment. Since social behavior is a prime example of a complex behavioral construct, the concept of social behavior and the behavioral tests currently used to assess it are covered in the following section.

The concept of social conduct

Many animals, including humans and rats, naturally exhibit social behavior, which has a significant evolutionary component because it is essential to both the individual's and the species' survival (Wei et al., 2021; Chen and Hong, 2018). Although these behaviors are intrinsic, they are highly influenced by the environment and will modify social behavioral output accordingly. Adolescent mice, for instance, will engage in social play interactions with their conspecifics; but, if they experience social isolation during this period, their adult neurobiological mechanisms and social behavioral repertoire will be changed (Musardo et al., 2022). It is difficult to define social conduct precisely because it is a broad concept that encompasses a wide range of distinct activities. Any conduct that affects or is influenced by other members of the same species is generally referred to as social behavior. This phrase encompasses aggressive and domineering behaviors, sexual and reproductive activities, and all behaviors that unite people (Chen and Hong, 2018; Whishaw et al., 2006; Mackintosh and Grant, 1963). Though not the main topic of this review, it is crucial to remember that this definition does not include social interactions between various animals or objects, which may make up a small percentage of social encounters but are nonetheless included in the social behavioral repertoire.

TASKS INVOLVING SOCIAL BEHAVIOR

In rats, social behavioral events usually start when a social interaction is detected. The social behavioral encounter, which depends on one or a mixture of many social behaviors, including following, feeding, playing, guarding, fighting, sexual engagement, and parenting, can be completed by the animal, or it can be ignored or avoided (Wei et al., 2021). The underlying social behavioral construct is difficult to evaluate because it depends on a variety of behavioral read-outs. These constructs are influenced by other neural modalities, such as motivation (Bariselli et al., 2018; Soli'e et al., 2022a), emotion (Sakaguchi et al., 2018; Pisansky et al., 2017; Keum and Shin, 2019; Jabarin et al., 2022), and decision-making (Scheggia et al., 2022). Nowadays, a range of behavioral measures measuring many social dimensions are used to evaluate social behavior (see Box 1).

These social behavioral domains in particular are of interest because they are well-established behavioral tasks in the field of stress neuroscience and demonstrate the evolution of the reductionistic approach in social behavioral tasks, even though there are many more variations of social behavior and related tasks.

DOMINANCE IN SOCIETY

A balanced and organized group of several animals from the same species depends on the social hierarchy, a crucial area of social behavior (Dwartz et al., 2022; Qu et al., 2017). A person's reproductive prospects, health, and access to food are all impacted by their social position, which also affects their chances of surviving (Tamashiro et al., 2005; Ellis, 1995; Sapolsky, 2005). Dominant, aggressive actions and the ensuing defensive, submissive behaviors—adaptive behaviors to lessen aggressiveness in established hierarchies—are the means by which social rank is communicated. The tube test (Fan et al., 2019; Lindzey et al., 1966) and the warm spot test (Zhou et al., 1979) are two of the most widely used behavioral tasks designed to examine the hierarchical structure in rodents. Long-term home cage observations are another method (Shemesh et al., 2013; Forkosh et al., 2019). Since they are impacted by the incentive for food and water and can change depending on saturation, other hierarchy tests that depend on competition for food or water have lost favor (Merlot et al., 2004; Cordero and Sandi, 2007; Ujita et al., 2018). Fan et al.'s standardized procedure and ease of use have contributed to the tube test's rise in popularity (Fan et al., 2019).

Nevertheless, the instrumental laboratory setting used for these studies is notably unnaturalistic. In the warm spot test, animals are driven into confrontation since there is only one area that is sufficiently warm, but in the tube test, animals are forced into confrontation within a small space. As a result, the inherent effects of motivation on the formation of hierarchies are not included in these assessments. Individual differences in the desire to engage in social interaction with conspecifics, including hostile animal confrontation, have been documented in a number of studies (Bariselli et al., 2018; Torquet et al., 2018). Because they simplify the behavioral read-out, these tests thereby demonstrate the reductionist approach.

AVOIDANCE OF SOCIAL SITUATIONS

Understanding the underlying mechanisms related to social avoidance is crucial because clinical research has widely recognized that social withdrawal and avoidance are key symptoms of anxiety disorders (Rinck et al., 2010; Heuer et al., 2007) and depression (Ottenbreit et al., 2014; Fernandez-

Theoduloz et al., 2019). A popular paradigm for examining the stress response system is the social behavior domain, which includes social avoidance. It is especially well-established for evaluating Box 1's stress resilience versus susceptibility.

the various behavioral tests and social behavioral domains. The numerous distinct behaviors within a free social interaction task are too complex, time-consuming, and repetitive to evaluate manually, but until recently, there were no software tools available to analyze and distinguish multi-animal interactions (Hånell and Marklund, 2014; Goodwin et al., 2020; Sturman et al., 2020). Rapid advancements in automatically annotated motion tracking have made it possible to evaluate a wide range of social behaviors in intricate settings at high throughput. Thus, the current state of motion tracking and machine learning for behavioral classifications, as well as their implications for social behavioral neuroscience research, will be covered in the next section.

REFERENCES

1. Aggleton, J.P., 1985. One-trial object recognition by rats. *Q. J. Exp. Physiol.* 37 (4), 279–294.
2. American Psychiatric Association, 2013. Diagnostic and statistical manual of mental disorders. *Am. Psychiatr. Assoc.* vol. 21.
3. Ayash, S., Lingner, T., Ramisch, A., Ryu, S., Kalisch, R., Schmitt, U., Müller, M.B., 2023.
4. Fear circuit-based neurobehavioral signatures mirror resilience to chronic social stress in mouse. *Proc. Nat. Acad. Sci.*
5. Bariselli, S., et al., 2018. Role of VTA dopamine neurons and neuroligin 3 in sociability traits related to nonfamiliar conspecific interaction. *Nat. Commun.* 9, 3173.
6. Barnes, C.A., 1979. Memory deficits associated with senescence: a neurophysiological and behavioral study in the rat. *J. Comp. Physiol. Psychol.* 93, 74–104.
7. Beery, A.K., Kaufer, D., 2015. Stress, social behavior, and resilience: insights from rodents. *Neurobiol. Stress* 1, 116–127.
8. Benner, S., Endo, T., Endo, N., Kakeyama, M., Tohyama, C., 2014. Early deprivation induces competitive subordination in C57BL/6 male mice. *Physiol. Behav.* 137, 42–52.
9. Berton, O., et al., 2006. Essential Role of BDNF in the

- mesolimbic dopamine pathway in social defeat stress (1979). *Science* 311, 864–868.
10. Bidinosti, M., et al., 2016. CLK2 inhibition ameliorates autistic features associated with SHANK3 deficiency (1979). *Science* 351, 1199–1203.
 11. Blumstein, D.T., 2010. Towards an integrative understanding of social behavior: new models and new opportunities. *Front Behav. Neurosci.* Bolhuis, J.J.
 12. Bondar, N.P., Lepeshko, A.A., Reshetnikov, V. v, 2018. Effects of early-life stress on social and anxiety-like behaviors in adult mice: sex-specific effects. *Behav. Neurol.* 1–13.
 13. Bordes, J., et al., 2022. Automatically annotated motion tracking identifies a distinct social behavioral profile following chronic social defeat stress,