Play and Adversity
How the Playful Mammalian Brain Withstands Threats and Anxieties

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STEPHEN M. SIVIY

Most mammals play, but they do so in a dangerous world. The dynamic relationship between the stresses created by their world and the activity of play helps to explain the evolution of play in mammals, as the author demonstrates in evidence garnered from experiments that introduce elements of fear to rats at play. The author describes the resulting fearful behavior and quantifies the fluctuation in play that results, and then he investigates how these are modified by increased maternal care or the use of benzodiazepines. In conclusion, he discusses how such research can help shed light on the neurobiology underlying human anxiety disorders, especially in children.

Introduction

As I write this, most if not all, industrialized nations are slowly emerging out of the worst economic downturn since the Great Depression of the 1930s. With chronic economic uncertainty comes considerable anxiety among adults who are unemployed, underemployed, or fear they might lose their jobs. Children feel the impact of adult fears. In a world plagued by crime, terrorism, and natural disasters, anxiety can easily trickle down. We might think it is amazing that children play at all, but getting from birth to adulthood has never been easy for humans—or any other species, for that matter. Yet various species have survived through countless episodes of adversity, and they did so partly because they developed arsenals of coping mechanisms. We presume that play as a phenotype has been through the rigors of natural selection and has afforded some advantage—or at the very least, has not been a significant disadvantage—to species that play.

Play is widespread among mammals. Well over 90 percent of all mammals engage in some type of playful behavior prior to sexual maturity (Fagen 1981). Although often specialists investigate play as a behavior typical of mammals (MacLean 1990), researchers have also observed it in several bird species as well as in some reptiles (Burghardt 2005; Fagen 1981) and even in an invertebrate (Mather and Anderson 1999). Indeed, play may have emerged as a stable behavior pattern across a variety of species over the course of evolution, but one that truly took hold in the mammalian brain. There, play seems to be largely a subcortical event. Studies show that almost complete removal of the neocortex in rats (Panksepp, Normansell, Cox, and Siviy 1994; Pellis, Pellis, and Whishaw 1992) or hamsters (Murphy, MacLean, and Hamilton 1981) leaves both with the urge to play and most of the components of play intact, which points to a brain system that probably appeared fairly early in the course of mammalian evolution. As prevalent as play proves to be, it does not occur in a vacuum. For the young of many species, the journey from birth to adulthood can be filled with peril and considerable danger. Because play evolved amid these dangers, we need to understand its interaction with them in order to understand the evolution of mammalian playfulness.

Play in Rats

Most of what I present in this article involves play in juvenile rats. There are many practical reasons for using rats as an experimental model in order to better understand the neurobiology of playfulness. With the exception of mice, which tend not to play very well, we know more about the behavior and neurobiology of the common lab rat than any other species available for research. So it seems natural to study the playful behaviors of rats in order to understand the neurobiological substrates of mammalian playfulness. But this was not always so obvious.

When I first walked into Jaak Panksepp's lab at Bowling Green State University in the summer of 1981, I had every intention of studying some type of social and emotional behavior in rats. But I never really thought of play as something that would be studied empirically in a laboratory. Most of the published work at that time coming from Panksepp's lab focused on separation distress in young dogs, guinea pigs, and newborn chicks, so I assumed that I would become involved in this line of research. After a brief chat on that first day, however, we went up to the lab, Jaak placed a couple of young rats in a test

chamber, and he asked me to watch them. At first, I was perplexed by what I saw. I vaguely remember being both mesmerized by the flurry of activity taking place in front of me and at a loss to explain it when asked what I thought the rats were doing. Up to that point in my career, I had only worked with large adult rats that routinely lived alone for most of their lives (common housing conditions for lab rats in the 1980s and earlier), so I never saw rats interact—let alone actually play with one another. Their play was tireless, and this enthusiasm fascinated me.

What struck me most was how soon rats began to play after they started to walk, when they are somewhere around fifteen days old. Rat play peaks in intensity at around twenty-eight to thirty-five days and then begins to wane as the rats reach puberty (Panksepp 1981). Play in rats can be very rich and deep in detail, although in our lab, we have tended to focus on two major postures that are readily seen during play but not often seen during other nonplayful social encounters—nape contacts and pins. We define a nape contact as occurring when one rat touches the nape of another rat (rats are always tested in pairs) with either its snout or front paws. We believe this measure to be essentially the same activity others call dorsal contacts (Panksepp 1998), nape attacks (Pellis and Pellis 2009), or pounces (Trezza and Vanderschuren 2008).

Pinning is also a commonly used measure for playfulness. It occurs when one rat lies on its back while the other rat climbs on top in what seems a dominant posture. Although a pin appears to be the same posture described by Pellis as a complete rotation, it is important to draw a subtle distinction between them. A complete rotation, as defined by Pellis, only occurs in response to contact directed toward the nape; a pin, as we define it, also occurs in the absence of contact directed at the nape. While this kind of unsolicited pin is not common during a standard play bout, it does occur. In any event, nape contacts and pins provide a fairly good index of the overall playfulness of a pair of rats and are sensitive enough for determining the impact on stressors and other threats to play.

How Does Play Hold Up to Threats?

It seems obvious that play would be disrupted when an organism feels threatened in some way. In fact, Burghardt (2005) posits that one of the criteria for determining that a behavior can be classified as play is that it occurs when players are relaxed. Play takes energy, so the nutritional state of a child, for

example, seems to be a factor in regulating his or her level of play. A study of 111 school-aged children in Kenya examined their nutritional intake and playground behavior: the children with a more adequate diet were more active on the playground (Espinosa, Sigman, Neumann, Bwibo, and McDonald 1992). Making food more difficult to obtain can drastically reduce play in squirrel monkeys (Baldwin and Baldwin 1976), and play can be readily disrupted by hunger in rats (Siviy and Atrens 1992; Siviy and Panksepp 1985). Yet despite the ease with which hunger can dampen playfulness in rats, there is still evidence of considerable resilience even in the face of limited food resources. For example, play virtually disappears among rats tested after twenty-four hours of food deprivation. However, when these animals are provided with a single twenty-minute opportunity to eat, they immediately begin to play at predeprivation levels (Siviy and Panksepp 1985).

We observed similar resilience when sudden changes were made to the conditions under which animals were being tested. For example, because rats tend to be nocturnal, they are more active and more likely to play during night conditions (Romeo, Karatsoreos, and McEwen 2006). They will not play as much under intense lighting as they do in a dark environment (Vanderschuren, Niesink, Spruijt, and Van Ree 1995). For this reason, we routinely observe rats in a darkened chamber lit only by low-wattage red light. Abruptly switching the lighting from darkness to bright light after one hundred seconds of a five-minute test results in an immediate reduction of play (Siviy and Baliko 2000). Turning off the bright light after another one hundred seconds leads to an almost immediate resumption of play in the darkness. We understand from our data that rats will not play if they are physically uncomfortable or if their routine is sharply disrupted. However, they are capable of quickly rebounding once the circumstances return to a state (internal or external) that is more amenable to play.

It also stands to reason that a young rat will probably not play if it is afraid or anxious or otherwise detects the presence of some type of serious threat to its well-being. Since rats commonly fall prey to larger mammals such as cats, we would expect them to be wary of predators. Not surprisingly, when adult rats are exposed to a cat, they stop any nondefensive behaviors such as eating or grooming. Rats become highly defensive and behave in ways that help protect against this threat (Adamec and Shallow 1993; R. J. Blanchard and Blanchard 1989a, 1989b). Given a chance to run, rats will try to escape. Given a place to hide, rats seek cover. If neither of the options to run or to hide arise, rats freeze

or stop moving altogether. Similar behavior occurs when rats are exposed simply to the smell of a predator, either from a cloth that has been rubbed over a cat (R. J. Blanchard, Blanchard, Rodgers, and Weiss 1990) or from a fabric collar that has been worn by a cat for several weeks or months (Dielenberg and McGregor 2001). Rats as young as eighteen days old act this way (Hubbard et al. 2004). Using predator odors to induce fear in rats has an important advantage over more traditional approaches of creating such fear (e.g., pairing a tone or light with a painful foot shock) because fear is innate: it does not require any learning; it does not induce any physical pain; and smelling cat odor represents a situation rats encounter in the natural world.

In his landmark book *Affective Neuroscience*, Panksepp (1998) described the results of a previously unpublished experiment where rats were given an opportunity to play in the presence of a small tuft of cat fur. Play disappeared on the day that the cat fur was placed in the testing chamber, and even though the cage was thoroughly cleaned after testing, the rats did not play in the space for three to five days after the exposure. An even earlier study from Panksepp's lab (Panksepp and Crepeau 1990) showed that transecting the vomeronasal nerve, which conveys pheromonal information from the vomeronasal organ to the accessory olfactory bulb, prevented the odor-induced suppression of play. The study suggested that rats might use pheromonal cues exuded by cats to avoid them. This suggestion is consistent with later findings in adult rats showing strong neural activation of the accessory olfactory bulb, which receives input from the vomeronasal organ, following exposure to cat odor (Dielenberg, Hunt, and McGregor 2001; McGregor, Hargreaves, Apfelbach, and Hunt 2004).

My curiosity piqued, then, I left on a sabbatical to Iain McGregor's lab at the University of Sydney. He ran a program to study the neurobiological substrates of predator odor-induced fear, so his lab was well situated to help me investigate how fear of predation also affected play in young rats. We began systematically to analyze the effects of predator odor-induced fear on play.

Our first experiment simply set out to replicate Panksepp's original finding by testing rats in a standard Plexiglas test chamber in the presence of either pieces of fabric collar that had been previously worn by a cat or pieces of collar that had never been worn. Our results proved nearly identical to Panksepp's. Play disappeared in the presence of the collar previously worn by a cat, and the rats did not engage in play for up to seven days after exposure. (See figure 1.) In our other experiments, as I reported, play soon returned after we fed our
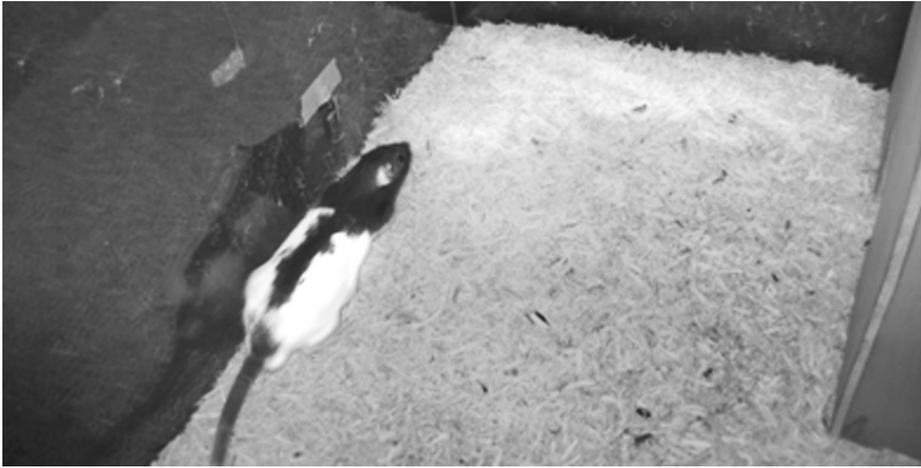
Figure 1. The area of the outer chamber with a piece of cat collar affixed to the wall just to the left of the rat's body.

hungry rats. We were initially puzzled to discover that the rats did not restart their play even after we removed the collar with the cat odor, and we asked ourselves why this was so. But other work with predator odors suggested why that might not necessarily be unexpected. I mentioned that rats' responses to predator cues depend to a large extent on the options available to them. (R. J. Blanchard and Blanchard 2003). A barren test chamber does not really give
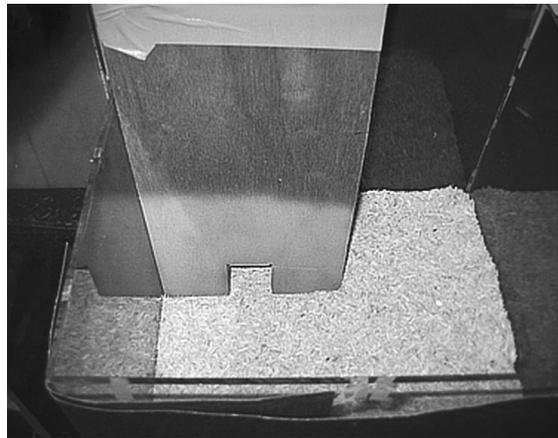

Figure 2. The chamber used to assess the effects of a predator odor on play behavior in rats. Note the main outer chamber (50 x 50 x 50 cm) with the hide box situated in the upper left corner.

rats many options. Thus, our results may have been telling us more about the apparatus we were using than about the phenomenon we were studying.

In order to determine whether the magnitude of this effect was, indeed, the result of testing rats in an unprotected, open field, our next experiment added a little complexity to the design. We provided the animals with an opportunity to hide. Inspired by the visible-burrow system pioneered by the Blanchards (R. J. Blanchard and Blanchard 1989a), McGregor's lab developed an automated system for assessing predator odor-induced fear using a test chamber that also afforded the animal an opportunity to hide (Dielenberg, Carrive, and McGregor 2001). We incorporated a hide box feature into our play paradigm (see figure 2) and tested another group of animals in the same way we had in the first experiment. The results from that study proved almost identical to those of the first study. Even with an opportunity to hide, rats still ceased to play in the presence of the cat collar and abstained from play for seven days after exposure.

Several other interesting observations followed from this initial look at the impact of fear on play. The first involved the amount of time rats actually spent in the relatively small hide box. When we initially decided to add the hide box to
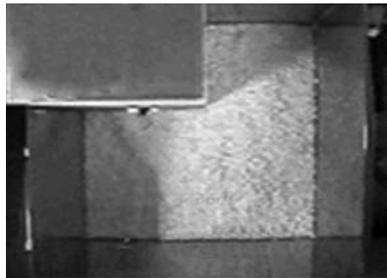

Figure 3. An overhead view of the outer chamber. The one rat engaged in a head-out posture barely extends its snout outside the box.

the play chamber, we guessed the rats would likely engage in most of their playful activity in the main part of the chamber, thinking that the larger surface area would better suit the rats' chasing each other and their more energetic forms of rough-and-tumble play. This assumption proves that humans should not try to think like rats (R. J. Blanchard and Blanchard 2003), because during the study approximately 75 percent of all pinning activity occurred in the hide box. We have since confirmed this figure in a number of other studies. It suggests that where rats choose to play may actually help minimize the risk of predation. We also found in both this study and in subsequent ones (Siviy and Harrison 2008; Siviy, Steets, and DeBrouse 2010) that levels of playfulness after a threat do not always map onto other measures of fear, such as hiding and risk assessment. For example, rats begin to play much sooner after exposure to a predator odor if the exposure occurs in a context different from that used for testing. But these rats still exhibit a substantial number of risk-assessment behaviors despite the return to play at prethreat levels. We measure risk assessment in this model by quantifying the amount of time at least one rat engages in a head-out posture (see figure 3), a type of vigilant scanning of the outer chamber from within the safe confines of the hide box (R. J. Blanchard and Blanchard 1989b; Dielenberg, Carrive et al. 2001). Our findings suggest that rats will engage in normal levels of play while still regularly scanning the environment for the presence of any continuing threat. Again, we see evidence for how resilient play can be.

How Can Responses to These
Threats Be Modulated?

The experiments using cat odor to suppress play may help us to understand better the neurobiological substrates of anxiety. Anxiety disorders are among the most common psychiatric disorders in young people, affecting approximately 13 percent of all children (Shaffer et al. 1996). Anxiety in childhood sometimes continues to progress and worsen into adolescence and even into adulthood. It can also lead to other childhood problems such as difficulty in school, substance abuse, and depression (Heim and Nemeroff 2001; Williams and Miller 2003). While smelling a cat is not likely to generate fear and anxiety among most children, we presume that the brain mechanisms generating these negative emotional states in the rat are at least similar to those that generate fear and anxiety in humans. Using cat odor to suppress play in the juvenile

rat may then offer us a handle on the brain mechanisms of childhood anxiety. And looking at the ways fear and anxiety in young rats can be modulated and blunted could be particularly beneficial for developing therapies to treat childhood anxiety, which may differ from those used to treat adults. As a starting point, our lab has focused on identifying both social and pharmacological factors that can temper fear in these models.

Most mammals tend to be fairly social, so social factors may figure prominently in coping with stress. Indeed, even simple social contact can have a substantial buffering effect on how animals handle stress. In an interesting study by Coan and colleagues (Coan, Schaefer, and Davidson 2006), female participants were presented with cues that predicted a mild electrical shock while in an fMRI scanner. In addition to monitoring brain activity, the study asked the participants to rate the unpleasantness of the experience and their arousal. Each participant was tested while either holding the hand of her husband, holding the hand of a male stranger, or holding no one's hand. Participants who held their husbands' hands during the study registered lower arousal from the threat, lower unpleasantness associated with the threat, and less intense activation of the cortical and subcortical areas affected by the threat. In addition, there was a significant negative correlation between brain activation and marital satisfaction. Higher levels of marital satisfaction were associated with lower brain activation. So simply holding a spouse's hand is enough to provide a buffer against the fear associated with an impending electrical shock.

For mammals, social experiences largely begin at birth, so early postnatal experiences can be particularly crucial in laying down an affective foundation, which an animal can then draw upon throughout childhood, adolescence, and adulthood. In rats, the first two weeks of life are particularly crucial for providing this affective framework. For example, increased maternal care during their first two weeks makes the rats less fearful and less reactive to stress later in life. These effects depend on the amount of licking and grooming a mother gives her pups. The pups raised by a mother that licks and grooms them often tend to be less fearful and less stressed as adults (Champagne and Curley 2009; Meaney 2001; Parent et al. 2005). Separating the pups from the mother for a brief period (e.g., fifteen minutes) each day during the first two weeks of life also results in less fearful rats. This effect seems due to increased licking and grooming by the mother when reunited with her pups (Caldji, Francis, Sharma, Plotsky, and Meaney 2000; Zhang, Chrétien, Meaney, and Gratton 2005).

Given the robust nature of these effects when tested in adult rats, we decided to look at the extent to which brief, daily periods of separation during the early-postnatal period (also known as handling) would modulate the ability of cat odor to affect play (Siviy and Harrison 2008). First, we found that handled rats were more playful overall than nonhandled rats. The increase in play was fairly consistent across testing, so it is unlikely that the increase reflected an attenuated response to novelty. Rather, brief periods of maternal separation during the first two weeks of life most likely resulted in some long-term change in the neural circuitry responsible for play. As for the response to fear, handling had no effect on the direct response to cat odor. Both handled and nonhandled rats exhibited a comparable suppression in the presence of the odor. However, the conditioned suppression seen in nonhandled rats when these rats were returned to the same chamber on the next day was not present in the handled rats. In other words, handled rats showed less conditioned fear when tested twenty-four hours later in the same context as the exposure. Interestingly, there was no difference between the two groups in terms of risk assessment, which indicated that these animals exhibited some degree of caution while continuing with prethreat levels of play. Once again, we see resilience and a return to playfulness even when other indices suggest continued levels of caution.

Another way to understand how fear-induced reductions in play can be modulated might be to control chemically the neural systems researchers believe turn on in rats when they face situations that make them fearful or anxious. As a step in this direction, we have begun to look at pharmacological agents commonly used to treat anxiety, known as anxiolytics, or at those that may have therapeutic value in the future. While I do not necessarily advocate the widespread use of pharmaceuticals in the treatment of childhood anxiety, this is a treatment used in some clinical practices (Compton, Kratochvil, and March 2007), even though most of the empirical data on various treatment options and dosing recommendations are based on studies of adults (rats and humans). Given the dynamic nature of neurochemical systems, especially in adolescence (Shen et al. 2007), it seems that looking at the efficacy of promising anxiolytics in younger rats would be particularly useful.

Benzodiazepines, which include drugs such as Valium and Librium, are generally considered the gold standard among putative anxiolytics, so our first set of experiments looked at the effects of chlordiazepoxide (Librium) on the extent to which cat odor reduces play (Siviy et al. 2010). When tested on rats in the presence of cat odor, chlordiazepoxide had no impact on the reduction in

play. However, treated rats hid slightly less often. They also seemed to employ a joint defensive strategy. For example, there was a reduction in the likelihood of both rats hiding at the same time. Times when both rats were not in hiding coincided with an increase in the likelihood that one rat remained in the hide box while the other rat stayed in the main part of the chamber that held the worn cat collar. Risk assessment on the exposure day was not affected by chlordiazepoxide. But there was elevated risk assessment on the following day in rats that received the treatment. These results suggest that treatment with a benzodiazepine may change the defensive strategy of rats to facilitate behaviors that allow a better assessment of any continuing threat. Others have reported similar results in adult rats, and our results are consistent with the idea that benzodiazepines do not necessarily make rats less afraid but rather change how they respond to fear-inducing stimuli (D. C. Blanchard, Blanchard, Tom, and Rodgers 1990; Dielenberg, Arnold, and McGregor 1999). When rats were treated with chlordiazepoxide, exposed in one context, and tested in a different context, play in the treated rats returned to prethreat levels sooner than in control rats even though the treated rats also showed elevated levels of risk assessment. So treatment with a benzodiazepine can result in an earlier return of playfulness when rats are tested under a particular set of conditions.

Several key points can be taken from these two lines of research. First and most obvious, play is severely compromised in the presence of a predator odor. This should not be unexpected, given the danger of failing to notice the presence of a predator. However, once the threat becomes less imminent, we begin to see a return to playfulness even though the rats are showing signs of caution (i.e., increased levels of risk assessment). The recovery can be accelerated by both social factors and benzodiazepines. Again, these findings highlight the overall resilience of playfulness in rats. These studies also provide a better understanding of anxiety in prepubertal rats. They shed some light on the mechanisms at work in human children and adolescents who are suffering from anxiety.

Playing to Help Cope with Adversities

Up to this point, I have discussed how threats and adversities can affect playfulness and how this can be blunted by experience and pharmaceuticals. It is also worth considering the possible beneficial value of play itself as one coping mechanism for dealing with adversity. There is already considerable evidence

from the rat literature that social contact can have a significant buffering effect on a variety of stressors. In one of the earlier studies on social buffering, Davitz and Mason (1955) tested rats for conditioned fear to a blinking light that had been previously associated with a foot shock. Some conditioned rats were tested beside unconditioned rats. These rats showed less freezing and more movement in the presence of the blinking light than conditioned rats tested alone. This basic finding has been replicated many times in studies (Armario, Luna, and Balasch 1983; Armario, Ortiz, and Balasch 1983; Kiyokawa, Takeuchi, and Mori 2007; Latane 1969; Taylor 1981) that, taken together, have proven social contact can have a clear and potent buffering effect on how an animal responds to a fearful and/or a stressful situation.

We also tested the social buffering hypothesis in a study where younger rats were exposed individually to predator odor in the same testing chamber as that used with the play described earlier. On the following day, rats were returned to the chamber either alone or with another rat that had not been previously exposed to cat odor. Consistent with the social buffering hypothesis, those rats exposed with a nonfearful partner spent less time hiding and were also more active than the rats tested alone (Siviy 2008). It remains unclear, however, if any of these effects can be modulated by systematically varying the playfulness of the partner, although this is obviously a line of inquiry worth pursuing.

Does play by itself have the potential for easing stress when placed in an anxiety-provoking situation? Some evidence in the literature about human play says it does. An early study that looked at preschool children found that those children distressed on the first day of school who were allowed to play became less anxious afterwards than distressed children to whom someone simply read a story (Barnett 1984). Interestingly, this lessening of distress became apparent only in those children who displayed high levels of baseline anxiety to begin with, and it was most evident in children who were allowed to play alone. In general, the evidence suggests that free play reduces anxiety in children (Burdette and Whitaker 2005), but how much and against which stressors remains unclear. Consider, for example, play studied in children being treated for leukemia compared to the control group of the same age in a daycare center (Gariépy and Howe 2003). While those with leukemia played less overall than the control group, an interesting pattern emerged among them. As anxiety levels increased in the kids with leukemia and they felt more stressed, they engaged more frequently in solitary play than parallel or group play, and their play became more repetitive.

One line of thinking is that sick children use solitary play to work through the anxiety caused by their illness. A more recent study (Li 2007) looked at children admitted for elective surgery. The study used therapeutic-play in-tervention with half of the children, then compared their anxiety to the other half—the control group. In the play-intervention group, researchers used a doll to demonstrate the procedure the children were to undergo. Then, the young patients were allowed to explore the equipment in the operating room, after which they were asked to use the doll themselves to mimic the procedure. The children who played out their operation showed less anxiety concerning their impending surgery. These results are consistent with the view that play can help children cope with stress. Indeed, they suggest that play more generally may help reduce anxiety in children.

Such suggestions could be verified in behavioral neuroscience by develop-ing a means to test them more fully in rats. There is already some evidence that depriving rats of play during a critical two-week window of development when play is most likely to occur can have a number of consequences when these rats are tested as adults. For example, rats housed in isolation as juveniles tend to be more anxious when tested as adults than rats housed socially during this younger age (Arakawa 2003; Einon, Morgan, and Kibbler 1978; Einon and Morgan, 1977). Rats housed in isolation during the juvenile period also engage less socially with novel rats when tested as adults, and they are less likely to assume a submissive posture when confronted and attacked by dominant rats, although their general-ized anxiety was not affected in this study (Van den Berg et al. 1999). Interest-ingly, previously isolated rats also exhibit an exaggerated hormonal response when confronted by dominant rats. These findings, produced in several studies highlight the importance of using multiple end points (e.g., both behavioral and hormonal) when studying the effects of stress on rats.

Conclusions

Stress and play are clearly not compatible, and stress occurs frequently in the lives of all animals. We have seen that play can be resilient even in the face of serious adversity. Animals stop playing when a threat appears in their envi-ronment, which indicates that the animal brain as it evolved saw an adaptive advantage in ceasing to play. But, once the immediate threat is over, they start to play again, suggesting that the animal brain as it evolved saw no adaptive

advantage in allowing feelings of fear and anxiety to linger. Using the smell of a cat to induce fear in juvenile rats has provided an interesting and ethologically valid model with which to study how young rats deal with this type of severe stressor. Our findings help us identify some factors that can accelerate the return to playfulness after being confronted with a predatory threat.

Social influences such as maternal care and play may be particularly salient for highly social mammals such as rats, and they could carry through from birth to adulthood. These types of social cues may provide critical information about resources and support that can help direct a multifaceted course of action (e.g., behavioral and hormonal) when confronted with stressors. For example, some have argued that the amount of maternal care exhibited by a mother towards her young provides a valuable clue to the type of environment into which the young have been born (Champagne and Curley 2005; Meaney 2001) and that early maternal experience can impact both play and responsiveness to a predator odor (Siviy and Harrison 2008). Growing up in a supportive environment along with having ample opportunities to engage in social play may provide the type of affective support that encourages a more rapid recovery from adversity. We need to delineate further these influences and to identify better the relevant neurobiological substrates in order to understand more fully the role of play in animal life.

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