

What Is It Like to Be a Swarm? :

Affective Considerations of Emergence in Biological Collectives

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May 2023

A THESIS PRESENTED TO THE PACIFIC NORTHWEST COLLEGE OF ART
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER OF ARTS

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Abstract

An autoethnographic exploration of emergent phenomena as found in biological collectives, specifically of *Solenopsis invicta* fire ants, human crowds, and murmurations of starlings. The author explores the motor behavior and material capacity of these swarms through a survey of the scientific disciplines of sociobiology, cybernetics, crowd science, fluid dynamics, system theory, and emergence theory. Finding these disciplines enlightening but dissatisfying, the author draws on critiques of scientific knowledge production and institutionalization through Donna Haraway, Karen Barad, and Thomas Nagel's hierarchy and biases entangled in the cultural studies of science and technology. The author advocates for an ethico-onto-epistemologically appropriate methodology in investigating the (inter)subjective experiences of collective emergent behavior and suggests that affect theory is a vital rubric of consideration. Reflecting on personal experience within a music festival crowd, the author draws on Berlant's conceptualization of affective "impasse" and "infrastructures" to describe the sensation of losing attachment to the crowd and experiencing confusion alongside Deleuze and Guattari's concept of "lines of flight." The thesis argues for an affective-inclusive transdisciplinary approach to investigating emergent swarm behavior. The author questions if a consideration of the affective dimensions of swarm behavior and the (inter)subjective experience of individual agents within their collective, *alongside* an empirical analysis of this behavior, can provide context for the physical and affective conditions necessary for emergence. This thesis concludes by questioning the nature of "self-attachment" and sovereignty during times of biological emergence.

“It will not help to try to imagine that one has webbing on one's arms, which enables one to fly around at dusk and dawn catching insects in one's mouth; that one has very poor vision, and perceives the surrounding world by a system of reflected high-frequency sound signals; and that one spends the day hanging upside down by one's feet in an attic. In so far as I can imagine this (which is not very far), it tells me only what it would be like for me to behave as a bat behaves. But that is not the question. I want to know what it is like for a *bat* to be a bat.”

Thomas Nagel, “What is it like to Be a Bat?”

In 2014, I attended the Lollapalooza music festival in Chicago, Illinois. This three-day, eight-stage festival of mainstream alternative rock, electronica, hip-hop, and rap drew around 100,000 concert-goers daily, and is a staple in the Chicago music festival scene. I attended with my partner and two fringe-friends. The four of us were funneled through multiple checkpoints and snaking lines, checking bags, tickets, and passing through metal detectors before our path opened up to the vast Grant Park downtown. (We lost our friends immediately.)

Even as early as we arrived, it was very crowded, with swarms of people flowing toward their preferred stages. My partner, Vasilios, and I had just started dating, and I clung to him (a seasoned concert go-er) as he led us to some artists that we both liked. It was a sunny day and quite chill for how populated it was. We began by joining a small crowd for a Vance Joy set, of “Riptide” popularity. This was, cheesily enough, one of “our songs” at this time in the relationship—Vasilios would change the “Michelle Pfeifer” lyric to “michelle brehmer.” (We were one of those couples.) If I had to name a genre, it’d be something like indie-folk/pop—Top 40, for sure. The others in the crowd, like us, were strictly cuddling their partners and sway-singing together in the sun.

After the set ended and we found some beer, we headed towards a Kate Nash performance. (Reminder that this was 2014.) She was a fun performer, stomping on the piano with her feet and being that kind of wild and fun. A bit past her initial popularity, I reminisced while hearing her set, reminded of listening to her songs with my undergrad peers during soft sculpture overnights.

As the set began to pick up, we gradually began to move from the edges of the crowd to the center of the excitement. I was having fun jumping and singing and laughing, but at some point, I began to feel that I was starting to lose myself a bit. It became too much for me, and I removed myself from the crowd and headed towards the Port-a-Potties on the outskirts of the park. I sat under a tree near young families and started hyperventilating. Some moms asked if I needed water, thinking that I was having a bad trip.

By the time my partner came to check on me, and was in the throws of a significant panic attack—I couldn’t speak, move, think, or breathe. I only remember that things

felt a little dimmer and duller and that I was completely consumed with a feeling of terror.

Eventually, the episode began to run its course and I started to return to myself. When I was able to walk, we moved to a different, hillier park area to get some extra distance from the bustling crowds and continue to relax a bit following the attack. I was very exhausted and overwhelmed, disengaged and frozen, as I often am following these types of shut-down episodes. As we settled on the hill further from the festival, our new vantage point, provided a kind of aerial view of the entire park and the swarms of people moving from stage to stage. We watched them move in globs through the park, sections breaking off towards bathrooms or beer. Their movements from this perspective reminded me of the movements found in ant colonies or other swarms, and I threw up.

Swarms

Why do swarms gross me out? They always have. Lots of children are nervous around mobilized insects, rationally distrustful of unfamiliar creatures. However, the disgust I have for swarms has remained firmly rooted in my adult body as well. To qualify, I wasn't *afraid* of them; they were just—*gross*. Not just insects either, but crowds of people, too. It always made me feel sick to look at seas of people in enclosed spaces; airport customs, football games, and dance clubs, especially. The issue wasn't simply that there were too many (nobody likes being outnumbered) but that I didn't know *how they worked*. This was true in other swarms as well; Though I'm not sickened when I witness a murmuration of starlings or watch TikToks of herring shoals flashing in the sea. But they have always had some sort of power over me that I couldn't name.

One particular example of swarms has stuck with me for so long that I had to return to it when researching this thesis. In 2017, I saw a Vox video on a friend's Facebook, "*The Bizarre Physics of Fire Ants*,"¹ featuring *Solenopsis invicta*, a species of fire ant native to the flood plains of South America. This species developed a way of surviving as a colony during high flooding by linking their bodies together to form a singular mass. The ants bodies are linked so tightly that water molecules cannot pass between them, creating a water-repellent colony able to float down the river until they reach dry land. Notably, this species' adaptation to surviving these conditions is such that they are, in fact, an invasive species in the southern US as well as the Caribbean, Australia, and China.

The video featured engineers and physicists from Georgia Tech who were curious about the species' behavior and unique material properties. Their experiments found that the ant-mass materially took on a viscoelastic structure, meaning that the collective ants as material behaved as liquid and solid simultaneously. One shot features a viscosity test in which a penny is dropped into a slide of ants and slowly sinks like molasses.

¹ Vox, "The bizarre physics of fire ants".



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The fire ant's ability to take on viscoelastic material properties during high flooding is an example of emergent behavior. As Nick Obolenksy says, "Emergence is the way complex systems and patterns arise out of a multiplicity of relatively simple interactions."³ In *Solenopsis invicta*, the simple acts of ants linking legs with their neighbors allow the collective to float, demonstrating collective behavior that could not be possible in the individual agents alone. One of the critical features of emergence is that it often arises through non-linear interactions within complex systems, which is why ants' decentralized organization makes them the prime example of emergence in biological swarms.

The Vox video, "*The Bizarre Physics of Fire Ants*", was the catalyst for me to begin investigating emergent behavior in complex systems, which I almost exclusively explored through biological collectives. I wanted to understand how these systems operated; what or who mobilizes their collective behavior? How does a single bird experience their collective flock during murmurations? Does an individual

² brehmer, michelle, "Screenshot of Viscoelastic Test from "The bizarre physics of fire ants", 2017", May, 19th, 2023

³ brown, "Emergent Strategy", 14.

temporarily “lose themselves,” receiving a message to act through a type of hive mind, or is it more of a domino situation?

These questions are entangled with considerations of material behavior, consciousness, agency, and the conditions and experience of emergence. It was my hope that in understanding how swarms functioned, I would better understand how to relate to them, both physically and conceptually. How do you trust something when you can't locate its brain?

Science

I began this project by investigating the ways that disciplines such as sociobiology, fluid dynamics, cybernetics, crowd science, systems theory, and emergence theory consider the motor behavior of these different swarm-systems. Through surveying these fields, I was able to identify their contributions, applications, and limitations in theorizing swarm behavior.

Sociobiology:

Sociobiology was most directly applicable to my research into ant colony behavior, having been introduced by a biologist and entomologist⁴ who specialized in myrmecology⁵, E.O. Wilson. His was my primary introduction to the field; Wilson's theorization of social instincts and behavior as evolutionary was highly influential to our current understanding of social behavior.

Researching sociobiology provided me with a biologist's theorization and language for collective behavior of living complex systems. Categorizations of select species with elite social capacities and exhibitions of emergence were "*eusocial*," enabling the collective mass to behave as "one single *superorganism*."⁶ One of Wilson's primary interests in myrmecology was his fascination with "the parallels between the world of insects and humans"⁷. Sociobiology provides insight into the influence of emotions and social forces on a swarm's behavior.

However, sociobiology's proposition that emotions as evolutionary was controversial when E.O. Wilson first introduced it, and has many negative ramifications to this day. People feared that in theorizing genetic markers that determined traits such as sexuality, intelligence, and socioeconomic status, he was justifying a return to older ideas of nature over nurture. This was—and currently is—concerning, as this

⁴ Branch of zoology concerned with the study of insects

⁵ Branch of entomology concerned with the study of ants

⁶ Schulze, "E.O. Wilson: Of Ants and Men"

⁷ Schulze, "E.O. Wilson: Of Ants and Men"

type of thinking fueled the spread of the eugenics movement and white nationalism, among other harmful agendas.

Cybernetics:

My research into cybernetics was primarily through mathematician and physicist Norbert Wiener's 1948 introductory text *Cybernetics: or Control and Communication in the Animal and the Machine*. His theories are described in the language of trigonometry and differential equations and are concerned with self-organizing systems, intelligence as an emergent phenomenon, and applications of information, noise, and psychopathology. In cybernetics, a crucial concept in understanding different social, biological, and technological systems is found in "feedback mechanisms"—processes where a system's output information is "fed back" into the system as input, allowing for self-adjustment (such as a room thermostat or the human body's capacity to maintain temperature equilibrium).

Weiner's contribution of Brownian motion to the field of cybernetics can also be helpful in researching collective behavior. Brownian motion models randomness in nature and can be applied to collective movements in birds, swarms, and crowds to determine the degree to which an individual is moving independently or towards a group's common goal. Cybernetics was a helpful discipline to explore for this project because it bridges material questions and theories of communication.

Crowd Science:

Crowd science is "an emerging field of research, which is primarily motivated by crowd safety issues in congested environments. Crowd science refers to the study of the effect of density, dynamics and behaviour on a crowd and crowd safety"⁸, by utilizing methods like crowd modeling (agent-based modeling software, real-life simulations), crowd counting, and crowd monitoring and management methods. Considering variables within the crowd, such as average speed, volume, and density, alongside psychological and social factors,

⁸ Still, Papelexi, et. al, "Place crowd safety, crowd science?"

crowd scientists analyze and predict the likelihood of emergent collective behaviors such as line formations, oscillations, or bottlenecks.

The field of crowd science combines cybernetic's mathematical and physical considerations alongside crowd psychology and risk analysis to research crowd behavior. The applications of this field help to understand and prevent crowd disasters, such as the injuries and fatalities that occur during crowd crushes, such as those that frequently occur in concerts, sporting events, and religious congregations.

The inclusion of psychological forces and “emotional contagion”⁹ is of interest to my research because it considers the subjective emotional experience of individuals within the crowd as a variable to influence crowd behavior. Interestingly, crowd scientists believe that “the motion of a crowd is governed by well-defined rules of behaviour. These rules imply a set of coupled, non-linear, partial differgroup's common goal density and velocity potential for each type of pedestrian in the crowd”¹⁰, and suggests that these phenomena can be empirically proven and predicted.

Fluid Dynamics:

I became interested in researching the material properties of collective masses after learning about the fire ants' emergent viscoelastic composition. Around the time I began this research project, a similar example of a collective's material behavior was discussed in the wake of the Travis Scott's Astroworld tragedy. In an article titled “The physics behind the Astroworld tragedy: When crowds behave like a fluid, people can wind up powerless”¹¹, author Erin Schumaker discussed the fluid-like material behavior that occurs during crowd crushes.

⁹ Xu, Shi, et. al, “Dynamics of emotional contagion”.

¹⁰ Hughes, “The flow of large crowds of pedestrians”.

¹¹ Schumaker, “The physics behind the Astroworld tragedy”.

A branch of engineering and physics—fluid dynamics—is concerned with the properties of fluids, how they move, and what causes their motion through analyzing substances' viscosity, density, inertia, center of mass, and many other properties. Fluid dynamics is utilized in crowd science analysis and can be used to analyze other collectives as material, as demonstrated by the Georgia Tech fire ant experiments discussed earlier in this thesis.

System Theory:

System theory is an interdisciplinary field concerned with understanding the interaction within complex systems. Like cybernetics, systems theory shares a foundation in the attention to feedback loops in understanding system functions. (Cybernetics is, in fact, a type of system theory.) Identifying a system's structure (such as a stock-and-flow system, reinforcing or balancing feedback loop, etc.) and utilizing visual mapping processes (concept, influence, and causal loop mapping) helps visualize the various factors and forces at play within and outside of these systems.

A systems theory approach requires one to “look beyond the players to the rules of the game”¹². When researching biological collective behavior, systems thinking helps clarify a swarm's objectives (surviving as a colony during flooding in *Solenopsis invicta*) and further illustrate the system's contributing elements.

“To ask whether elements, interconnections, or purposes are most important in a system is to ask a very unsystemic question. All are essential. All interact. All have their roles. But the least obvious part of the system, its function or purpose, is often the most crucial determinant of system behavior.”¹³

¹² Meadows, “Thinking in Systems”, 12.

¹³ Meadows, “Thinking in Systems”, 17.

Emergence Theory:

Emergence theory is a different type of systems theory that focuses on how complexity can arise from simple interactions between individual parts within (often decentralized) systems. As I mentioned earlier in this paper, *Solenopsis invicta*'s viscoelasticity is an example of emergent behavior, and so is a crowd's self-organization of line formations or bottlenecks. Emergence can arise out of non-biological systems as well. A weather system exhibits emergent behavior through the formation of tornadoes and hurricanes, and machine learning algorithms of artificial intelligence exhibit emergence when developing new strategies (such as when Google's DeepMind AI program AlphaGo discovered a new move in Go)¹⁴.

However, some traits are often confused with emergence. For example, a chameleon's ability to camouflage is often mistaken as an emergent trait, as it is born of interactions between the animal and their environment. However, because this characteristic does not emerge from an interaction between other chameleons in a collective, it is not truly emergent. Similarly, not all collective behavior is inherently emergent either; In a flying V formation, the birds' actions are primarily intentional and autonomous. Conversely, in starling murmurations, a bird's actions emerge from interactions with their neighbors, producing decentralized, collective movement. This distinction is critical to understanding the conditions of the emergent behavior found in biological collectives. Under these conditions, some theorize that intelligence, consciousness, and agency are emergent properties as well, which could provide further insight into collective action relative to this thesis.

Surveying these fields provides insight into the different material, social, biological, and systemic considerations attached to questions of emergent collective behavior. Each discipline involves utilizing scientific methods to explore natural phenomena and relying on empirical data to pursue their research and justify their findings. Though I appreciate that there is an empirical language with which to discuss complex theories and emergent behaviors, I didn't find any of the disciplines to be

¹⁴ Metz, "In Two Moves".

particularly satisfying in addressing the mysterious quality that these swarms emitted—why they had such a strange power over me. When I began this research, I had hoped that a thorough investigation into the structure and function of swarms as a material system would provide insight into this quality. I imagined that “the answer” would lie outside the individual disciplines' range of vision and that a transdisciplinary approach to swarm behavior would illuminate what the respective fields may be “missing.”

However, after exploring the aforementioned scientific disciplines, I found that they did not provide much insight into how an individual agent might experience their swarming collective. Because these fields are concerned with objective, predictive, deterministic discoveries—to varying degrees—their scope of inquiry is limited and does not account much for the subjective experiences of individual agents in the system.

As my research progressed, I noticed that *my approach* to this project was limiting in itself. Throughout the course of my literature review, I was subconsciously searching for a theory that *best* answered my research objectives and imagined a way to use elements of other theories to support that hypothetical conclusion. Reflecting on the concepts of decentralization and non-linearity mentioned frequently in emergent systems, I realized that this pursuit of ‘best’ was an inappropriate, counterintuitive approach to this project. This realization prompted further reflection into the origin of that scientific instinct that had taken root in me as the default investigative process. I was researching extraordinary self-organizing, emergent systems and wanted my research approach to reflect their expansive nature.

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Before proceeding with my further swarm research, I wanted to explore the history and philosophy of science better to understand the structure and constraints of the disciplines and to learn about the institutionalization of sciences as the dominant investigative process. Exploring cultural studies of science and technology provided context into how scientific knowledge is socially and culturally shaped.

There are many contemporary theorists whose work is critical of the biases within, motivation of, and production of scientific knowledge. Donna Haraway, for example, discusses a feminist critique of science and technology throughout her work by highlighting the ways that science and technology have historically been used to uphold patriarchal, capitalist, and colonialist systems of power and domination. Her conceptualization of “the god trick” is particularly applicable to this project. In *Modest_Witness@Second_Millennium.FemaleMan_Meets_OncoMouse*, Haraway discusses the ways in which the science’s pursuit of objectivity—of an “infinite vision”¹⁵, untouched by social or cultural influences—is a “god trick,” a fetish. She believes that science is concerned with “metaphors of possession” and that “from the stance of the god trick of scientific creationism, only fetishism—the culture of no culture, the language of no language, the trope of no trope, the one self-referential word—is possible.”¹⁶

Haraway is clearly disinterested in objectivity and instead advocates for “situated knowledges,” in which knowledge production is situated within social and cultural contexts. She writes, “The codes of the world are not still, waiting only to be read. The world is not raw material for humanization; [...] the world encountered in knowledge projects is an active entity”¹⁷; that is to say, shaped by the historical, political environment in which it was constructed. Haraway’s critiques provide context into the institutionalization of scientific knowledge and the origins of why my first instinct in approaching this project was to discover an objective true nature of swarm phenomena. According to Haraway, scientific knowledge production is purposefully designed. “From this point of view, science – the real game in town – is rhetoric, a series of efforts to persuade relevant social actors that one’s manufactured knowledge is a route to a desired form of very objective power.”¹⁸

Theorist and physicist Karen Barad similarly challenges objectivity and the production of scientific knowledge. In their book *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*, Barad develops their theory of “agential realism”, which broadly emphasizes the

¹⁵ Haraway, “Situated Knowledges”, 582.

¹⁶ Haraway, “Modest_Witness@Second_Millennium”, 138.

¹⁷ Haraway, “Situated Knowledges”, 593.

¹⁸ Haraway, “Situated Knowledges”, 577.

'intra-connectedness'¹⁹ of all things in the universe, the role of scientific inquiry in shaping our understanding of this interconnectedness, and the ontological implications of these interactions. This includes Haraway's considerations of the social, cultural, and historical influences within which scientific pursuits are situated.

"There is in this sense no privileged position from which knowledges can be produced, as the researcher is of the world. Researching phenomena, then, is a methodological practice of continuously questioning the effects of the way we research, on the knowledges we produce. This unfolds itself as an ethico-onto-epistemology of knowing in being. Ethics is about being response-able to the way we make the world, and to consider the effects our knowledge-making processes have on the world".²⁰

While Haraway's contribution of "situated knowledges" is an epistemological pursuit, Barad's is a new materialist consideration of the ways that matter and meaning are intertwined. This "ethico-onto-epistemology" describes the interdependence of ethics, ontology, and epistemology—how none of these can be understood separately from the others. "The separation of epistemology from ontology is a reverberation of a metaphysics that assumes an inherent difference between human and nonhuman, subject and object, mind and body, matter and discourse."²¹ In this way, Barad suggests that scientific knowledge is formed through co-constitutive relationships.

As I reflected on Haraway and Barad's contributions of "god tricks," "situated knowledges," and "agential realism," I became aware of the objectivity associated with my own knowledge pursuit, and how my research methods were born from, and work to uphold, a hierarchy of knowledge. Their contributions also reminded me of the importance of subjectivity within this thesis—at the core of emergent behavior are the subjective experiences of individual agents.

¹⁹ "Intra-" here references the Baradian term "intra-action", adjacent to "agential realism". It "*signifies the mutual constitution of entangled agencies. That is, in contrast to the usual "interaction," which assumes that there are separate individual agencies that precede their interaction, the notion of intra-action recognizes that distinct agencies do not precede, but rather emerge through, their intra-action.*" Barad, "Meeting the Universe Halfway", 33.

²⁰ Barad, "Meeting the Universe Halfway", 381.

²¹ Barad, "Meeting the Universe Halfway", 185.

In Thomas Nagel's essay, "What Is It Like to Be a Bat?", the author explores a bat's subjective experience of consciousness and, in doing so, critiques the limitations of scientific objectivity in understanding non-human experiences; Nagel writes, "In so far as I can imagine this (which is not very far), it tells me only what it would be like for me to behave as a bat behaves. But that is not the question. I want to know what it is like for a *bat* to be a bat. Yet if I try to imagine this, I am restricted to the resources of my own mind, and those resources are inadequate to the task."²²

As I am similarly interested in understanding the subjective experience of a non-human creature—an agent in a collective, a bird within a flock—I was excited to discover this piece. In Nagel's considerations on bat consciousness, however, he is concerned with a mind-body dualism in which consciousness exists independently from the physical world. Though, in my research, I am also concerned with non-human conscious experience, the ontology that I ascribe to—alongside Barad—is more of an agential, situated, entangled ontology. This distinction between myself and Nagel's approach to non-human consciousness is that in a Baradian non-dualist ontology, the individual (bird, bat) and their collective are mutually constitutive. This ontology feels more representative of collective emergence within the context of this thesis project.

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Haraway, Barad, and Nagel's criticisms on the limitations of scientific objectivity provide context to the functions, biases, and agendas of a science-system. Their contributions serve as a reminder of the importance of subjectivity within this thesis, particularly in understanding the subjective experience of individual agents in swarms. Reviewing their work also helped clarify my own personal ontology, which is actively forming as I move throughout this research process. As I move forward with the remainder of this research, I hope to recalibrate my methodologies in a way that is more equitable, situated, and a more appropriate approach with which to investigate swarm emergence. As Nagel says, "We must consider whether any method will permit us to extrapolate to the inner life of the bat from our own case and if not, what alternative methods there may be for

²² Nagel, "What Is It Like to Be a Bat?", 439.

understanding the notion.”²³ The concept of affect²⁴, as described by affect theory, offers another perspective on subjectivity and can serve as a possible alternative method to consider collective emergent experiences.

Affect

Affect theory describes the sets of precognitive, ubiquitous forces that circulate between bodies and throughout the world. “Affect... is the name we give to those forces—visceral forces beneath, alongside, or generally *other than* conscious knowing, vital forces insisting beyond emotion—that can serve to drive us toward movement, toward thought and extension...”²⁵

In Brian Massumi’s “*Autonomy of Affect*” he describes an experiment that supports and explains this phenomenon. While hooked up to electroencephalography (EEG) machines, volunteers were asked to flex a finger & record the moment that they decided to do so. While the volunteers believed that the flexes followed .2 seconds after the decision, the EEG machine recorded a spike in brain activity .3 seconds *prior* to that choice. Another similar experiment accounted for a half-second difference between a bodily event and its outward expression. Brian Massumi describes these experiments to illustrate different characteristics of affect, explaining that “the half-second is missed not because it is empty, but because it is overfull, in excess of the actually performed action and of its ascribed meaning.”²⁶—in a way, saturated with unseen, unknown, non-conscious forces.

Outside of these controlled experiments, we constantly interact with these affective forces in our daily lives. There are many ways in which these forces may be experienced. When embodied, these mysterious forces can be processed into physical experiences, such as pleasure or pain. Affective forces shape environmental or situational atmospheres and influence our experiences of these

²³ Nagel, “What Is It Like to Be a Bat?”, 438.

²⁴ “I don’t mean in the psychological sense, but in a cultural study sense—*affective, preconscious capacity to affect and be affected—contagious, intracorporeal, strictly precognitive bodily experience.*” Pitts-Taylor, “EMBODIMENT CONFERENCE”, 27:32.

²⁵ Gregg, Siegworth, “The Affect Theory Reader”, 1.

²⁶ Massumi, “The Autonomy of Affect”, 90.

spaces, and consequently impact our behavior and mood. Social, cultural, and political forces are also considered in affect theory, alongside their resulting impact on interpersonal and collective experiences. These forces can vary in intensity and affect the degree to which they are experienced, from subtle sensations like tones or vibes to overwhelming experiences like terror or bliss.

I was excited to discover this affective world and started noticing affect's presence everywhere as I encountered my day; on neighbors' faces during slightly-off interactions, the incessant barrage of advertisements throughout the city, radio, and internet, how Fridays feel. Because this theory is very much rooted in a human experience of affective forces, it was natural to process them bodily *and* cognitively, as I learned. Though the literature describing affect theory was difficult to enter, I still experienced the research very intuitively, knowing that this process was applying language to something that I already knew and trusted nonverbally. I suspected that applying affect theory's principles to this project would provide richer insight into swarm dynamics, as well as into the mysterious reactions of disgust and terror with which I experienced them. On a larger scale, however, I also questioned how including affect theory could support, challenge, and recontextualize default scientific investigations. How could considering affect alongside scientific disciplines offer further insight into their limitations, problematics, and potentials?

Theorist Lauren Berlant expands this systemic investigation with their conceptualization of “affective infrastructures”—a type of architecture of affective conditions of possibility. One of Berlant's largest contributions to affect theory was their theorization of “cruel optimism”; the nature of affective attachments to that which is inherently harmful to an individual's well-being and which hinders them from achieving their goals (the pursuit of *The Good Life*, allegiance to a political party, romantic relationships, etc.). Through their employment of infrastructures, Berlant suggests that included in these entangled, affective (social, cultural, emotional) landscapes is an additional layer of attachment through which we navigate.

Infrastructures are crucial in mobilizing collective movement by shaping the affective and material environment within which individuals and groups experience the world. For example, affective infrastructures such as television and social media

can create the conditions to shape public opinions and mobilize social justice issues. Similarly, economic infrastructures can impact collective mobilization—financial freedom or debt, corporate influence, food access, etc. We could look to the 2020 Black Lives Matter (BLM) movement for a recent example of how these infrastructures shape collective movement. Following the murder of George Floyd by former Minneapolis police officer Derek Chauvin, a video of his violent death circulated virally around the world, generating strong affective responses globally. In the wake of increasingly visible murders of Black men by police, videos and posts circulated on social media, gaining visibility and momentum with hashtags #BlackLivesMatter, #GeorgeFloyd, and #BlackoutTuesday, mobilizing people to act (donating money and goods to organizers, attending protests, holding companies accountable, etc.). Situated in the middle of a countrywide lockdown during the COVID-19 pandemic, many Americans (and other global citizens) were more available and motivated to attend BLM protests. Having physical space for folks to gather, march, protest statues, and loot storefronts created collective atmospheres of solidarity, sadness, anger, etc. These are all examples of affective infrastructures that facilitated the collective movement necessary for the BLM movement to act against police brutality and racial injustice.

Including a consideration of affective infrastructure in system analysis can provide insight into affective dimensions of systems and the nature of their attachments. Earlier in this paper, I discussed the different scientific disciplines explored at the beginning of my research. These empirical fields concentrated on the mechanical and deterministic mechanisms of swarm behavior. An affective consideration of infrastructures provides insight into the quality of relationships within the sciences and their resulting and enacting biases.

While these fields offered insights into the behavior of large groups, they did not fully capture the complexity and richness of the individual agent's experience. (What is it like to be a bat?) Their reliance on objectivity and empirical qualifications prevented them from considering the subjective social and cultural experiences of individual constituents and, in doing so, overlooked a whole sea of potentialities.

Alternatively, affect theory's focus on entanglement and relationality has the capacity to address empirical science's limitations in describing individual

experience and agency. In moving away from the objectivity found in the sciences, affect theory allows for an investigation that incorporates an individual's unique experiences. What's more, through affect theory, we are able to move even beyond the subjective into the *intersubjective*. Affective intersubjectivity enriches and accounts for the entanglement of social and environmental forces at play within and outside of our experiences and embodies a rhizomatic system structure²⁷ from which emergence materializes. Including affective considerations diversifies swarm research and opposes reductionist approaches within the sciences while modeling and theorizing the intersubjective relationships between individuals and the collective infrastructure in which they are entangled.

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As in any field, there are variations of approaches amongst theorists. In affect theory, for example, Massumi's conceptualization and utilization of affect seems to focus more on the relationship between affect and one's body, while Berlant's "attachments" incorporate the social, cultural, and historical atmospheres in which we exist. This contribution allows for a more feminist approach to affect theory comparatively in considering how affect theory is entangled with the power dynamics within gender, race, class, and sexuality.

In "The Matter of Affect in the Quantum Universe", Şengül Yıldız-Alanbay describes a quantumly inclusive affect when comparing Massumi's "ontological imaginaries of 'affect'"²⁸ with Lauren Zanotti's social-material theorization of the relationship between emotions, agency, ethics, and quantum ontology, as described in her essay "Ontological Entanglements, Agency, and Ethics in International Relations: Exploring the Crossroads." Yıldız-Alanbay suggests that "connecting particularly 'affect' to Zanotti's quantum ontology is pertinent in terms of demonstrating how the indeterminate and dense tangle of affective human and non-human relationalities is also involved in our becoming in and of the world and how affect also constitutes the non-human becoming of all matter (human and non-human) and its ontology is also compatible with quantum ontology."²⁹

²⁷ A rhizome refers to a non-hierarchical, decentralized system or network, such as mushrooms or the internet. Rhizomes are fundamental to the work of Deleuze and Guattari in "A Thousand Plateaus".

²⁸ Yıldız-Alanbay, "The Matter of Affect in the Quantum Universe".

²⁹ Yıldız-Alanbay, "The Matter of Affect in the Quantum Universe".

By incorporating principles of agential realism and quantum ontologies into a conceptualization of affect, we can extend affect theory to accommodate for a non-human intra-action of forces, providing a more holistic understanding of the additional ways this entangled web of interact with each other and us—applied here as within and beyond swarms.

In Deleuze and Guattari's *"A Thousand Plateaus: Capitalism and Schizophrenia"*, they discuss similar affective considerations as theorized in their conceptualizations of "multiplicities" and "assemblages." For example, in "1914: One or Several Wolves?", the authors take the example of a wolf:pack to describe the ways in which it can operate as a "multiplicity." They have elsewhere³⁰ described these multiplicities as non-totalized, constantly open interactions of heterogeneous elements—interactions in an eternal state of dynamic transformation and change. Regarding a pack of wolves, they describe the relationship between an individual wolf and their counterparts.

"You can't be one wolf, you're always eight or nine, six or seven. Not six or seven wolves all by yourself all at once, but one wolf among others, with five or six others. In becoming-wolf, the important thing is the position of the mass, and above all the position of the subject itself in relation to the pack or wolf-multiplicity: how the subject joins or does not join the pack, how far away it stays, how it does or not hold to the multiplicity."³¹

The openness found in wolves-as-multiplicities (where pack wolves are not a fixed system but a constantly changing assemblage of relationships) could be interpreted through an affective lens. When animal collectives (multiplicities) are open in this way, they are, by design, receptive to the affective forces within and outside their bodies and environment. These themes of openness and potentiality recur in Massumi and Berlant's work, as well.

We can take this wolf system further and explore their use of "assemblages;" an "increase in the dimensions of a multiplicity that necessarily changes in nature as it

³⁰Deleuze and Guattari worked non-linearly, and there is no one place that they describe these concepts. Their description of "multiplicity" here is instead dispersed throughout their lectures and literature.

³¹ Deleuze and Guattari, "A Thousand Plateaus", 29.

expands its connections”.³² This multiplicitous pack of wolves is part of a larger assemblage, made up of the individual wolves, their social dynamics, their prey, their environment, etc. We can begin to apply these affective considerations when theorizing emergent behavior within animal collectives. Hunting wolf packs, for example, exhibit emergent behavior during self-organized, collective decision-making. This emergent behavior cannot be reduced to any singular component but emerges from the constantly shifting, dynamic forces interacting with and within this wolf-multiplicity.

We can extend these affective considerations to describe other animal collective’s dynamics and their emergent capacities, such as the affective dimensions of ant colonies or human crowds. The authors go on to discuss these dynamics in more depth, this time from the perspective of an individual’s experience of the crowd.

“I am on the edge of the crowd, at the periphery; but I belong to it, I am attached to it by one of my extremities, a hand or foot. I know that the periphery is the only place I can be, that I would die if I let myself be drawn into the center of the fray, but just as certainly if I let go of the crowd. This is not an easy position to stay in, it is even very difficult to hold, for these beings are in constant motion, and their movements are unpredictable and follow no rhythm. They swirl, go north, then suddenly east; none of the individuals in the crowd remains in the same place in relation to the others. So I too am in perpetual motion; all this demands a high level of tension but it gives me a feeling of violent, almost vertiginous, happiness.”³³

This excerpt felt especially relevant to include in this project and was instantly reminded of my experience in the crowd at Lollapalooza. I was familiar with the fear of being consumed by the crowd and was curious if my extreme emotional reaction at its periphery could be reflective of this state of limbo they describe, between fear of being consumed and fear of breaking away. This simultaneous experience of fear and “violent, almost vertiginous, happiness” active in this state of limbo are opposing in content, but share an affective core of intense arousal before being processed cognitively into emotions. (To use affective language, this

³² Deleuze and Guattari, “A Thousand Plateaus”, 8.

³³ Deleuze and Guattari, “A Thousand Plateaus”, 29.

describes the transition from affective ‘intensities’³⁴ through a ‘threshold’³⁵ when these forces transform into a recognizable emotion.) This suggests a kind of affective attachment to the crowd where the speaker's sense of identity and well-being is bound to their relationship to the collective—where a loss of this attachment could be interpreted or experienced as a loss of self.

I can see Berlant's attachments playing out in the Deleuze and Guattari's above crowd scene. Both accounts describe the nature of attachments as constantly in flux. In a paper titled “*Encountering Berlant Part One: Concepts Otherwise*,” the multidisciplinary authors describe the breadth of Berlant's employment of affect. “[Berlant's] approach to affective life never seeks to straighten complexity, they urge us to consider how feelings and desires are always unruly, multiple, often incoherent. What makes Berlant's thought so significant then is its capaciousness, an ability to hold together multiple affects and contradictory attachments – pleasure and pain, joy and sadness, optimism and exhaustion, to think with the both/and rather than the either/or.”³⁶ This capacity for simultaneous, contradictory affect, as well as amplification of a “both/and” dynamic is another reason why I find affect theory to be an extremely useful lens through which to dissect the complexities and attachments and experience at play within large collective groups. My experience at Lollapalooza could be described affectively as an (optimistic) attachment to the crowd. As my body processed the simultaneous, conflicting affects at play within my body and around the crowd, with the resulting confusion that I experienced presenting as a panic attack.

As I reflect on my experience of being in the crowd that day with new attention to these affective dimensions, I am remembering how my attachments felt as I shifted from dancing to panic. At the beginning of the set, I began on the outskirts, and felt balanced, grounded, and secure. As the band's set began to pick up and the dancing intensified, I found myself in the center of the crowd. While jumping, yelling,

³⁴ “Tendency-Intensity: Each transition is accompanied by a variation of capacity: a change in which powers to affect and be affected are addressable by a next event and in how readily addressable they are, or to what degree they are present as futurities. This “degree” is a bodily intensity, and its present futurity is its tendency.” Massumi, “Parables of the Virtual, XXXIIV.

³⁵ “Threshold: When you affect something, you are opening yourself up to being affected in turn and in a slightly different way than you might have been the moment before. You have made a transition, however slight. You have stepped over a threshold. Affect is this passing of a threshold, seen from the point of view of the change in capacity.” Massumi, “Parables of the Virtual”, XXXIIV.

³⁶ Anderson, Aitken, et. al, “Encountering Berlant”, 133.

dancing, touching, my arousal levels increased in intensity, synchronized with the crowd. As things became more intense, I began to feel like I was losing myself to the crowd. Oversaturated, I felt my attachment to the crowd change. I did not recognize it anymore, and remember feeling lost.

While I did end up leaving the crowd for a panic attack in the outskirts, there was a moment in between dancing and vomiting, of disconnection and pure experience. Berlant's conceptualization of affective "impasse" is helpful in describing this dynamic. They write,

"Usually an "impasse" designates a time of dithering from which someone or some situation cannot move forward. In ["*Cruel Optimism*"]'s adaptation, the impasse is a stretch of time in which one moves around with a sense that the world is at once intensely present and enigmatic, such that the activity of living demands both a wandering absorptive awareness and a hypervigilance that collects material that might help to clarify things, maintain one's sea legs, and coordinate the standard melodramatic crises with those processes that have not yet found their genre of event."³⁷

This description of impasse feels representative of my Lollapalooza experience. Often in my life, I have used the phrase "reaching around in the dark" to describe this sensation, without any affective language. Impasse has been similarly described to me as swimming in an affective pool with no anchors; the walls are just too far, the floor is too deep, and you are looking for anchors and feeling anchorless.³⁸ When I lost my object (the crowd), I experienced this sensation of reaching and confusion due to the muddling of affects that I was experiencing within and surrounding me. This sensation did not last long, only marinating in it for around 10 minutes before I began to come back to myself.

It is here that I am curious about my panic attack. If I am understanding the affective dimensions of this event correctly, I experienced an attachment to the crowd and reached an impasse. I do think that when I lost my attachment to the crowd, my attachment to *myself* was also suspended in some way. As I separated

³⁷ Berlant, "Cruel Optimism", 4.

³⁸ As described by Steve Marotta!

myself from the crowd and moved towards the edges of the park, things began to feel heavier and thicker with each step until I was overfilled with terror and a feeling that I have only ever been able to describe as “!!!!!!!!!!”. What I am wondering is if I affectively chose to have a panic attack in wanting to re-attach to myself, firmly, and in a way that was very intensely rooted.³⁹

Deleuze and Guattari’s concept of “lines of flight” concept is interesting here. As introduced in “A Thousand Plateaus,” “lines of flight” can be understood as “movements of deterritorialization and destratification.” The deterritorialization that they discuss describes a kind of destabilization of a collective’s former system structure, while destratification attends to the dissolution of social hierarchies (race, class, gender, etc.). These processes create “lines of flight”; pathways through which agents can follow to break through from former structures and create new landscapes. One model that they generously discuss is that of the rhizome, a system of connection, heterogeneity, multiplicity and regeneration. (Think ginger, the internet.) However, as affects are precognitive, these movements are not necessarily conscious decisions. Looking to Lollapalooza again, it could be said that I followed a line of flight from the crowd to the Porta-Potties; from an attached, collective crowd relationship, to affective impasse, to panic attack.

This question of “losing oneself” in collectives is central to this thesis project. When I initially embarked on this project, I wanted to understand how swarms functioned, with particular interest in the collective governing agent. I sensed a bird has its own experience of consciousness and agency, but when part of emergent group behavior—such as swarming starlings—does a bird still experience that consciousness and agency? Or, like me, do they “lose themselves” to their surrounding forces? The tension that exists between individual agency and collective behavior here is the place of this research that is most exciting to me.

When I began this project, I wondered how an individual animal experienced its consciousness and agency during times of emergence; was it dispersed, found at different densities, or temporarily switched off? Might it be necessary to lose oneself—or at least for individuals to reach an impasse—in order to create emergent conditions? During these moments when affects are swarming, and attachments

³⁹ “So, it’s really about the possibility of losing your object without becoming psychotic.” Berlant, “LAUREN BERLANT Interview”, 7:50.

are suspended, there are infinite possibilities of action. “Lines of flight” can be seen as a way of navigating the tension between individual and collective agency. When new attachments are formed, it bridges new and different ways for agents to act. In biological collectives, this can lead to new, emergent behavior. Though I do not want to assume that other living beings experience affective dimensions in the same way that I do, maybe examining my personal experiences in a swarm can provide insight into animal experiences of emergence.

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As I conclude this project, my attention rests on the agentic dimensions of emergence. I reflect on my experience in the crowd, of impasse and loss, and the question of choice regarding attachments. Within the context of affect theory, is there such a thing as choice?

In the example I gave, I described a scene in which I began to dissociate from a concert crowd. In my analysis, I theorized that I was affectively attached to the crowd and lost said attachment. I questioned if, in its absence, I somehow “chose” to return back to myself, presenting physically as a panic attack. If I had more time to unpack this further, I would explore the affective dimensions of a “self-attachment” and explore the conditions around which one experiences a loss of self-attachment. In my given crowd example, perhaps my identity was, in some specific way, entangled with the crowd-attachment. What would those conditions have been, and what would their implications be? Further, how could the question of “choice” (to return to a self-attachment) be viewed through the lens of affective sovereignty and control or lack thereof, and what would be the implications of that pursuit?

In my perspective, we do have free will, but that our actions follow an affective grid. Affect theory offers insight into the linkages between subjectivity and objectivity of individual and collective dynamics within swarms, providing context for the complexity of forces throughout and surrounding themselves. Affect theory has the capacity to hold instances of simultaneous joy and fear, emergence and divergence in a single moment. Its “both/and” capacity is a necessary alternative/addition to other scientific forms of investigation that may not account for these more entangled, relational possibilities and their influence on complex behavior. I began

this project looking for a theory that would “best” answer my initial research questions regarding emergent swarm behaviors. However, I do think that whatever “answer” there could be would involve both affect theory and scientific disciplines. A critical and multidisciplinary research approach provides the most expansive and comprehensive insights into this research project and others to come.

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