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# The Dynamics of Psycho-Social-Ecological Resilience in the Urban Environment: A Complex Adaptive Systems Theory Perspective

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As the proportion of people living in urban areas continues to grow (United Nations et al., 2019), it becomes increasingly important to understand urban resilience in the face of both chronic and acute, endogenous, and exogenous stressors. Indeed, there is a growing literature on urban resilience, which includes several recent frameworks to operationalize and assess the concept and its indicators. Inherent in this literature, though rarely explicitly, is the psychology of the people comprising urban environments. The purpose of this paper is to explore the intersection of urban resilience and psychological resilience by viewing both in the context of complex adaptive systems theory. Arising from this juncture is a more robust and dynamic understanding of resilience, a psycho-social-ecological resilience. The discussion will draw from this notion of resilience a more thorough framework for understanding the reciprocal relationships among urban dwelling people and their total environments. Areas for future research and implications for our understandings of psychological resilience, urban resilience, and sustainable cities will be highlighted.

**Keywords: urban resilience, psychological resilience, complex adaptive systems theory, social-ecological resilience, sustainable cities**

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The proportion of people living in urban areas continues to grow around the world (United Nations et al., 2019). These highly populated areas face numerous and varied stressors, including acute events such as hurricanes and flooding, as well as more chronic challenges to everyday urban life such as inefficient transportation and unemployment (Spaans and Waterhout, 2017). Further, these events and challenges may interact with one another and can be influenced by contributing factors across numerous scales, many of them outside the control of municipal leaders (e.g., regional or national policies, climate change, global food systems). Indeed, in efforts to understand the development of urban systems in the face of these stressors, literature on urban resilience has expanded, including several recent frameworks to operationalize and assess the concept and its indicators (e.g., Spaans and Waterhout, 2017).

The concept of resilience has evolved over the past several decades and has distinct meanings in different disciplines. In engineering, resilience refers to a system's ability to sustain or quickly recover function following the experience of a stressor or disturbance [Hosseini et al., 2016; United Nations Human Settlements Programme (UN-Habitat), 2017]. In the ecological sciences, resilience has been understood as the ability of a system to persist and adapt,

maintaining essential functions while self-organizing, learning, and adapting to the environment (Folke et al., 2002, 2010; Walker and Salt, 2006). Resilience is also studied in psychology on the level of the individual. Thus, the people comprising urban environments can be described in terms of their *psychological resilience*, which is generally understood to be the process through which one mobilizes the mental, behavioral, and social resources to adapt positively to adverse or stressful situations (e.g., Fletcher and Sarkar, 2013; deTerte et al., 2014).

The purpose of this paper is to explore this intersection of urban resilience and psychological resilience. For researchers in Psychology, this analysis aims to expand current approaches to psychological resilience, drawing attention to the system dynamics linking psychological processes and the total human environment. For researchers in urban resilience, this analysis aims to draw attention to the dynamic process of psychological resilience, and its role in shaping urban resilience. The theoretical framework for a multi-system analysis such as this is an important consideration. There are many loosely connected systems theories spanning several disciplines, most of these identifying resilience (variously defined) as a system property (Mitchell, 2009). Complex adaptive systems theory, with its origins in the ecological sciences, has been chosen as the theoretical approach to this analysis. Systems engineering (e.g., De Weck et al., 2011) offers a related but distinct disciplinary perspective. From this juncture new insight into the dynamic and reciprocally impacting nature of people and their urban environments will be drawn. Resilience as a property of complex adaptive systems will be discussed next, and then the literatures on urban resilience and psychological resilience will be contrasted and integrated. This analysis will demonstrate a more robust and dynamic perspective on human resilience in its urban environment and beyond, a psycho-social-ecological resilience.

# RESILIENCE IN COMPLEX ADAPTIVE SYSTEMS THEORY

## Complex Adaptive Systems

Resilience has been studied extensively within the ecological sciences as a property of complex adaptive systems. Complex adaptive systems are systems comprised of many agents or components, each of whom is independent to act as they will, but also interdependent with each other and their environment. These agents adjust the simple rules guiding their behavior in order to adapt and learn. The resulting interactions among the agents in context thus produce emergent system-level outcomes. These are outcomes that could not be predicted from the actions of the individual agents themselves (Gunderson and Holling, 2001; Holland, 2006). One essential observation from the CAS approach is that a complex adaptive system of interdependent agents does not require coordination to produce system-level behavior. Such behavior emerges or self-organizes through the internal dynamics of the system (Corning, 2002; Goldstein, 2008). Examples of CAS include the brain where the agents are neurons (Gregson, 2009; Hollis et al., 2009), human groups, organizations, and communities where the agents are individual people (Stacey, 1996), and ecosystems where the agents are members of different species (Walker et al., 2009).

One of the most enticing aspects of CAS theory is its description of naturally occurring processes and principles that can be observed in, and indeed link, human systems with those of the rest of nature (Stacey, 1996). However, the concept of self-organization or emergence, that system level behavior emerges from the adapting dynamics of the system itself without requiring coordination, is a challenging notion for some to grasp in applying complex adaptive systems theory to human systems. This is also the main point of divergence between complex adaptive systems theory and the systems engineering approach to systems that are planned and designed such as urban infrastructure systems. The choice to ground an analysis of psychological and urban resilience in CAS theory reflects the position that people are fundamentally an animal species of this planet and that ultimately, our survival depends upon the processes and dynamics of linked human-ecological systems. Nevertheless, the ways in which human systems emerge and adapt through interactions with both the ecological systems and the engineered systems in our total environment is a theme to which this analysis will return.

Within complex adaptive systems theory, resilience is the capacity of the system to absorb disturbances, to adapt and change while remaining in the same regime. A regime, which may be described mathematically as an attractor or basin of attraction, can be stable or dynamic, such as an oscillating or cyclical regime. Once pushed outside of that regime however, the variables and feedback loops that shape the system fundamentally change, and thus so too do the system's basic structure and function (Folke et al., 2010). In other words, resilience is the system's ability to learn and adapt responsively in context, retaining the same essential structure and function in the face of disturbances. Fundamental to understanding resilience in complex adaptive systems are the concepts of the adaptive cycle and panarchy (Gunderson and Holling, 2001; Holling, 2001).

## Adaptive Cycle and Panarchy

The adaptive cycle is a heuristic model to describe change over time in complex systems. The cycle involves four phases that reflect changes in an x axis of connectedness and a y axis of potential or wealth, as well as a z axis of resilience (**Figure 1**; Holling, 2001). In the Growth phase, which slowly shifts into the Conservation phase, the wealth or potential of the system gradually increases as resources are accumulated and passively stored. The internal connectedness or structure of the system and the rigidity of its internal controls also increase. In the Conservation phase, the accumulated resources of the system are high, but its connectedness is also high to the point that the system becomes rigid, and its resources unavailable for active use in novel ways. At this point, the resilience of the system declines, and the system is not able to adapt in response to a disturbance. This can trigger the Release phase, which is the release of the system's resources and tight internal organization. Following release is a phase of Reorganization characterized by experimentation and the active use and recombination of resources in new ways, potentially resulting in a new phase

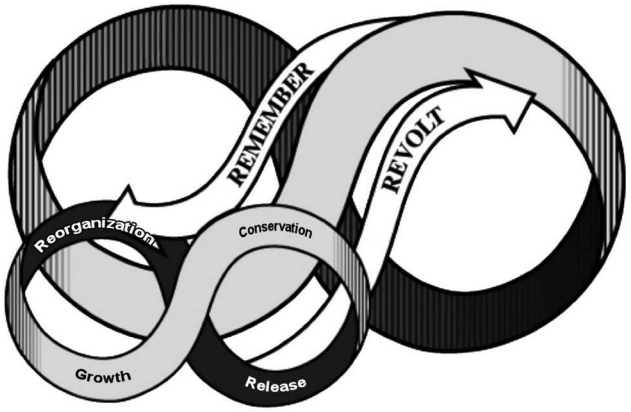


**FIGURE 1 |** Adaptive cycle and panarchy (adapted from Nelson and Stroink, 2019; based on Gunderson and Holling, 2001).

of Growth and increasing resilience. By moving through the adaptive cycle, the system is able to remain responsive to its environment while introducing novelty (Gunderson and Holling, 2001; Holling, 2001).

Complex adaptive systems are also interconnected with each other along multiple scales in what (Gunderson and Holling, 2001) called a panarchy to represent a nested set of adaptive cycles (**Figure 1**). In a panarchy, systems at a smaller scale (e.g., municipal policies) move more quickly through the adaptive cycle and are nested within and influenced by larger systems that usually move more slowly through the adaptive cycle (e.g., state or provincial policies), which are in turn nested within and influenced by still larger systems generally moving even more slowly through the adaptive cycle (e.g., federal or national policies, earth systems, and climate). The ongoing adaptations of a system at a given scale are influenced by the processes of the next higher scale in a process called remembering. Remembering stabilizes the overall system, as it perpetuates certain patterns in smaller scales undergoing reorganization. Likewise, when a system undergoes a release phase, it may trigger a cascading release into linked systems at the next higher scales in a process called revolt.

For example, a city is comprised of networks of agents (people) who act independently but also interdependently with the agents in the broader environment (people, organizations, other species), as well as technical and infrastructure systems in formal and informal ways to accomplish tasks. In doing so they observe the impacts of their own actions, learn and adjust their behavior, forming schemas (mental structures) on the individual level, as well as institutional infrastructure such as policies on the social level to guide and facilitate subsequent behavior so as to maximize the accomplishment of the tasks. This makes the city a Complex Adaptive System. Over time, the pursuit of tasks generates wealth or potential for the city, including knowledge and refined or stored resources. At the same time, increasingly formalized or structured connections (committees, policies, governing structures) form in order to bring internal order to the system. As the networks of agents and the task complexity increases from the Growth phase into Conservation, these internal structures may become overconnected, making it difficult for the agents to adapt their behavior to changes either internal to the system or in its environment, reducing resilience. At this point a Release phase results in the whole or partial collapse of the internal order. If a system collapse at the city level triggers collapses in other linked systems in the panarchy (e.g., regional or national processes), a Revolt has occurred. Following collapse, through experimentation and the introduction of novel approaches to meeting goals, the system Reorganizes. Through Remembering, that reorganization will be influenced by the internal structures of other systems surrounding the city in its panarchy. When relatively small Release phases occur regularly, the developing urban system shows adaptive capacity, adjusting its internal structure while remaining in the same attractor basin, maintaining overall resilience (Carpenter and Brock, 2008).

## Resilience and Transformability

Research and theoretical work in social-ecological systems differentiates among specified and general resilience as well as between resilience and transformability (Walker et al., 2009; Folke et al., 2010). These concepts are important in understanding urban resilience in its psycho-social-ecological context. Specified resilience asks, "resilience of what to what?" (Carpeneter et al., 2001), perhaps the resilience of urban ground transportation systems to disturbances from flooding. General resilience does not specify the aspect of the system nor the particular disturbance and instead focuses on the overall ability of the system to respond to disturbances with which it may or may not have had previous experience (Folke et al., 2010). The distinction between specified and general resilience draws attention to the interconnected layers of systems shaping human lives, and that by enhancing the resilience of one system (a neighborhood) to a particular disturbance (floodwater, by creating dams), one may create disturbances for other linked systems (flooding upriver, species disturbance) or reduce the overall resilience of the system to novel disturbances. It is also important to point out here that resilience is simply a property of a system, and that it is possible for unhealthy systems (e.g., addiction; Randle et al., 2015) to display resilience. Indeed, at times a social change initiative may be seeking to reduce the resilience of an unhealthy system to initiate a transformation to an alternative regime.

While resilience addresses the ability of a system to adapt and remain within its regime, transformability involves shifting to an alternate regime that is defined by different state variables, in a process called regime shift (Folke et al., 2010). Regime shifts can be both intentional, as in a shift in land management practices (Walker et al., 2009) and forced as a result of changes occurring at a scale beyond the control of local agents, such as changes in climate or national policy. Either way, systems vary in their ability to navigate transformation. Folke et al. (2010) describe high levels of capital and diversity (ecological and human), the presence of learning platforms, the capacity for collective action and experimentation, as well as support from higher levels of government as important to transformability. They also

indicate that transformational change involves shifts in meaning and social networks as well in leadership, political relations, and organizational arrangements, which suggest psychological and social processes (see also literature on social innovation, reflexivity, and resilience, e.g., Moore et al., 2018). When smaller scale systems undergo transformation, introducing novelty, they may enhance the resilience of the system on the larger scale. Discussions of urban resilience and the reciprocal impacts and interdependencies among urban systems and psychological processes are best grounded in this perspective, recognizing that individual people, social groups, cities, and ecosystems are all nested complex adaptive systems.

## MEETING IN THE MIDDLE: URBAN AND PSYCHOLOGICAL RESILIENCE

### Urban Resilience

The academic literature bringing the resilience perspective to the study of cities is rapidly expanding, inclusive of diverse disciplinary perspectives and critical tensions (Cretney, 2014; Rogov and Rozenblat, 2018; Meerow and Newell, 2019). There is a robust and increasing tendency in this literature to conceptualize urban resilience in a perspective informed by complex adaptive systems theory. For example, Meerow et al. (2016) conducted an extensive critical review of this literature on urban resilience and identified 6 conceptual tensions latent within 25 identified unique definitions of urban resilience. The first tension related to how the urban is characterized, with 17 of the 25 unique definitions presenting cities as complex systems inclusive of social-ecological and/or socio-technical networks. The remaining tensions reflected underlying variation in the degree to which definitions of urban resilience explicitly and comprehensively draw upon concepts from complex adaptive systems theory. For example, 7 of the 25 identified definitions of urban resilience included notions of transformability within resilience and 5 addressed change in general, while another 12 definitions adopted a more static view of resilience focused on persistence.

From this analysis of the literature, Meerow et al. (2016, p. 39) define urban resilience as "the ability of an urban system—and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales—to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity." Thus, the conceptual trajectory of the urban resilience literature is toward urban systems as complex adaptive systems. Cities are seen as multi-leveled, dynamic, and open systems, embedded in their regional context (e.g., regional resilience, or cities as systems of cities; Ruth and Coelho, 2007; Ernston et al., 2010; Rogov and Rozenblat, 2018), their ecological context (e.g., urban ecosystem services; McPhearson et al., 2015), and their social and technical contexts (e.g., water supply infrastructure, or economic disturbances; Rogov and Rozenblat, 2018; Tellman et al., 2018). Urban resilience is also understood to be inclusive of both adaptability and transformability (Folke et al., 2002, 2010; Walker et al., 2009; Bahadur and Tanner, 2014), incorporating learning and the formation of knowledge systems at both the individual and collective levels (Grabowski et al., 2019).

The urban resilience literature also shows some movement toward addressing critical perspectives and the underlying politics of urban resilience. Issues of equity and power emerge for example when determining whether to address the general or specific resilience of a system, and whether to address the resilience of one given system or another to various disturbances, as well as the overarching question of who is addressing these resiliency issues and on whose behalf. Social scientists have noted that academic discussions of urban resilience, particularly those that take a biophysical scientific approach, may neglect these questions and fail to note the roles of power and equity in determining how they are addressed (Cretney, 2014; Meerow and Newell, 2019). Social scientists in the area of urban political ecology and critical urban studies articulate the human experiences of surviving in urban environments under social, political, and economic systems that are disproportionately influenced by those with privilege and power in a historically shaped context (Angelo and Wachsmuth, 2014; Gabriel, 2014; Rademacher, 2015; Loftus, 2020). Indeed, the character and properties of the overall urban system emerge from the independent yet interdependent actions of the people in the system, as they actively pursue their goals in dynamic response to others and their immediate social, economic, political, infrastructure, and ecological environments. Yet the actions of some of these people exert greater influence on these environments than others, shaping the context of adaptation in ways that suit their own goal pursuit, often at the expense of others.

While academic discussion continues in search of consensus in definition and theory of urban resilience, policy makers have begun using the concept in urban planning and design. Indeed, a range of approaches to enhancing urban resilience through urban design and planning, risk management, and upgrading across and within many sectors have been described in the literature (e.g., Ruth and Coelho, 2007; Jha et al., 2013). To this end, several significant efforts have been made to operationalize and measure urban resilience. For example, the Rockefeller Foundation began the 100 Resilient Cities Programme in 2013, and, through its City Resilience Framework (Arup International, 2015), defines resilience as "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience" (Arup International, 2015, p. 2; Spaans and Waterhout, 2017). The inclusion of growth in this definition of urban resilience distinguishes it from other definitions of urban resilience as well as resilience as a concept in complex adaptive systems theory.

The analysis of the literature and fieldwork conducted to support the City Resilience Framework resulted in 7 qualities and 12 indicators of urban resilience in 4 categories. Two qualities that are noteworthy for the current analysis are *reflective* and *resourceful*. Reflective systems accept uncertainty and change, and its people and institutions continuously and systematically learn, modify standards and norms, and leverage learning

for decision making. Resourceful systems include people and institutions that are able to quickly find new ways to achieve goals under stress, perhaps by anticipating conditions, setting priorities, and mobilizing and coordinating resources (Spaans and Waterhout, 2017). These qualities are noteworthy for their emphasis on the capacity of *people*, in their social contexts, to learn, set goals, and act flexibly and responsively toward those goals under conditions that may be stressful.

## The Psychology of Urban Resilience

The psychological level of the person is inherent across the urban resilience literature, though rarely explicitly. For example, the two qualities of resilient urban systems outlined in the City Resilience Framework (Arup International, 2015; Spaans and Waterhout, 2017) above, reflectiveness and resourcefulness are both largely presuming psychological processes. For a system to accept uncertainty and change, the people who comprise that system must also be able to accept uncertainty and change. Comfort with or tolerance of uncertainty and ambiguity has been studied extensively in Psychology as an individual difference dimension (Furnham and Ribchester, 1995; Jessani and Harris, 2018). Likewise, learning and decision making under conditions of uncertainty have been studied in cognitive psychology and neuroscience (Soltani and Izquierdo, 2019).

Stress is known to alter how memory systems operate in learning processes, and can both enhance and disrupt learning, depending for example on the type of learning (e.g., trial and error vs. instructed), and task complexity (LePine et al., 2004; Schwabe and Wolf, 2012; Raio et al., 2017; Vogel and Schwabe, 2018). Trauma, such as one might see resulting from a major disturbance (e.g., hurricane) in an urban setting, has wide-ranging effects on the brain and psychological functioning, including enhanced fear expectancy, sensitivity to cues of threat, and difficulty disengaging from negative emotion (Brown and Morey, 2012; Maren and Holmes, 2016; McLaughlin and Lambert, 2017; Harnett et al., 2018). To understand how people can be resourceful and mobilize and coordinate resources in the urban environment, one might also explore the literatures on goal pursuit and flexibility (e.g., Guinote, 2007; Hassin et al., 2009; Kelly et al., 2013), and the predictors of learned resourcefulness in children (Wang and Zauszniewski, 2018) and in various populations of adults (Lai et al., 2014; Bekhet and Zauszniewski, 2016).

In Rogov and Rozenblat's (2018) systematic review and mapping of the urban resilience literature, the individual is addressed at the micro level, with resilience as a process at the level of actors, referred to as economic actors. The resilience of the city itself as a complex adaptive system is placed at the meso level, and resilience as a process of inter-city or regional processes at the macro level, and these three levels are interwoven in a panarchy framework. Bergström and Dekker (2014) articulate a similar model and refer to human resilience at the micro level, seeing resiliency processes repeating across scale in a fractal manner. However, little else is articulated in terms of the psychological processes undergirding urban resilience at the micro level in this model.

A close examination of the definition of urban resilience provided by Meerow et al. (2016) also reveals the psychological level. These authors refer to the multi-scale constituent socio-ecological and socio-technical networks of the city. The social level of these networks is comprised of people interacting with one another and their surrounding technical and ecological systems in pursuit of individual and joint goals. The ability of these people to maintain or return to desired functions in the face of disturbance, to adapt, and transform in their actions and interactions with each other and their surroundings is itself a psychological process, and strikingly similar to the definition of psychological resilience to which we will return (Fletcher and Sarkar, 2013).

## Psychological Resilience

While the literature on urban resilience thus implicitly recognizes the role of psychological processes, it generally stops at the level of the individual. Likewise, the literature on psychological resilience examines internal processes and generally stops at the level of the individual, with some recognition of social support from family or workplace playing a role. We will turn now to a brief review of the psychological resilience literature and then explore the place where these two literatures meet.

Similar to the urban resilience literature, a review of the psychological resilience literature first reveals a lack of consensus in operationalization and definition. Recent reviews, such as that by Fletcher and Sarkar (2013) bring some order to this diversity. Broadly, psychological resilience is understood to involve positive adaptation in response to adversity or challenging circumstances, with the caveat that understandings of what constitutes both positive adaptation and adversity are contextual and culturally situated (Fletcher and Sarkar, 2013).

Within this broad definition, approaches to psychological resilience can be differentiated by whether they treat the construct as a trait or as a process. Trait based approaches examine characteristics that enable people to adapt favorably to difficult circumstances, such as optimism, flexibility, and resourcefulness (He et al., 2013; Grol and De Raedt, 2018). Process based approaches examine the process through which people mobilize psychological and, to some degree social, resources to respond favorably to adversity. The process approach recognizes that resilience is a capacity that varies over time and both within a situation as it unfolds over time, and across different situations, allowing for the dynamic influence of the interaction between person and environment over time. The trait-based approach facilitates quantitative measurement and reveals relationships between psychological resilience and other individual characteristics such as personality or belief in a just world (Wu et al., 2011; Oshio et al., 2018). The process-based approach encourages deeper examination of *how* people respond adaptively to disturbance and allows for *in-situ* variation. They thus allow for the possibility that programs could increase the availability and accessibility of psychological and social resources within communities and workplaces to thereby facilitate the activation of resilience when situations arise (e.g., Ijntema et al., 2019).

Parsons et al. (2016) proposed a cognitive model of psychological resilience, focusing on the internal cognitive processes involved in resilience. They propose an overarching mapping system that enables one to flexibly apply different information processing approaches in response to the particular situation and one's own perceived goals and needs. Rooted in literature on executive functioning and emotion regulation processes, the mapping system draws on feedback loops to shift cognitive styles between flexibility and rigidity to balance situational demands and goals. For example, they describe automatic cognitive processes involved in shifting and focusing attention to goal-related information when threats to that goal are perceived in the situation, as well as automatic emotion regulation strategies as part of the cognitive mapping system of resilience.

Most theories and models of psychological resilience are not explicitly rooted in complex adaptive systems theory. However, many of the process-based approaches do incorporate dynamic variables that are open to influence through interventions (e.g., deTerte et al., 2014; Ijntema et al., 2019). In sport psychology, Hill et al. (2018) explored resilience from a dynamical perspective. They argued that resilience is a complex and iterative process that unfolds over time, as the underlying components in the athlete's system adjust, adapt, and self-organize. Through patterns of cognition, emotion, and behavior in a sport context, attractor states, or regimes emerge that lend a degree of stability to athletic performance. Resilience then is the degree to which the athlete's system is able to remain within its regime following a disturbance, such as from an unexpectedly poor performance (Hill et al., 2018).

Research on the process of psychological resilience generally positions the individual in his or her social or community context, recognizing the role of social support or perceived social support, such as from friends and families, or work colleagues and supervisors on adjustment through traumatic or stressful experiences (Bonanno et al., 2006; Pietrzak et al., 2009; deTerte et al., 2014). In these lines of research, levels of perceived social support predict direct measures of psychological resilience, as well as lower scores on measures of stress, depression, and PTSD following adverse or stressful experiences (e.g., military deployment). Ingulli and Lindbloom (2013) found a positive correlation between sense of connectedness to nature and self-reported psychological resilience. They argued that this finding reflects the restorative opportunities associated with time in nature, and this would support the view that resilience is a process unfolding in a system that draws upon various resources in the individual's given social and physical environment.

While psychological resilience is thus understood to draw upon resources and supports in the social and physical environment, the reciprocal notion, that psychological resilience is influenced by levels of resilience in the surrounding urban or community environment, as well as the broader ecological environment, is an area in need of further development. Specifically, one's ability to shift cognitive strategies, pursue goals flexibly, regulate emotions, and both draw upon and nurture connections with one's social and physical environment is influenced by the resilience properties of the social (including economic, political, and infrastructure) and ecological environment of the person. In other words, the person and his or her resilience process is adapting continuously and dynamically within a total environment that includes social, economic, institutional, infrastructure, and ecological systems. To some degree, this is recognized in findings that people who experience discrimination or socio-economic disadvantage have lower levels of psychological resilience (e.g., Bonanno et al., 2006). However, no theory or model has attempted to integrate the individual's resilience into its nested panarchy of interdependent systems.

The process approach to psychological resilience is thus somewhat dynamic and situated in its social and ecological context. This approach also enables inquiry into the details of the psycho-social-ecological process of urban resilience in a way that could make significant contributions to our understanding of urban resilience. However, in the light of what is known about resilience in complex adaptive systems, the position of transformability, and the role of the adaptive cycle and particularly the release phase of the cycle, has not yet been addressed in the psychological resilience literature. We turn now to a brief discussion of psychology and complex adaptive systems theory and then articulate a dynamic psycho-social-ecological perspective on urban resilience.

## PSYCHOLOGY AND COMPLEX ADAPTIVE SYSTEMS THEORY

Scholars in various disciplines have discussed interdependencies between ecological and human built systems as complex systems (e.g., Machlis et al., 1997; Folke, 2006; Liu et al., 2007; Burkhard et al., 2010). These "outer" systems do not interact with a static individual however, as the individual constitutes a set of nested, interacting complex, or non-linear systems, including physiological (e.g., circulatory, digestive) processes, neurological processes, developmental, cognitive, and affective processes (Cervone, 1997; Eidelson, 1997; Greenberg et al., 1999; Freeman, 2007; Vallacher and Nowak, 2008; Guastello et al., 2011).

In Psychology and other Behavioral Sciences, there is a long history of incorporating systems concepts into the study of human behavior (e.g., family systems theory, Broderick, 1993; see also Hudson, 2010). There is also increasing work that applies models of non-linear dynamics and aspects of complex adaptive systems theory to human behavior (e.g., Miller and Page, 2007; Freeman and Ambady, 2011; Guastello et al., 2011; Davis and Stroink, 2015; Randle et al., 2015). CAS theory can be used to understand the individual person as an agent interacting dynamically with other human and non-human agents and with agents in surrounding environments, responding to feedback loops, and adapting to change. Through these interdependencies and interactions, collective patterns of behavior emerge (Marion, 2008; Schwandt, 2008; Hudson, 2010).

Researchers have begun developing non-linear mathematical models of psychological processes (e.g., Pincus et al., 2019), as well as agent-based modeling techniques that draw from the mathematical study of non-linear systems to describe human

behavior or psychological processes (Guastello et al., 2011). For example, CAS and non-linear dynamical systems concepts have been used to understand the emergence of consciousness from neural activity (Ibáñez-Molina and Iglesias-Parro, 2014), the dynamic nature of language (Ellis and Larsen-Freeman, 2009), and symptom networks underlying emerging mental illness (Nuijten et al., 2016). Thus, while there is little explicit connection between theories of psychological resilience and either non-linear dynamical systems or complexity theories, there is a developing background within the discipline to support such an effort.

# DISCUSSION: DYNAMIC PSYCHO-SOCIAL-ECOLOGICAL RESILIENCE IN THE URBAN ENVIRONMENT

I argue that to fully understand the reciprocal impacts of human processes and urban resilience, we must position both in complex adaptive systems theory, and address the dynamics of psycho-social-ecological resilience. Through the interdependencies of systems across scale as well as through the panarchy processes of remembering and revolt, the resilience of an urban system is influenced by the adaptive and transformative dynamics shaping the psychological resilience of its people as well as by the adaptive and transformative dynamics shaping the resilience of the surrounding social (including infrastructure) and ecological systems of the city. There are two topics for further exploration immediately emerging from this conceptualization of psycho-social-ecological resilience. First, the role of the adaptive cycle and transformability on the psychological level of resilience needs to be developed. Second, when considering the process of psychological resilience, of mobilizing resources to adapt and/or transform, the person needs to be considered in the context of the total human environment.

## Psychological Resilience, Transformability, and the Adaptive Cycle

The process approach to psychological resilience digs into the cognitive, emotional, and social process of how people respond and adapt to adversity, which is useful in understanding psycho-social-ecological resilience in the urban environment. However, the adaptive cycle, with its recognition of the need for the occasional release of capital and internal connectedness to a system's overall resilience (Gunderson and Holling, 2001) has yet to be incorporated. On a similar note, the ability of a system to undergo occasional regime shift or transformation is known to play an important role in overall resilience (through the introduction of novelty), but this notion of transformability is not captured in the psychological resilience literature, which instead tends to focus on the person's ability to maintain *existing* structures and functions in the face of adversity.

Perhaps human thought and meaning systems emerge through the interdependencies and interactions that occur among the constituent agents of the person's perceptual and cognitive systems, which also interact continuously with the person's environment. Through these interdependent interactions, stabilizing structures emerge that can be identified in the individual's mental models or belief systems. These dynamic emerging patterns on the cognitive level may then resemble those of the social-ecological environment as repeating fractal patterns, interdependent with each other through remembering and revolt processes (e.g., Varey, 2011; Pincus et al., 2019). These cognitive structures would thus serve to stabilize behavioral responses to the environment. Pickett et al. (2004) likewise argue that human behavior and perception are part of a human ecosystem, continuous with the urban environment as an "integrated ecological-social-infrastructural system" with "humans and ecological processes combined into a reciprocally interactive network." (Pickett et al., 2004, p. 378).

Thus, resilience at the urban level may hinge upon the ability of this cognitive level to undergo transformation or release, to shift to a different regime or set of meanings, thereby introducing novelty and supporting different patterns of emerging behavior that are ultimately more adaptive in the wider social-ecological environment. In other words, in order for an urban system to operate differently, the people comprising that system may have to undergo release or transformation in their thought or meaning systems; they may have to think differently. There has not been a lot of research on the psychological process of releasing thought and meaning systems, nor on the link between this kind of transformational cognitive change and psychological resilience. However, the social cognition literature indicates that people generally avoid information that disconfirms existing thoughts (e.g., Oswald and Grosjean, 2004), and that beliefs can persevere in the face of inconsistent information[1] (Anderson et al., 1980, see also Anglin, 2019). Furthermore, a loss of meaning is experienced as psychologically unpleasant and often accompanies grieving (Vanhooren et al., 2017; Milman et al., 2019). The literature on post traumatic growth suggests that for some people a traumatic or adverse experience can bring about positive psychological change that is experienced as meaningful (Tedeschi and Calhoun, 1995; Park, 2010).

Some recent attempts have been made to assess psychological resilience as a dynamic process inclusive of the ability to undergo release in cognitive systems (Trovarello, 2014; Cahill, 2016). Further research is needed to better understand the process through which cognitive systems of meaning and thought support or undermine resilience on other levels. For example, people may appear to display resilience, as their thought and meaning systems persevere through adverse and changing conditions (difficult relationships, environmental crises) yet may actually be undermining their own general resilience or the resilience of the larger systems in which they are components, by preventing a necessary release or transformative introduction of novelty.

[1] Interestingly, this belief perseverance could be thought of as the specific resilience of the cognitive system in the face of disturbance from the introduction of inconsistent or disconfirming evidence or information.

## Psycho-Social-Ecological Resilience in the Total Human Environment

While the psychological resilience literature has revealed many aspects of how people mobilize resources and adapt in the face of adversity, the current analysis highlights the necessity of considering the psychological person in the context of the total human environment. This environment is inclusive of all nested panarchical layers of people, other animals, institutional, infrastructure, economic, and ecological systems, outward to the systems that influence the climate itself. This notion that the total human environment of adaptation includes both the biophysical environment and the social-economic and infrastructure environments, and that these environments comprise systems that are tightly coupled (Liu et al., 2007) is addressed in different combinations in various literatures. Some of these systems are described as complex adaptive systems with an ecological perspective, while others are described as technical systems with an engineering perspective.

The interdependency of human systems and the ecological systems of the biophysical environment is identified with terms such as eco-diversity (Ostrom, 1990; Nyssens and Petrella, 2015) and human ecosystem (Machlis et al., 1997). The ecosystem services literature likewise addresses the relationships between people and their biophysical ecosystems from the perspective of the benefits provided by these ecosystems (clean air, water, well-being, pollination) Burkhard et al., 2010; Fischer and Eastwood, 2016. Discussions of the interdependence of human systems and ecological systems are typically couched within complex adaptive systems theory.

Technical or infrastructure systems such as those essential to the functioning of cities (energy, water, transportation) are typically described from a system engineering perspective (De Weck et al., 2011), including socio-technical systems theory in the context of organizations and workplaces (Emery and Trist, 1960; Badham et al., 2006; Mumford, 2006; Baxter and Sommerville, 2011). Technical systems are designed and engineered, they are typically mechanical and do not self-organize or display emergent outcomes. As the product of some human engineering, one could explore the ways in which political, economic, and institutional systems also operate like technical systems (e.g., Schrunk, 2012). However, these technical and mechanical systems become dynamic in their interactions with people, who self-organize and co-evolve with them, thus collectively displaying unintended, emergent outcomes. People are independent yet interdependent agents. We can actively assess the environment, respond to feedback and learn, co-evolve with other agents and systems, and adopt and pursue goals (with varying amount of flexibility) in dynamic responsiveness with our social, technical, and biophysical environments. In other words, people display agency at the local or individual level, in interaction with the technical, infrastructure, social, economic, and biophysical systems in our immediate perceived environment.

This agency drives emergent outcomes that could not be predicted individually, in interaction with both the engineered and naturally occurring systems around us. Therefore, humanity and its total human environment is a complex adaptive system. Yet within that overall system are institutional and infrastructure systems that are technical and engineered. The interconnectedness of people's technical, social, and biophysical environments is particularly evident in the context of the human food system. While individual people and their psychological processes are embedded within this total environment of interdependent systems, the most frequent and direct daily interactions that most urban dwelling people have is with social, technical, economic, and institutional systems. Even survival-related behaviors of food acquisition are fully mediated for most people by social and economic systems (Allen and Wilson, 2005; Béné et al., 2019).

If human thought and meaning systems emerge into patterns and structures through interactions with the environment, then these systems may primarily or exclusively reflect and mediate the technical, social and economic systems, thereby lacking connectedness with the ecological or biophysical environment. At issue here is that the cognitive systems of meaning and thought that support adaptive patterns of behavior are keyed largely to these technical, social, and economic environments, and not to the biophysical or ecological environment. This results in the emergence of patterns in human decision-making and behavior that prioritize social and economic systems, contributing to their resilience. The limited receptivity of human thought systems to signals from the biophysical or ecological environment (i.e., a lack of psychological tuning to this environment, lack of connectedness between person level systems and ecological level systems), reduces the ability of human systems to adapt quickly to change in the biophysical or ecological environment, and to produce behaviors and decisions that prioritize this environment (see also Environmental Generational Amnesia, Kahn, 2002). This relative disconnect between human cognitive systems and the biophysical environment has implications not only for environmental behavior, but also for dynamic psycho-social-ecological resilience in the total human environment.

This analysis has revealed that psychological resilience and urban resilience are mutually interdependent. Urban systems are able to adapt and transform to the extent that their constituent systems, including individual people, are able to mobilize resources, adapt and transform thought systems, and influence each other to act flexibly toward coordinated goals. Psychological resilience as a process depends upon the presence of stabilizing and survival-supporting systems at the urban level and beyond. Furthermore, psychological and urban resilience depend on the resilience of surrounding regional and ecological systems. Ultimately, it is not simply the resilience of a given urban environment with which humanity is concerned, but rather the resilience of our total human environment. This overall resilience requires that both adaptation and transformation occur at different points in the overall system over time.

## CONCLUSION

The purpose of this paper was to explore urban resilience and psychological resilience together, and to provide some analysis of the zone in which these processes interact. The

literatures on psychological resilience and urban resilience share a high level of diversity and lack of consensus in how these terms are operationally defined. The urban resilience literature has more fully and explicitly incorporated concepts from complex adaptive systems theory, though in the psychological resilience literature there is some articulation of the dynamics of resilience, particularly in those studies adopting a process view of psychological resilience, considering the process of *how* people mobilize resources to adapt favorably to disturbance.

Psychological resilience is an inextricable component of urban resilience. The capacity for institutional and organizational systems within an urban setting to respond resourcefully and flexibly, to adapt and transform in the face of expected and unexpected challenges, assumes that the people who comprise these systems are able to draw on their inner and outer resources to mobilize such responses, to adapt and transform in their thoughts and behaviors and ultimately retain their essential functions and processes. Likewise, I argue that psychological resilience as a process is affected by the current state, system properties, and dynamics of surrounding social-ecological and infrastructure systems, including urban systems. People mobilize not only inner cognitive, emotional, and behavioral resources, but also social, institutional, and ecological resources, to respond effectively to stressful or threatening situations. Therefore, the current resilience of the individual's social, infrastructure, and ecological systems will impact their ability to mobilize the associated resources. Likewise, the biophysical foundations of survival (e.g., food, water), are emergent from ecological and social systems, such that a loss of resilience in these systems will impact the individual's psychological resilience directly through the experience of adversity as well. In this dynamic multi-layered system, the individual person is active and adaptive, and themselves comprised of numerous internal complex adaptive systems that reflect and mediate these wider systems.

The concepts of adaptive cycle and panarchy (Gunderson and Holling, 2001) provide a framework in which to conceptualize these multi-layered dynamics (e.g., Varey, 2011). The individual's systems of thought form out of interdependent component interactions, emerging as stabilizing structures (e.g., mental models, schemas, beliefs) through the adaptive cycle phases of growth to conservation. Once these become over-structured and non-responsive to contextual changes, their resilience declines and they are released and then reorganized along with new combinations of resources and information to form new emergent structures, repeating the cycle. This dynamic through the adaptive cycle is connected through the panarchy to similar cyclical processes occurring in other interlinked systems both within the person (e.g., hormonal cycles) and beyond the person (e.g., family, workplace, city), influencing each other through remembering and revolt processes as described above. Ultimately, the resilience of an urban environment depends upon the continued cycling of its component sub-systems, as this is how novelty and adaptive solutions to new challenges in the environment are formed.

Further research on the psychological aspects of navigating a release phase and transforming systems of thought and meaning would be valuable, as would gaining some understanding of how such processes contribute to psychological resilience. Likewise, both the psychological resilience and urban resilience literatures would benefit from further consideration of how a system's transformability contributes to its overall resilience. The adaptive cycle and panarchy may be useful heuristics in initiating such research and providing a way to conceptualize the interactions of people and their urban environments and the resulting psycho-social ecological resilience of the total human environment.

## AUTHOR CONTRIBUTIONS

MS reviewed literature, conducted conceptual analysis, integrated literatures and theory, and wrote all aspects of the paper.

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