

Theoretical or Methodological Article

What Do We Mean by Accumulation? Advancing Conceptual Precision for a Core Idea in Gerontology

Kenneth F. Ferraro^{1,2} and Patricia M. Morton^{1,2}

¹Department of Sociology and ²Center on Aging and the Life Course, Purdue University, West Lafayette, Indiana.

Correspondence should be addressed to Kenneth F. Ferraro, PhD, Center on Aging and the Life Course, Purdue University, 1202 West State Street, West Lafayette, IN 47907-2055. E-mail: ferraro@purdue.edu.

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Abstract

In recent decades, the concept of accumulation has gained prominence in research on aging, health, and social stratification. Accumulation is now studied in multiple disciplines, revealing that cumulative processes are crucial to understanding patterns of differentiation over the life course. Although this research has demonstrated the empirical value of studying accumulation, the concept has taken on different and sometimes inconsistent meanings. To address these inconsistencies, we propose an interdisciplinary conceptual framework of accumulation that focuses on objects, timing, thresholds, de-accumulation, and the levels and consequences of accumulation. Providing a coherent framework of accumulation will aid conceptual precision, guide future research, and inform public policies related to aging and the life course.

Keywords: Aging—Cumulative processes—Life course—Theory—Thresholds—Timing

Perhaps no single concept has become more pervasive in studies of health, aging, and social stratification than that of accumulation. Processes of accumulation are integral to the study of aging in fields as diverse as biology, epidemiology, psychology, sociology, and toxicology. Whether studying desirable phenomena such as cognitive reserve (Stern, 2002) or undesirable phenomena such as oxidative stress (Shringarpure & Davies, 2009), gerontologists identify accumulation processes as central to the aging experience. Beyond empirical investigations, many theories or models of aging make accumulation (or de-accumulation) a central concept: somatic mutation theory of aging (Morley, 1995); exchange theory of aging (Dowd, 1975); cumulative inequality theory (Ferraro & Shippee, 2009). Even if the term is not used saliently, the idea is often implied in writings on topics such as social convoys and selective optimization with compensation.

Interest in accumulation processes has advanced our understanding of the aging process, but relatively

few scholars actually define the term when using it. Of those that do, there is often inconsistency in the conceptualization. For instance, some scholars use the term accumulation to refer to the recurrence of a particular event, experience, or exposure, whereas others think of it as amassing phenomena across multiple domains. Both uses are wholly acceptable, but they reveal very different processes.

Some scholars view accumulation as a *gradual* acquisition of something, but others do not hold such an assumption; rather, they are intrigued by differences in timing, especially bursts of rapid collection. Also, many study accumulation itself, but others study the consequences of accumulation. These and other variations in the use of the concept make it difficult to advance theories, models, and empirical research to optimize the aging experience. The purpose of this manuscript, therefore, is to bring clarity to this core concept in gerontology, especially for social and behavioral science research on aging. We do not develop a

theory of accumulation *per se* but offer a typology for uses of the term to aid development and refinement of existing theories. From another view, this manuscript is a prolegomenon to clarify future use of the term accumulation in theories and empirical investigations.

The specific objectives of this article are twofold: (i) develop a typology for common uses of the term in research on human aging and the life course and (ii) articulate a conceptual framework that prioritizes temporal and multilevel variability in accumulation in order to advance research on human aging. Our approach is intentionally multidisciplinary but focused on social and behavioral gerontology. We provide a few examples from the physical sciences, but creating a taxonomy of accumulation that covers the breadth of gerontology is beyond the scope of this article. Instead, a focus on human societies treats human agency as an overarching theme, especially because accumulation may activate it (i.e., adaptive individual action).

To begin, we define *accumulation* as a process of amassing one or more objects, whether desirable or undesirable, within or across domains of interest. (By object, we refer to a thing or phenomenon that is relatively stable and may be perceived or measured.) We use *amass* as a synonym for accumulate but reserve the term *aggregate* to depict a new entity resulting from accumulation. We specify six major elements of the typology.

Object of Accumulation

Scholarly interest in the concept has a long history in sociology and economics, where the object of accumulation was often wealth, capital, or material goods (e.g., Marx, 1977 [1867]; O'Connor, 1984). Gerontologists similarly have studied accumulation of wealth and material goods but also a wide array of other phenomena—from amyloid plaques to social support. Indeed, perhaps because the term is so widely applied in gerontology, many scholars have varied assumptions about what accumulation means. This can vary within and between disciplines, leading to a fundamental inconsistency regarding the kind of phenomena that are accumulated. The phenomena of interest may include specific events, experiences, or substances.

Source

To advance a typology of accumulation, it may be useful to consider a fundamental distinction in the source of the object. The source of accumulated objects may be challenging to identify, but differentiating exogenous and endogenous sources helps to illuminate accumulation processes. By *exogenous* sources, we refer to origins that are external to the phenomenon studied and not caused by the phenomenon of accumulation. By contrast, *endogenous* sources refer to some type of influence that is a part of the phenomenon being studied; it refers to an internal origin,

typically conceived of as part of a system involving “mutual causal relationships” (i.e., self-regulating or amplifying; Maruyama, 1963, p. 164). The system under consideration can be an intra-individual entity or involve multiple people and their relationships to one another.

It is tempting in studies of accumulation to focus on exogenous sources, especially by scholars in the emerging field known as “exposure science.” Exogenous exposures, some of which may be referred to as structures, are vitally important, but an exclusive focus on them in studies of accumulation in humans is unduly reductionistic, treating the individual as a passive entity. People may be actively involved in planning and shaping accumulative processes: the structure-agency debate should be salient in studies of humans (Sewell, 1992). Moreover, accumulation itself often acts back on the system (i.e., person or collectivities). Accumulation often begets accumulation; but if humans are aware of accumulation, agency is often activated. It is also plausible that accumulation may be initiated by an exogenous source but give way to a combination of exogenous and endogenous influences.

Consider, for example, the social breakdown cycle in later life whereby an individual's sense of competence is assaulted by the challenges of growing older, leading to a sense of vulnerability and dependence (Bengtson & Kuypers, 1985; Kuypers & Bengtson, 1973). The authors' depiction of a “vicious spiral of induced incompetence”—which is very common among nursing home residents—springs from exogenous factors such as a personal loss, crisis event, or ageism but also from endogenous factors including a dependence of external definitions of competence and learned helplessness (Bengtson & Kuypers, 1985, p. 264). The combination of exogenous and endogenous factors often *amplifies* the dynamics in one or more chains of risk. It also elucidates the need for detailed study of the complexity involved in delineating between exogenous and endogenous sources of accumulation.

Presumed Valence

Most research on aging focuses on the accumulation of negative phenomena. In the medical sciences, for example, frailty may be conceptualized as the “accumulation of deficits” (Rockwood & Mitnitski, 2007). In the social sciences, much attention has been given to the accumulation of disadvantage, focusing on insults, risks, adversity, or misfortune. The practice of measuring disadvantage is manifest in conceptual models of accumulation that use terms such as *risk clustering* and *chains of risks* (Ben-Shlomo & Kuh, 2002; Lynch & Smith, 2005). Echoing this emphasis on disadvantage, conceptual frameworks such as the weathering hypothesis and allostatic load are also based on the cumulative effects of insults (Geronimus, 1992; McEwen, 1998).

The emphasis on negative exposures is understandable because it raises the significance of research on how

accumulated biological, psychological, and social phenomena may lead to health problems; however, multiple theories of aging are premised on amassing both positive and negative exposures: cumulative advantage/disadvantage (Dannefer, 2003; O’Rand, 1996) and cumulative inequality (Ferraro, Shippee, & Schafer, 2009). The accumulation of resources, moreover, needs to be considered in tandem with risks because the former are central to ameliorative efforts. Indeed, the development of effective interventions requires attention to resources—their source, magnitude, and timing of activation (Ferraro & Shippee, 2009). Gerontology needs studies of the accumulation of both positive and negative phenomena, but the accumulation of advantage—e.g., rewards, fortune, or privilege—remains relatively underexplored in gerontology.

As noted earlier and consistent with life course perspective, our proposed typology of accumulation prioritizes the tension between structure and agency (Elder, 1998). Humans think of the objects of accumulation as having a *presumed valence*. People use cultural elements (e.g., education, science, religion, and language) to characterize objects and position themselves to intentionally accumulate the desirable and minimize the accumulation of undesirable objects (i.e., ethic of moderation). Knowledge is a social resource, and one’s stock of knowledge shapes personal choices—sometimes in profound ways (Merton, 1948; Plowman et al., 2007).

The judgment of whether an object of accumulation is good, bad, or benign is couched in cultural context. People may draw on cultural meanings to purposively accumulate some objects while avoiding accumulation of others. Historical change is replete with examples of how one generation positively valued certain objects, but social change challenged those evaluations. The point is that actors draw on their knowledge base to presumptively judge the valence of an object in order to acquire, avoid, or ignore it.

Domains

Scholars also vary in whether they consider accumulation to be the acquisition of the same thing or different things (cf., Bengtsson & Boström, 2009; Felitti et al., 1998, respectively). These inconsistencies lead not only to confusion in how to define and measure accumulation but also to different substantive conclusions, as demonstrated in a study comparing cancer risk associated with an overall sum versus specific domains of childhood misfortune (Morton, Schafer, & Ferraro, 2012). In defining a typology of accumulation, therefore, it may be useful to distinguish whether one or more domains are studied.

Some studies of accumulation are focused on a single domain. For instance, in toxicological studies of human aging, a single element such as mercury may be studied to identify potential health risks. In this case, one is focused on a very specific entity and tracking the buildup of it. Does

mercury accumulation (perhaps from shark consumption) lead to premature aging?

By contrast, one may be interested in amassing objects from multiple domains or spheres of activity. One can study accumulation across multiple domains with reports that several or many exposures have occurred or that two or more domains are related, even if information on the timing of the exposure is quite elementary. Of course, all studies are constrained—one cannot study all life domains simultaneously—but considering more than one domain may open up new vistas of understanding how biopsychosocial processes operate as one grows older.

Studying multiple domains, however, raises at least three questions for the investigator. First, it implies a consideration of how to define a domain. The scope and definition of a domain may vary by discipline and is admittedly somewhat arbitrary. For instance, in a study of health and wealth, the former may be conceptualized as a domain. Yet health is widely recognized as multidimensional; it would be equally valid to explicate domains of health (e.g., morbidity and disability). In short, the definition of domains is a matter of abstraction, typically defined theoretically and/or to address a specific research question.

Second, if multiple domains are involved, there is the additional question of the relationship among the domains. Are the domains correlated? Is accumulation in one domain antecedent to another? Did the accumulation processes occur by chance or are they related (perhaps causally)? Answering these questions may lead the investigator to study the possibility of *interdependency of accumulation processes*. More than a spurious correlation, accumulation in one domain may lead to accumulation (or de-accumulation) in another domain. Although interdependency of accumulation may occur in a wide array of contexts, this is a critical issue in humans because *awareness* of accumulation in one domain may prompt actions to modify the accumulation or compensate for it in some way (upon which we elaborate in a succeeding section). Aging, therefore, is rife with change across interrelated domains or systems of human functioning.

Third, the very nature of accumulation suggests that additional domains may eventually be involved—accumulation changes the person and often the social networks in which he or she is engaged. It is wholly appropriate to isolate a single domain for detailed study, but there may be spillover from one domain to another (Ferraro & Shippee, 2009).

A poignant example of this spillover is Fredrickson’s (1998) broaden-and-build theory of emotions. Although many people regard positive emotions as evidence that a person *is* flourishing, she finds that the accumulation of positive emotions also *leads to* flourishing: “positive emotions broaden people’s momentary thought-action repertoires” and the scope of cognition and attention (Fredrickson, 2001, p. 221). Thus, accumulation in one domain leads to—spills over into—other domains such as

intellectual and social resources. If it is known that multiple domains are dynamically intertwined, it is incumbent on the investigator to acknowledge, and hopefully analyze, those relationships.

Recurrence

In studies of health and aging, great interest has been shown in repeated events and experiences. Although a single episode of a positive or negative experience may impact the aging process, many studies have revealed the manifold consequences to health and well-being due to recurring experiences (e.g., chronic stress). Exposure, whether its source is exogenous or endogenous, refers to the act of coming in contact with or being subject to a condition or state; it is the conduit for object accumulation. Repeated exposure is accumulation *ipso facto*, but gerontologists are also interested in the consequences of such accumulation.

By combining domains and recurrence, it is clear that there are cases of accumulation that involve recurrence across multiple domains. The data requirements for studying it, however, are more rigorous because one must tap multiple domains of the person's life over time, including some record of the frequency of recurrence. For example, to study mercury accumulation and family violence over time, one needs information about the timing of each. It is plausible that family violence may weaken immune systems, thereby heightening susceptibility to mercury accumulation. The value of these types of studies examining multiple domains of accumulation is considerable. Failure to account for other types of accumulation, moreover, may lead to overestimating the effects due to accumulation in one domain.

Timing of Accumulation

There is consensus among scholars that temporal aspects of accumulation are vitally important. In his study of status in scientific communities, Merton (1968) noted that accumulation worked very differently for those who experience early advantage: early distinction in a scientific career led to more opportunities for further advancement. (This does not mean that all "rising stars" attained career brilliance, but they had greater *opportunity* for advancement than those with a less auspicious start.) The life course principle of *timing* also advanced understanding that the consequences of life events and transitions are "contingent on when they occur in a person's life" (Elder, 1998, p. 3).

Gerontology has long embraced rigorous attention to the concept of timing in theories and empirical research (Ferraro, 2014). Indeed, many exemplary studies explicate how the accumulation of events within a temporal context—both normative and non-normative—is consequential to well-being (e.g., retirement, widowhood, and caregiving). At the same time, there has been less systematic

attention to what is meant by the timing of accumulation. Knowledge that accumulation has occurred is very useful, but explicating features of accumulation timing will aid theoretical development and empirical generalizations. Based on the extant literature, we identify three essential features of the timing of accumulation: (i) onset, (ii) duration, and (iii) pace.

Onset

The most commonly examined element of timing is that of onset—when an event or exposure *first* occurred. Onset is the starting point for accumulation. It is needed to quantify the duration of accumulation, but it also situates the beginning of accumulation for the individual in a historical context (Elder, 1988). If we know when the subject was born and the age of onset, we are positioned to bring context more meaningfully into the analysis.

Onset also is important for gerontology because many studies reveal that some periods of the life course are more consequential to later life functioning. A given experience may have different effects simply by varying the age and/or time of onset. Indeed, life course epidemiology now differentiates *critical* and *sensitive* periods to highlight this principle. Viewing an individual's life course as a trajectory, a critical period is when the trajectory can be permanently altered by an exposure—that is, a deterministic effect (Godfrey & Barker, 2000), but a sensitive period is when an exposure has a heightened probability to alter a life course trajectory—that is, a probabilistic effect (Ben-Shlomo & Kuh, 2002; Lynch & Smith, 2005).

Duration

An event or exposure may be unique and limited to a single episode or it may recur. Duration implies recurrence; it expresses the length of time that the exposure occurred. Duration without onset information renders the information disconnected from historical context; together they situate the exposure in history and the person's life.

Partly due to a lack of longitudinal data, duration is an understudied element of the timing of accumulation. Many surveys use retrospective questions to probe an experience at a given time but do not capture duration of the experience. Incorporating measures of duration over time, however, enables one to characterize parts of the life course and study the consequences of a recurring or chronic exposure. For instance, many people experience a bout of depressed affect some time during their lives, but a long period of depressed affect signals psychological distress with more gravity, perhaps sparking a chain of additional risks. For cross-sectional research, posing just two or three questions will enable assessment of onset and duration: When did *x* begin? Is it still occurring? If not, when did it stop?

Pace

If onset and duration are known, a logical next step might be to identify the *quantity of events or exposures* over time. For events, one may count the number of times the event occurred during the time window. With this information, one could create a rate (events per time metric), which could be used to compare people or to compare a person over time (inter-individual differences and intra-individual change, respectively). If the event was infrequent during the observation period, the “average” value will be fairly crude, but at least it taps the number of events experienced within or across people studied per some temporal metric. The time metric may vary according to the subject under investigation.

For many experiences, however, it might be more helpful if one can identify the pace of the accumulation. Would variability in the frequency of an experience be consequential to the outcome studied? Ideally, we want to know the “temporal clustering” of accumulation such as whether the rate was *steady* or *intermittent*. If the accumulation is fairly consistent (not tightly clustered), then the average value may be quite informative. On the other hand, many events do not occur at a steady pace; rather they pile up (Diehl, Hay, & Chui, 2012). If the accumulation was intermittent, an average value will be less informative, and perhaps misleading.

If an experience accumulates intermittently, it would be very useful to integrate information on the temporal clustering. Is the buildup accelerating, decelerating, or stable? Although a basic rate (such as falls per year) may be useful, far more telling would be whether the rate is increasing or decreasing. With that information, interventions could be better targeted and, presumably, more effective.

Thresholds of Accumulation

Nonlinearities

One reason why pace is important to consider is that it may be an oversimplification to presume that accumulation proceeds in a linear fashion. Whether one considers atherosclerosis, automotive traffic, or compound interest in finance, it is clear that *accumulation itself may change the pace of future accumulation*. Thus, if we are interested in the accumulation of oxidative stress, cognitive reserve, or frailty, we need greater attention to variability in pace resulting in (i) nonlinear patterns of accumulation *per se* or (ii) nonlinear relationships between the accumulated object and some outcome, which generally refer to a probabilistic effect (i.e., shift in the probability of y given accumulation of x).

There are clear examples of the importance of thresholds in gerontology. Concepts such as comorbidity and drug interactions imply different effects as diseases or prescription medications accumulate, respectively. Although each new disease is a threat to optimal aging, is the difference

between zero and one disease similar to the difference between four and five diseases? Probably not, and the inherent mandate is to test for thresholds. Is there an inflection point in the relationship between two variables that signals a threshold? Does having five prescription medications result in a much higher likelihood of drug interactions than having four such medications? Or might one observe diminishing influence at higher levels of accumulation? Answers to these questions may lead to clinically significant discoveries.

Some scholars are leading the way by identifying thresholds that have great public health significance in gerontology. For instance, a consensus panel on frailty concluded that three deficits signal the development of this condition, which they define as a treatable medical syndrome (Morley et al., 2013). Vigilance is strongly recommended for older persons manifesting even one deficit, such as a 5% weight loss, but three deficits signal a much more grave condition. Identifying evidence-based thresholds is clinically significant. In statistical terms, investigators may turn to the family of Poisson models, including the negative binomial regression model, to detect nonlinearities in the relationship between some type of accumulation and an outcome of interest (Long, 1997). Indeed, in their study of frailty in later life, Rockwood and Mitnitski (2007) argued for a modified Poisson model to best capture a threshold of elevated need. At the same time, nominalization tests of a quantitative independent variable with an outcome may help define the inflection point of theoretical and clinical significance.

Aggregation

Thresholds convey the notion that accumulation, which can be quantified, results in a qualitative difference, either in what has accumulated or in its relationship with an outcome. Although some authors use the term aggregation as a synonym for accumulation, we reserve the term *aggregation* to refer to when a new entity is formed from the accumulation of multiple elements. When accumulated elements or particles become a new entity, they have different properties. (Many of these new entities either cannot be disaggregated after formation or are quite difficult to disaggregate.) In this sense, aggregation can be viewed as a *state transition*.

Adipose tissue in humans may be used to illustrate the idea of an aggregate. All humans need adipose tissue (fat) to store energy, but after it accumulates to form intra-abdominal (visceral) fat, it functions much like an endocrine organ (Hutley & Prins, 2005). At that point, it is consistent with Aristotle's axiom of aggregation: The whole is greater than the sum of its parts. In this sense, some types of accumulation are more consequential than others.

The concept of *syndromes* is frequently used to refer to the aggregation of phenomena into a new entity: “the aggregate of symptoms and signs associated with any morbid

process, together constituting the picture of the disease” (Stedman, 2006, p. 1888). Symptoms are presumed to result from “accumulated impairments” (Flacker, 2003, p. 58). In the study of aging, *geriatric syndromes* take on a distinctive character that results from accumulation across multiple domains (Inouye, Studenski, Tinetti, & Kuchel, 2007).

De-accumulation

Although we have sought to clarify what gerontologists mean by the concept of accumulation, the tandem concept of *de-accumulation* also needs systematic consideration. Especially because of differences in presumed valence, and the changing time horizon spurred by aging, actors may give heightened attention to whether it makes sense to de-accumulate some objects. Theories of aging, including socioemotional selectivity (Carstensen, Isaacowitz, & Charles, 1999) and selective optimization with compensation (Baltes, 1993), give explicit attention to how aging brings a fresh evaluation of what is considered important and efforts to modify accumulation processes in order to optimize fewer priorities.

Not all de-accumulation processes, however, are intentional and salubrious; many are involuntary and perhaps indicative of negative biopsychosocial spirals (e.g., loss of muscle mass and an increase in functional limitations). Human aging is rife with change, and most people are accumulating objects in some domains while de-accumulating objects in other domains. Gerontology, therefore, requires systematic study of both dynamics (accumulation and de-accumulation). In doing so, the elements of the typology specified herein for accumulation (e.g., objects and timing) are equally germane to the concept of de-accumulation.

Social gerontology’s focus on cumulative disadvantage and biogerontology’s focus on senescence—each of which suggests a downward spiral or entropy—are important for the timely identification of human needs. At the same time, it should be recognized that accumulation processes may be modified or interrupted (DiPrete & Eirich, 2006) and that there is tremendous intra-individual plasticity in the aging process (Baltes, 1987). Accumulation processes are not always determined by prior experience, nor are they necessarily inexorable. The concept of de-accumulation also gives voice to those who are growing older, enabling scholars to attend to whether the person believes that routines of accumulation should be continued or interrupted. Thus, this process of de-accumulation can take three basic forms: slowing, halting, or reversing. Each may be intentional (the actor seeks to alter the accumulation process) or unintentional (exogenous forces, perhaps unknown to the actor, constrain or disrupt further accumulation), but we illustrate the three processes with examples involving intentionality.

Slowing

Slowing refers to a deceleration in the pace of accumulation. A person may sense a growing frequency of angina—chest pain or discomfort that is related to coronary heart

disease—and identify potential solutions to reduce the accumulation of these symptoms. The actor judges the valence as undesirable and seeks to slow the accumulation of these episodes, perhaps through dietary restriction; the purpose is to reduce health risks. This illustrates how the actor’s awareness of undesirable accumulation activates agency in what may be viewed as a pathway model (Ferraro, 2011).

Halting

Halting may operate similarly, but it refers to stopping an accumulation process. Some efforts at halting result in a slowing, but do not achieve cessation of the accumulation, process. Others may actually terminate further accumulation, and we refer to these as halting. Both slowing and halting may reduce further risk, but the aim of halting is more substantial. The difficulty in halting a behavior is contingent on how the person views the behavior in his or her environment (linked lives), including whether it is perceived as a need or a desire (definition of the situation).

Reversing

Reversing refers to not only slowing or halting accumulation but also removing some of what has been accumulated. The life-cycle hypothesis in economics refers to dissaving as a way to spend down or distribute wealth (Ando & Modigliani, 1963; Modigliani & Brumberg, 1954 [2005]). Many people scrimp and save to accumulate wealth, and some begin to realize that they have accumulated sufficient wealth to meet their needs based on a subjective sense of their life expectancy. As a result, they may treat themselves to new bouts of consumption (e.g., luxury items) or launch a series of transfers (e.g., gifts to children or grandchildren). The idea is that it is time to de-accumulate. This may also occur with personal possessions as older people elect to “downsize.” Research suggests that older people are slow to release their “material convoy” but do so as a way to foster stewardship of possessions that they no longer need (Ekerdt & Baker, 2014; Ekerdt, Luborsky, & Lysack, 2012).

Level of Accumulation

Individual

So far, the bulk of empirical research on accumulation has been done at the individual level. Some examples of individual phenomenon that can accumulate include chronic conditions, positive affect, inflammation, maltreatment, and wealth. Moreover, when a person is asked to reflect upon his or her own health and aging, a list of physiological and behavioral factors will likely to come to mind (e.g., blood pressure, diet, and number of diseases). Thus, conceiving of accumulation as an individual process is intuitive and has greatly advanced our understanding of health and avenues to optimal longevity. Perhaps this is why some conceptual frameworks have focused on accumulation as

an individual-level process (Ben-Shlomo & Kuh, 2002; Kirkwood & Holliday, 1979; Lynch & Smith, 2005).

Collection of Individuals

Mostly missing from the empirical literature in gerontology, however, are examinations of accumulation at the level of human collectivities. Whereas accumulation occurs for individuals living in groups, accumulation at the individual-level influences properties of the group(s). And accumulation at the group or collective level often acts back on the person. We need more attention to accumulation processes in collectivities of individuals, including systems, not just the individuals *per se* (Dannefer, 1987; Maruyama, 1963). Systematic study of levels of accumulation, moreover, may help keep the structure-agency debate salient.

Some theories and conceptual frameworks identify such multilevel processes. Cumulative inequality theory, for instance, holds that inequality is generated by social systems and manifested via demographic and development processes (Ferraro et al., 2009). Thus, *accumulation needs to be studied as a multilevel process*, including but not limited to the individual. The delineation of levels is highly dependent on the research question, but we heuristically identify four common groups or collectives for gerontology research: families, communities, regions, and nations.

At the family level, cumulative processes can be initiated through transmission of biological, economic, or social traits. Heritable diseases, wealth, and dietary habits, for example, are often passed down through generations; as such, risks and resources may accumulate across generations. Accumulation within communities, such as neighborhoods and workplace organizations, provide local context for life chances. Accumulated neighborhood wealth influences exercise habits, educational outcomes, and victimization. Regions, which refer to areas or divisions of a country or continent, and nations provide a higher-order context for how the accumulation of risks and resources shape well-being. For instance, an individual's risk of a disease, whether the Ebola virus or diabetes, is a result of accumulation at multiple levels, encompassing individual lifestyle choices, neighborhood sanitation, regional health care resources, and governmental health initiatives. Indeed, context is important because of exogenous sources of exposure but also because it constrains choice in such contexts; actors' options—perceived or otherwise—are shaped by cultural context.

Financial strain is another topic of salient interest to gerontologists and may be used to illustrate how accumulation processes cut across multiple levels. Although financial strain is widely viewed at the individual level, there is also an ecological context involving financial strain. An individual may report the stress of financial strain, but the individual is nested within a social network, neighborhood, region, and multiple governmental districts. Each of these ecological units may also experience financial strain as reflected in indicators such as rates of housing foreclosures

and unemployment. The point is that the ecological context may exert an independent effect on how financial strain influences the individuals dwelling within it (Cagney, Browning, Iveniuk, & English, 2014).

Considering multiple ecological levels is useful for elucidating contextual effects, but accumulation typically involves adding temporal variation to the analysis. Thus, imagine a 2 × 2 contingency table for levels of analysis (e.g., individual and neighborhood) and categories of the timing (e.g., episodic and recurrent). Not only do communities and municipalities influence financial strain, but history and life course exposures differentiate the population. Many people may occasionally experience a period of financial strain, but recurrent or chronic strain is more consequential to health and well-being (Shippee, Wilkinson, & Ferraro, 2012). Thus, financial strain likely accumulates at multiple levels and over time.

Thinking of accumulation processes within multiple levels enables scholars to systematically consider context and the potential for cross-level influence. Moreover, because people judge valence based on their reference groups, assessing where an individual lies relative to a group can also provide insights into how objects of accumulation are perceived and whether the actor seeks to continue, slow, halt, or reverse accumulation processes. In short, ecological context can exacerbate or reduce individual-level perceptions of the accumulated object.

Consequences of Accumulation

Intrinsic

As noted earlier, research on aging often involves one of two different approaches to the study of accumulation. Some scholars study accumulation in and of itself. For example, economists may study wealth accumulation principally to identify the multitude of factors that lead to ample assets. We describe it as an intrinsic consequence because the focus is on the very nature of the phenomenon. Intrinsic would also apply to benign accumulation processes.

Extrinsic

By contrast, other scholars study the consequences of some phenomenon on another phenomenon. For example, the effect of accumulated wealth on longevity. This illustrates extrinsic consequences of accumulation because the amassed entity is related to some other entity.

When most scholars refer to a *cumulative effect*, they are drawing attention to an additive form of an independent variable (a sum) influencing one or more dependent variables either positively or negatively. The form of the relationship may not be linear, but scholars typically are counting the occurrence of some entity to examine its effect on another entity. This is consistent with what Hill (1965) referred to as a *biological gradient* or *dose-response*

relationship. Part of the attraction in the concept of accumulation is due, in part, to studying such consequences. If one can establish a dose–response relationship, then it adds considerably to the evidence suggestive of cause and effect. For instance, identifying that the duration of an experience (e.g., a count variable in years or months) is related to an outcome yields much more compelling evidence of causality than simply identifying that a person had a given experience (e.g., binary variable). Dose–response is in no way proof of causality, but it strengthens the case for concluding that there is causal influence when combined with other criteria of causality (i.e., correlation, temporal order, and nonspuriousness). Most social scientific investigations of accumulation examine probabilistic relationships—not deterministic ones—and dose–response relationships bolster evidence to plausibly interpret results as reflecting causal influence.

Concluding Remarks

The concept of accumulation is central to how gerontologists view the aging process in humans. Whether cognitive reserve or oxidative stress, gerontologists are intrigued by accumulation processes and are using the term to explicate how and why we age. We embrace the enthusiasm for using the term but have sought to aid conceptual precision in how it is used. Table 1 summarizes our typology, specified in six essential elements with two to four components of each element. We began with characterizations of the object of accumulation, then considered timing and thresholds of accumulation, de-accumulation, levels of accumulation, and the consequences of amassing objects. In each section, we identified terms that express variability in what we observe in social gerontological research and clarified meanings to facilitate their effective use. We now call for the systematic study of these elements and for specifying additional features of the proposed typology. We urge scholars to prioritize human agency and endogenous sources of accumulation in order to help differentiate which processes are voluntary or involuntary.

It is apparent that accumulation is important to many gerontological fields of study, but greater clarity in the use of the concept will advance research on aging. Moreover, a typology of accumulation enables scholars from multiple disciplines to use a shared language and schema of meaning when conceptualizing and operationalizing the term. Consequently, we invite others to use, refute, or refine this typology in an effort to facilitate more appropriate use of terms and advance theoretical development.

In conclusion, we define accumulation as a process of amassing one or more objects, whether desirable or undesirable, within or across domains of interest. By contrast, an aggregate is a special type of accumulation because it refers to a new entity that is formed from amassing objects from one or more domains.

Table 1. Typology of Accumulation for Research on Aging and the Life Course

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1. Object of accumulation
 - a. Source
 - (i) Exogenous
 - (ii) Endogenous
 - b. Presumed valence
 - (i) Desirable
 - (ii) Undesirable
 - c. Domains
 - d. Recurrence
 2. Timing of accumulation
 - a. Onset
 - b. Duration
 - c. Pace
 3. Thresholds of accumulation
 - a. Nonlinearities
 - b. Aggregation
 4. De-accumulation
 - a. Slowing
 - b. Halting
 - c. Reversing
 5. Level of accumulation
 - a. Individual
 - b. Collection of individuals
 - (i) Families
 - (ii) Communities
 - (iii) Regions
 - (iv) Nations
 6. Consequences of accumulation
 - a. Intrinsic
 - b. Extrinsic
-

Accumulation occurs in varied ways, and understanding its influence depends on identifying the object(s) acquired; the actor's view of the object(s); efforts to accelerate or decelerate accumulation; the timing of accumulation; related systems; and ways in which accumulation itself may change the process of accumulation. We also emphasized the need to give more attention to how accumulation occurs at multiple levels beyond the individual—from dyads to nations—and potential cross-level influence. Doing so should aid attention to the structure-agency debate in studies of accumulation: structure influences individual action, and individual action influences structure.

Although our discussion and examples have focused on the accumulation of phenomena that are independent variables, accumulation also occurs within dependent variables. Indeed, our consideration of the consequences of accumulation clarifies that it can refer to either a predictor or outcome variable.

We endeavored to articulate the implications of greater precision in the use of the term accumulation for both interpreting research findings and designing future research projects. At a minimum, we hope to stimulate the collection of better data that will enable scholars to explicate

the intricacies of accumulation and how it shapes the aging experience. There is a need for research to identify the correlates and consequences of accumulation in human lives. There are also public policy implications of scholarship examining accumulation processes. Better understanding accumulation will enable us to identify critical and sensitive periods; pinpoint thresholds and inflections points in accumulation processes; interrupt chains of risks; and develop interventions to target the accumulation of risks and resources at multiple levels.

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