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What contributes to perceived stress in later life? A recursive partitioning approach

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Abstract

One possible explanation for the individual differences in outcomes of stress is the diversity of inputs that produce perceptions of being stressed. The current study examines how combinations of contextual features (e.g., social isolation, neighborhood quality, health problems, age discrimination, financial concerns, and recent life events) of later life contribute to overall feelings of stress. Recursive partitioning techniques (regression trees and random forests) were used to examine unique interrelations between predictors of perceived stress in a sample of 282 community-dwelling adults. Trees provided possible examples of equifinality (i.e., subsets of people with similar levels of perceived stress but different predictors) as well as for the identification both of contextual combinations that separated participants with very high and very low perceived stress. Random forest analyses aggregated across many trees based on permuted versions of the data and predictors; loneliness, financial strain, neighborhood strain, ageism, and to some extent life events emerged as important predictors. Interviews with a subsample of participants provided both thick description of the complex relationships identified in the trees, as well as additional risks not appearing in the survey results. Together, the analyses highlight what may be missed when stress is used as a simple unidimensional construct and can guide differential intervention efforts.

Keywords

Perceived Stress; Loneliness; Regression Trees; Random Forests; Aging

Stress has implications for mental and physical health in later life. Although some research has focused on exposure to specific life events (e.g., loss of a spouse) or chronic conditions (e.g., pain), most of this work conceptualizes stress as one's perception of difficulty adjusting to or coping with everything from major trauma to daily hassles. For example, Lazarus and Folkman (1984) emphasize the demands versus resources aspect of psychological stress and describe it as the “particular relationship between the person and the environment that is appraised…as taxing or exceeding his or her resources and endangering his or her well-being” (p. 19). The aim of this project is to better understand the combinations of strain in diverse life domains that relate to perceived stress in a later life

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sample, as well as to illuminate the possible pathways by which people appraise the stressfulness of their lives.

Although perceived stress is a commonly used predictor in the literature, the stress-outcome link is not a simple unidirectional effect, in which stress produces negative health and well-being outcomes. This relationship could also work in the opposite way, with health problems or depression contributing to the appraisal that life is stressful (Mitsonis et al., 2009). Resilience research (see Ong, Bergeman, & Boker, 2009 for review) has focused on possible protective factors (e.g., social support, personality) that may buffer the effect of stress. Although much research has been directed to these questions, less attention has focused on what factors produce this stressed state. Specifically, prior to determining which characteristics of an individual may modify the effect of perceived stress, it is useful to explore which features of person's life contributed to him or her appraising life as stressful in the first place. A variety of contextual and personal risk factors have separately been linked to negative outcomes using traditional regression techniques. Beyond examining *which* domain of risk is most important, it is also important to consider *for whom* certain circumstances are particularly risky; more exploratory methods specialize in identifying these nuanced relationships (Gruenewald, Mroczek, Ryff, & Singer, 2008). By examining multiple domains in the same analysis, it is possible to examine the contexts in which people live and the unique combination of factors that put them in jeopardy.

Certain aspects of later life may be especially noxious. For example, regardless of how well or poorly the individual fares in other life domains, the presence of chronic health problems may distinguish those who are highly stressed from those who are not. There may also be specific combinations of strain from various life domains (e.g., financial concerns, health problems, isolation) that interact with one another to impact the extent to which people feel overwhelmed in later life. In an effort to address these questions, the present study explores the patterns by which life events, neighborhood strain, age-related discrimination (i.e., ageism), social isolation (i.e., loneliness), financial strain, and physical health affect the extent to which older adults perceived themselves as generally “stressed.” A brief review of the relevant research on each of these six domains is presented here to support their inclusion in the analysis.

Life Events

Theorists have long recognized that experiences such as widowhood and retirement are major life events (Palmore, Cleveland, Nowlin, Ramm, & Siegler, 1979; Holmes & Rahe, 1967, Neugarten, 1979), and as such are important influences on perceptions of stress. Older adults nominate these experiences and others such as personal illness, death of a loved one, and loved one's illness as being particularly pernicious (Hardy, Concato, & Gill, 2002; Sematter-Bagnoud, Karmaniola, Santos-Eggimann, 2008). Studies examining the impact of negative events in later life have focused on mental health outcomes, such as depression or anxiety (De Beurs, Beekman, Geerlings, Van Dyck, Van Tilburg, 2001; Kessing, Agerbo, & Mortensen, 2003), on indices of physical health and mortality (Clémence, Karmaniola, Green, & Spini, 2007;) and disease precursors and symptoms (Golden-Kruetz et al., 2005; Mitsonis et al., 2009; Rafanelli et al., 2005; Rosengren et al., 2004; Wigers, 1996).

Financial Strain

Financial strain is another factor that is likely to impact the degree to which people feel “stressed.” Lower socioeconomic status and circumstances of economic disadvantage have been associated with increased rates of depression (Pinquart, Silbereisen, & Korner, 2010), as well as detrimental health behaviors such as smoking, inactivity, and poor diet, which in turn lead to increased morbidity, particularly cardiovascular disease (Kershaw, Mezuk,

Abdou, Rafferty, & Jackson, 2010; Rosengren, et al., 2004). There is also evidence that financial strain has an impact on well-being over and above current socioeconomic status or economic circumstances (Kahn & Pearlin, 2006).

Neighborhood Strain

Neighborhoods provide both physical (i.e., upkeep of houses in area, access to stores and religious outlets) and social (i.e., long-standing relationships with neighbors, safety) contexts and have implications for both health and well-being in later life (see Yen, Michael, & Perdue 2009 for review). Pearlin and Skaff (1996) refer to concerns about the quality of neighborhood as *ambient strain*, which are conditions in a person's environment that may increase feelings of vulnerability through threats to security and safety or limitations on access to services. In older adults, such neighborhood strain has been linked to reports of more physical health problems, as well as poorer mental health functioning (Krause, 1998), and is a potentially powerful predictor of overall perceptions of stress.

Ageism

Discrimination is consistently associated with negative outcomes across a variety of demographic characteristics, but discrimination on the basis of age—or *ageism*—is especially threatening to the health and well-being of older adults (Levy, 2009). For example, being a victim of negative stereotypes of aging have been linked with elevated cardiovascular response to stress (Levy, Hausdorff, Hencke, & Wei, 2000; Levy, et al., 2008, Pascoe & Richmond, 2010), increased mortality risk (Barnes, et al., 2008), the will to live (Levy, Ashman, & Dror, 2000), greater psychological distress and lower positive well being (Yuan 2007), and a variety of psychosocial domains such as social involvement and responsibility, physical activity, self-rated health, and subjective age (Sanchez, Palacios, Trianes, Torres, & Blanca Mena, 2008).

Loneliness

Feelings of loneliness are associated with a myriad of negative outcomes. These include psychosocial factors such as depressive symptoms (Aanes, Middlemark, & Hetland, 2010; Steptoe, Owen, Kunz-Ebrecht, & Brydan, 2004), poorer health-related quality of life (Maxwell, et al., 2009), and greater perceptions of distress (Cacioppo, Hawkley, & Berntson, 2003; Kiecolt-Glaser, et al., & Glaser, 1984); behavioral factors such as physical inactivity (Hawkley, Thisted, Masi, & Cacioppo, 2010) and sleep problems (Cacioppo et al., 2003; Steptoe, Owen, Kunz-Ebrecht, & Brydan, 2004); physiological factors including increased levels of cortisol (Doane & Adam, 2010, Steptoe et al., 2004), markers of poor cardiovascular health (Hawkley, Burleson, Berntson, & Cacioppo, 2003; Hawkley, Masi, Berry, & Cacioppo, 2006), more pronounced physiological reactions to stress (Steptoe et al., 2004), and poorer immune system functioning (Glaser, Kiecolt-Glaser, Speicher, Holliday, 1985; Kiecolt-Glaser, et al., 1984). Loneliness is consistently associated with an increased risk of morbidity and mortality across demographic characteristics (Berkman, Leo-Summers, & Horwitz, 1992; House, Landis, & Umberson, 1988; Penninx, et al., 1997).

Chronic and Somatic Health Problems

Although the association between chronic health issues and perceptions of stress makes intuitive sense, there is a large body of empirical support for this relationship as well (Lagana & Reger, 2009; Linn, Sandifer, Stein, 1985; McDade et al., 2006; Strodl et al., 2003). Chronic pain from arthritis, for example, may itself be a stressor; in this overtaxed state, individuals may narrow their focus to negative experiences rather than the more demanding processing of both positive and negative information which has been linked with well-being (Davis, Zautra, & Smith, 2004). For example, among individuals with

rheumatoid arthritis and fibromyalgia, more severe and/or chronic symptoms were related to elevated levels of stress (Murray, Daniels, & Murray, 2006; Tak, Hong, & Kenneday, 2007).

Present Study

The focus of the current study is to elucidate the contexts (e.g., financial strain, neighborhood, social isolation, ageism, health problems) and life events that may converge to make older adults generally perceive their lives as stressful. The first aim was to use exploratory recursive partitioning to analyze survey data of contextual stress indices across a variety of domains. These analyses allow us to examine how combinations of the contextual features of individuals' lives may be related to overall feelings of stress. Specifically, these analyses allow for an examination of *equifinality*, meaning multiple different pathways to the same outcome (Cummings, Davies, & Campbell, 2000; Gruenewald et al., 2008). In other words, individuals who have comparable levels of perceived stress may have similar responses for very different reasons. Intervention or prevention strategies designed to diminish levels of stress need to be sensitive to these different pathways. The second aim is to use interview data to profile individuals who have these unique combinations of life contexts to further probe our quantitative findings. Although subjective in nature, it is hoped that the life stories of older adults will aid our understanding of the processes through which individuals view their lives as challenging, and better articulate what it means to feel stressed.

Regression trees and random forests, described in the method section, are particularly appropriate because they allow for different weightings and contributions of the risk factors across different portions of the sample. In traditional regression, the influence of a predictor such as number of life events experienced is constant across all levels of the predictor itself (e.g., the same regression coefficient is applied to both 1 and 10 life events). In contrast, the recursive partitioning procedures employed here not only allow for the identification of the domain that best divides the sample on the outcome at each split, but also determines the level at which this predictor best splits the sample (e.g., people who report experiencing life events one standard deviation above the sample average are at particular risk for high perceived stress). Additionally, unique interactions and nonlinear relationships may be identified that are especially useful in profiling one subset of participants whereas other predictors and interactions may be identified to describe another. The selected risk domains are not typically examined together, thus it is difficult to specify a priori the numerous interactions that may appear or the predictors that may best “split” the subjects into the various pathways. These techniques have been applied in prior aging research (see Gruenewald et al., 2008; Gruenewald, Seeman, Ryff, Karlamangla, & Singer, 2006; Wallace, Bergeman, & Maxwell, 2002), however, the present study is the first article to appear in this journal using the method and serves as an introduction to the framework, terminology, and application. Exploratory techniques such as this one provide an opportunity to describe the relationships in a particular dataset, which can then be used to develop specific confirmatory hypotheses in other samples and to link separate domain-specific stress literatures.

Method

Participants

Participants included 282 adults ranging in age from 54 to 91 years (M=68.79, SD=5.10) who completed the second yearly survey of the longitudinal Notre Dame Study of Health & Well-Being (NDHWB; Bergeman, et al., 2010). Demographic information is provided in Table 1. Year 2 data was used because it coincided with the interview portion of the study. Slightly more than half the sample was female and it reflects the cultural diversity of the

Northern Indiana area. The interview participants were selected from the pool of participants who endorsed at least two events on the life events checklist in their survey. From this larger group, 37 NDHWB participants were selected for possible interviews; 26 interviews were completed. The remaining 11 participants were not interviewed for various reasons (e.g., unable to be reached by phone, lived too far away, not interested). Although not selected to be directly representative of the larger sample, they reflect similar demographic characteristics.

Survey measures

Global perceptions of stress—Overall perceptions of stress were assessed using the 14-item Perceived Stress Scale (PSS; Cohen et al., 1983). The PSS was designed to assess the degree to which individuals appraise the situations in their lives to be unpredictable, uncontrollable, and overloaded. Participants are asked to reflect over the last month and report the frequency of agreement on a four-point scale (never, sometimes, often, always). A higher overall score represents more perceived stress. Cronbach's alpha in this sample is 0.89.

Life events—Life events in the past year were assessed using the Elders Life Stress Inventory (ELSI; Aldwin, 1990). Participants endorsed the occurrence of 31 events across a variety of domains including health, finance, family, and work. A simple count of events is typically used with this instrument (i.e., Isaacowitz & Seligman, 2001; von Dras, Powless, Olson, Wheeler, & Snudden, 2005).

Chronic and somatic health problems—Respondents reported on a variety of medical conditions and physical health problems using a checklist following Belloc, Breslow, and Hochstim (1971). Fourteen items assessed chronic health problems such as high blood pressure, arthritis, cancer, and diabetes. Fifteen items assessed somatic health complaints such as joint stiffness, headaches, tiring easily, and shortness of breath.

Financial strain—Four items, modeled after those contained in the MIDUS (Brim et al., 1995–1996) were used to assess financial strain. Using an 11-point scale, participants rated their current financial situation, the amount of control over their current financial situation, and the amount of thought or effort they put into their current financial situation. Additionally, participants selected one category from three to describe their current finances (i.e., “We do not have enough money to meet our needs,” “We have just enough money to meet our needs,” “We have more money than we need”). Responses to the four items were standardized and summed; α in this sample was 0.74.

Neighborhood strain—Participants' ratings of their neighborhood were assessed using a 12-item scale developed based on research by Keyes (1998) and Ryff, Magee, Kling, and Wing (1999). Items tapped a variety of features of neighborhood, including cleanliness, safety, and extent to which participants could call upon neighbors for help. Participants responded on a 4-point scale; α was 0.91.

Loneliness—Social isolation was measured using the 20-item Revised UCLA Loneliness Scale (Russell, Peplau, & Curtona, 1980). Respondents are presented with a statement about perceived social connectedness and are instructed to rate each on a scale of *1*, indicating never, to *4* indicating often. One item was changed from the original source (i.e., from “People are around me but not with me” to “I often feel alone even when in a crowd”) for clarification; α in this sample was 0.92.

Age discrimination—Experiences of discrimination were assessed using a 20-item checklist of experiences following work by Palmore (2001). Respondents were asked to endorse events that they experienced because of their age. Higher scores were indicative of more discrimination experiences.

Interview

The interview component of the larger project was not designed specifically for this study; the data, however, allow for a more rich profile of the lives of individuals in the terminal nodes produced by the recursive partitioning analysis. The focus of the interviews, which included a description of the life events and difficulties in the last year fits well with the components assessed in the survey data. It allows not only for a confirmation of the recursive partitioning results, but also extends this approach to provide a more detailed examination of these pathways to perceived stress.

The interviews were semi-structured, following the format of the Life Events and Difficulties Schedule (Brown & Harris, 1978) a semi-structured interview with a series of questions regarding life events in the previous year in a variety of domains (e.g., work, family, health). In addition, interviewees were asked more broadly about their life experiences and were encouraged to discuss important turning points and to contextualize the joys and sorrows of their lives. The interview was designed to be flexible and have a conversational flow, rather than a clinical interview or standard survey (Wethington et al., 1997). Interviews were audio recorded and transcribed verbatim.

Procedure

Participants were mailed a packet of questionnaires which included a variety of paper-and-pencil stress measures. Upon returning their packets, participants received a $20 gift card. Those participants who met the sampling criteria were contacted via telephone and asked if they would participate in a follow-up interview. Interviews took place either at participant homes or at research offices. Interviews generally lasted about 1.5 hours, but ranged from 1 to 3 hours. Participants received a $30 gift card for their participation.

Analyses

Recursive partitioning: Regression trees of perceived stress—A goal of the present study was to examine the interrelations between various life events and difficulties in putting people at-risk for generally perceiving their lives as stressful. Regression trees were used to conduct a tree-structured, non-parametric data analysis of predictors of perceived stress in a later life sample. The description of regression trees below draws from several sources (Berk, 2008; Brieman, Friedman, Olshen, & Stone, 1984; Hastie, Tibshirani, & Friedman, 2001; Merkle & Shaffer, in press; Strobl, Malley & Tutz, 2009). Perceived stress was used as the outcome in this analysis and treated as a continuous variable. Regression trees fall under the broad category of a binary recursive partitioning techniques. Recursive partitioning has been used in the aging literature to identify interrelations between protective factors (Wallace et al., 2002), biomarkers predicting mortality (Gruenewald et al., 2006), and pathways to positive and negative affect (Gruenewald et al., 2008).

In this study, we used the software program CART Pro Version 6.0 (Steinberg & Colla, 1997) to conduct the tree analyses. The procedure begins with a *root node*, containing the entire sample. In the case of regression, the software uses a least squares splitting rule to compare all possible cutoff points on all the predictors. The optimal predictor and its cutoff point, which minimizes the within-group variance on perceived stress, are identified; the two groups produced by these binary splits are called *child nodes*. The same procedure is repeated for each of the child nodes, recursively identifying the predictor that optimally

separates the participants in that node into two subsequent child nodes. This process is often displayed in an inverted-tree structure in which the multiple splits resemble branches that end in *terminal nodes*, groupings that cannot reliably be further divided.

CART Pro first grows a large tree because it is impossible to identify a good stopping point a priori. If the procedure stopped too early, key splits could be missed. It should be noted, however, that overly large trees are difficult to interpret and their structures are unlikely to be replicated. One way of limiting tree complexity is by imposing a constraint on the minimum number of cases necessary for a terminal node. In this study, the minimum terminal node size was set at 10. This large tree is then *pruned*, removing branching splits that may capitalize on chance relationships.

With a large enough sample, an ideal method for assessing the extent to which a particular tree overfit the idiosyncrasies of a dataset is to split the data into a learning sample and an independent test sample. A large tree is grown on the learning sample, then the test sample is used to examine the error the sequence of trees produced that are special cases of the large tree, and a best tree is selected by its cost. In smaller samples for which dividing the participants into learning and test samples is not feasible, as in this study, cross-validation methods are used. In cross-validation, the software determines how much to prune the large tree by constructing a series of trees that are grown on subsamples of the entire dataset. In this study, 10-fold cross-validation was chosen. In this procedure, the sample is randomly divided into 10 equal-sized subsets. A tree is then grown on nine of those subsets (90% of the overall sample) and then the remaining 10% of the sample is used as a pseudo-test sample, and the sum of squared error for the sequence of trees that are special cases of the large tree is calculated. This was repeated 10 times, resulting in all subsets serving as both learning sample and pseudo-test sample. Those branches or splits that do not improve the accuracy in cross-validation are pruned. The error information is combined across trees and used to prune the large tree to identify the optimal tree. The *optimal tree* has the lowest cross-validated relative error rate for trees grown, providing the smallest tree with error comparable to the large tree.

Missing data and data transformations—Of the 297 available participants at this wave, 15 (approximately 5% of the sample overall) were missing on at least one of the domains of interest. These participants were excluded from the dataset[1]. Regression tree results are unaffected by monotonic transformations of the predictors (Wallace et al., 2002). As neither the perceived stress outcome nor the predictors have a common metric or clinically-relevant-cutoff values, all survey scales were standardized prior to analysis to aid in interpretation of the cut-points

Results

Descriptive Statistics

Descriptive statistics and correlations are displayed in Table 2. As expected, all the contextual risk domains were positively related to the Perceived Stress Scale. Age was unrelated to PSS and all predictors except for chronic health problems. Gender, race, and marital status were not related to PSS, however, both SES-related indicators (e.g., education:

[1]As a rule of thumb, listwise deletion is an option for handling missing data in cases where fewer than 5% of the total observations would be excluded (Berk, 2008). CART Pro software manages missing data by using *surrogate* predictors as splitters (Steinberg & Golovyna, 2006). For a given node, surrogates closely mimic the primary splitter (i.e., node size, composition, which cases are assigned to left and right child nodes) and function as back-up splitters in cases for which the primary splitter is missing. This can be a useful option in some applications, but because the focus of the current study was in determining the relationships between specific contextual risk variables and perceived stress in this sample, we chose not to rely on surrogates and thus limited the available data to complete cases.

F=2.65, $p < 0.02$; income: F= 2.42, $p < 0.03$) were, with higher SES participants reporting lower overall perceived stress.

Regression Tree Results

The optimal tree, which is the tree with the minimum cost regardless of size, identified is displayed in Figure 1; all predictors and the outcome were z-transformed to aid interpretation. Additional descriptive data by node are provided in Tables 3 and 4. It is important to remember that although this tree was identified as the smallest with an error comparable to the large tree, the analyses produced many trees including 11 of which were within 1 standard error of the large tree. Each of the trees identified within the *1 SE rule* (Breiman et al., 1984) could be nominated as the best tree; the selected tree, however, was chosen for its low relative error and relatively even distribution of participants and interviews across terminal nodes. The tree includes six pairs of branches (e.g., splits) and seven terminal nodes describing the relationships between contextual risk domains and overall perceived stress in this sample. Following other studies using recursive partitioning (Gruenewald et al., 2008; Seroczynski, Cole, & Maxwell, 1997), we calculated the percent variance explained by the model as one minus the ratio of average within node error variance of the optimal tree to the total sum of squared errors of the baseline model with only the root node. The optimal tree selected explained 45% of the variance in perceived stress. Upon recommendation of a reviewer, we examined the R-square of a traditional linear regression model for perceived stress using all the contextual risks and their two-way interactions as predictors. This resulted in an R-square of .42 which is quite close to the pseudo-R-square value calculated for the selected tree. Given that previous work tended to examine individual contextual domains and perceived stress separately, we did not have specific hypotheses about how these may interact. The tree approach employed has the benefit of being exploratory from the outset.

In the resulting tree, loneliness, financial strain, neighborhood, and life events were identified as splitters. Loneliness appears twice in the tree. It is the primary splitter at the root node (Node 1), which separates those who report very high loneliness (Node 3) from the rest of the sample. Participants in this high-loneliness pathway can be further described and separated by their level of neighborhood strain; this is an example of an interaction and is discussed below. Loneliness appears again as a splitter in the path to the left of the root node (Node 2), an example of the intricate relationships that trees and other recursive partitioning techniques can identify. That is, among those participants who do not report extremely high levels of loneliness, different profiles emerge. For those who report moderate to low levels of loneliness (Node 5), financial strain further explains differences in overall level of perceived stress. For those who report very low levels of loneliness (Node 4; loneliness 0.20 standard deviations [SDs] below the sample average), recent life events further subdivides this group, differentiating those who report extremely low perceived stress (Node 8; PSS scores that are nearly one SD below the mean) from those who report more low to average levels (Node 9; PSS 0.34 SD below average). Financial strain also appears multiple times within the tree, both in the low-to-medium loneliness path (Node 5) as well as for those who report very low loneliness, but some life events (Node 9).

Terminal nodes (Nodes 6, 7, 8, 10, 11, 12, and 13) are indicated by circles in Figure 1. Multiple pathways to perceived stress are apparent in the terminal nodes. Those persons in Node 8, who reported the lowest loneliness and life events scores (0.20 and 0.69 SDs below average, respectively), reported perceived stress scores nearly one SD below the average person in the study. (Note: in this sample, 1 SD reflects a difference of almost 6 points on the raw scores of the PSS which ranges from 15 to 47). Node 9 participants had similarly low levels of loneliness, but reported more life events, and these individuals' perceived stress was further differentiated by their financial strain. Participants in the Node 12 pathway, had

average (or lower) levels of financial strain and reported perceived stress about ½ SD below the sample average; whereas those participants in Node 13 reported higher levels of financial strain and had scores at about the average of perceived stress.

Moving across the figure from left to right, we can examine the role of more moderate levels of loneliness and its interactions with other domains in predicting perceived stress. Interestingly, the adults in terminal Node 10 have similar levels of perceived stress as terminal Node 12 (approximately ½ SD below average), but it is the interaction between low-medium loneliness and very low financial strain that is most related to their low overall level of perceived stress. Their pathway neighbors in terminal Node 11 report higher levels of financial strain, and perceived stress scores 0.4 SDs above the sample average.

For those participants who reported very high values of loneliness (Node 3 pathway), neighborhood strain was a useful predictor in distinguishing levels of perceived stress. Participants in terminal Node 6 report high levels of loneliness, but relatively low-to-average neighborhood strain. Average perceived stress in this group is 0.6 SDs above average, not that dissimilar to Node 11. In addition to the very high loneliness characteristic of this pathway, those in terminal Node 7 reported higher levels of neighborhood strain. These participants appear to be at particular risk for feeling that life is overwhelming or unpredictable; they report perceived stress nearly 1½ SDs above the rest of the sample.

In summary, the highest levels of global perceived stress tended to be related to higher levels of loneliness. Different predictors, however, were helpful in separating participants with moderate and high levels of loneliness. For example, it may be that their lower levels of strain in other domains (i.e., finances and neighborhood) provided offsetting influences for Nodes 10 and 6 compared to their counterparts in nodes 11 and 7 who perceived their lives to be much more stressful. We use random forests to further examine the contributions of predictors.

Follow-up: Random forests

It is important to keep in mind that trees are very sensitive to the particularities of the sample, meaning that "the entire tree structure could be altered if the first splitting variable, or only the first cut point was chosen differently because of a small change in the…data" (Strobl, Malley, & Tutz, 2009, p. 330). Cross-validation is one way to prune a tree and limit the tendency to overfit the data. A recent development in recursive partitioning techniques is to take advantage of this variation in individual trees by aggregating over multiple trees to obtain more stable results, a procedure called random forests (Breiman, 2001). Random forests incorporates additional variability through two methods – varying the sample and varying the predictors. Similar to the resampling of the dataset in the cross-validation procedure above, the random forest procedure either bootstraps or subsamples the participants to vary the sample; this step is sometimes referred to as bagging. In addition to varying the participants by bagging, in random forests the predictors are sampled with replacement in order to produce an even more diverse set of trees. When a particularly strong predictor (e.g., loneliness), is not sampled, another predictor may be selected and interactions that may have been missed can be identified.

Although random forests produce too many trees to make sense of visually, they provide indices of variable importance across the "forest" of trees (Strobl et al., 2009a). In this study, we use the cforests procedure in the party package in R (Strobl, Boulesteix, Zeileis, & Hothorn, 2007; Strobl, Boulesteix, Kneib, Augustin, & Zeileis, 2008)[2]. To address sample

[2]A constraint of at least 10 participants per terminal node, the default setting for bagging (subsampling .632*n), number of trees (ntree=500), and sampling from the predictors (mtry=5) were specified.

size and correlated predictors, we follow recommendations to vary the starting seed and to examine the conditional permutation importance (Strobl, Hothorn, & Zeileis, 2009; Strobl et al., 2009a). If we were to randomly permute (i.e., shuffle or reorder) the values on a predictor such as financial strain, the original relationship between financial concerns and perceived stress would be broken. If the original version of financial strain was related to perceived stress, using this permuted-version along with the other original (i.e., non-permuted) contextual predictors[3] would result in much worse prediction. Poor predictors, on the other hand, would only be subject to a small random decrease and in some cases a small increase in prediction after permutation. This difference in prediction before and after permuting a predictor is referred to as *permutation importance*. The relative ranking of predictors in terms of permutation importance should be interpreted rather than their absolute values (Strobl et al., 2009a).

Random forests results provide support for the domains selected as splitters (and their relative importance when both participants and predictors available are varied) as well as a reminder to use caution when interpreting a single tree. Across starting values, loneliness was by far the strongest predictor (Figure 2), meaning that permuting loneliness greatly decreases its predictive utility. It is followed by financial strain, neighborhood strain, and ageism. Chronic and somatic health problems were poor predictors; negative permutation importance values indicate that randomly shuffling responses on these health domains actually increases prediction of perceived stress. Life events also had a small permutation importance value, which means that the life events split in the tree in Figure 1 should be interpreted cautiously as it may be the product of random variation in the dataset. Depending on the sample, this domain may not appear as an important predictor.

Together, the selected tree and the random forests indicate that loneliness is a particularly important risk domain, but that the impact of loneliness on perceived stress may depend on other, different contextual domains for different people. Although permutation importance suggests that the impact of life events may not replicate, the tree displayed in Figure 1 still provides one possible depiction of the multidimensional relationships between life contexts that may underlie responses – even similar levels of response – on the commonly used predictor perceived stress. One goal of this study was to not only identify which domains are especially related to overall perceived stress, which the random forests results speak to, but to use the trees to profile the people for whom certain situations are particularly risky. Pursuing this idiographic goal, we also examined the interviews of participants in selected nodes to gain another perspective on the contexts of these individuals' lives.

Follow-up: Interviews

Transcribed interviews were sorted based on terminal node membership derived from the optimal tree. A formal qualitative analysis was not conducted for this study; instead, the authors listened to and read the interviews multiple times and used the stories to add additional contextual detail to the other findings. The distribution of interviews across terminal nodes is indicated in Figure 1. Selection criteria for the interview project required endorsing at least 2 life events in the last year; therefore, no interviews appear in Node 8. Of those interviewed, terminal nodes 12 and 7 represent maximal diversity, both in terms of PSS and interacting domains of risk.

Node 12 participants reported low loneliness and financial strain and were nearly 1/2 SD below average on perceived stress. In their interviews, these individuals had social networks of varying sizes, which appeared to fit their needs. These participants described being

[3]For technical details on permutation in the case of continuous and correlated predictors, see Strobl et al., 2009b.

financially secure and those who were still working were doing so mostly because they enjoyed it or liked the benefits (e.g., discounts at a retail store). An absence of pressure and confidence in being able to manage was audible in some responses, “my goal is to be where I need to be when I need to be there,” and “don't take bad events seriously. Things are going to happen, [either] there's nothing you can do or if [there is something] you can do, you can overcome.” Interview participants reported events ranging from retirement, an incident at work involving police, best friend's death, and surgeries.

Node 7 represents the highest risk group in the sample. In the interviews, social isolation is apparent – the loss of two close friends in the last month, a major break in friendship, considering ending relationship with boyfriend, and reluctance to ask children for help in order not to be a burden were all mentioned. Additionally, one person explained her social isolation, “I have a tendency to hibernate…and because I hibernate, I don't do so good on making friends.” Neighborhood strain, however, is not as clear in the interviews. Although financial strain did not appear as a predictor in this branch of the tree, their financial resources were likely quite limited. More than half of the participants in this node reported an annual income less than $15,000 (Table 3). In some ways it is surprising that more risk domains do not appear in the tree, given the contexts described in the interviews. One woman related the story of a difficult year with many events and strains. Isolated from her children since her divorce over 10 years ago, she fell at home and hurt her wrist which resulted in multiple surgeries and complications. She had to take unpaid leave from work and did not have insurance. Bills accumulated, including taxes which she could not pay and she faced losing her house. Before she could get medical clearance to return to work, she was let go from her position. She said, “I really wanted to commit suicide…I've never had it so bad and been alone so totally…I lost my job, I lost my insurance…my family wasn't there to help me out…losing my house was the final blow.” She recounted that on the night she was going to commit suicide by leaving the car running in the garage, her car was stolen. This insight, albeit extreme, gives us opportunity to better understand the contexts of the lives of highly stressed individuals.

These interviews provide support for the role of chronic difficulties, like financial strain and loneliness, in putting people at-risk for feeling stressed. Further, the role of appraisal may be important to the understanding the difference between objectively identifiable stressors such as those detailed in the interviews and the risk domains appearing in the perceived stress tree. It is not necessarily the case that participants in Nodes 6 and 7 did not have any other strains in their lives beyond loneliness and financial strain, clearly some of them did. Instead, as suggested by permutation importance, the effect of loneliness may be particularly overwhelming and related to how they generally perceive the stressfulness in their lives.

Discussion

The current study provided both idiographic and nomothetic information regarding the life domains that are particularly salient to perceptions of stress in this later life sample. First, at the idiographic level, regression trees were used to identify the contextual features that contributed to perceptions of being stressed and reflected the pathway of splits that led to node membership. The interview data helped to better flesh out these important relations. Second, the use of random forests, a nomothetic approach to understanding contexts important to perceptions of stress, identified risk domains in the analysis that were of greatest importance—in this case, loneliness, followed by financial strain, neighborhood stress and age discrimination. These findings are discussed in turn.

Regression Trees: Idiographic Understanding of Perceived Stress

One way to consider the results of the tree analysis is to consider cumulative and compensatory pathways to perceptions of stress (Seroczynski, et al., 1997; Wallace et al., 2002). *Cumulative pathways* indicate a compounding of risk or, alternatively, protection through the interactions of multiple domains; whereas *compensatory pathways* display possible ways in which being of low risk in one domain may offset high risk status on another. For example, the split that lead to terminal Nodes 7 and 8 are good examples of cumulative pathways, in which the experience of each of the domains result in splits that further differentiate the most (Node 7) and the least (Node 8) stressed groups. For the high-stressed group there may be a cumulative negative effect of high loneliness and high neighborhood strain, in addition to the many insights gleaned from the interview data described above. On the least-stressed side (Node 8), low loneliness or high social integration and support, in addition to fewer major life events, related to low levels of perceived stress. It is not surprising that greater severity of stressors accompany higher perceptions of being stressed and vice versa. Of greater interest are the compensatory pathways that reside in the center nodes of Figure 1. In Node 6, participants reported very high loneliness relative to the rest of the sample, but there may have been something protective about their neighborhood situation that resulted in above average levels of perceived stress, but ones that were much lower when compared with Node 7. In other words, something about the neighborhood characteristics (or contexts related to it) were protective in the relationship between loneliness and perceived stress.

Regression tree results also provided interesting examples of equifinality (Nodes 10 and 12; and to a lesser degree Nodes 6 and 11). For the participants in Nodes 10 and 12, perceptions of stress are about ½ SD below the mean of the sample, but the pathways are different. That is, even though individuals report similar levels of perceived stress, the contexts of their lives contribute differently to their feelings of stress. Efforts to intervene at the level of social isolation would likely benefit Node 10 participants more than those in Node 12 who appraise their social opportunities as adequate. Both sets report relatively low financial strain. What might be contributing to adults in Node 12 feeling similarly overwhelmed is the experience of life events in the last year. For example, one interviewee in Node 12 described multiple deaths in his extended family and social network, his wife experienced moderate health concerns, and his sister was in the later stages of Alzheimer's disease. On the other hand, he had good relationships with family and was active with friends (e.g., volunteering, senior men's club), had been pleasantly surprised about how well his investments had done, and felt comfortable in his financial situation. Thus, social support and a lack of financial hardship may help to compensate for life stressors, and shows how individuals with similar levels of stress have different predictive risks.

Also interesting are the somewhat similar mean scores of Nodes 6 and 11. Although Node 6 is clearly higher (average perceived stress 0.64 vs. 0.38 SDs above the mean), both are above the sample average and participants reside in these nodes through a different set of predictive associations—Node 6 through high loneliness and low neighborhood strain and Node 11 through moderate loneliness and high financial strain. For example, interviewees in Node 6 reflect on social losses (death of a spouse or fiancé), whereas subjects in Node 11 reported “losing their nest egg,” and having constant “struggles” or “worries” about finances. Thus in one group, low neighborhood strain may have buffered the negative effects of high loneliness, whereas high financial stress undermined the positive effects of social integration. The tree analysis allows for the identification of these differing reasons for the perceptions of stress and provides valuable insights for prevention and intervention efforts.

Random Forests: Nomethetic Understanding of Perceived Stress

Although the identification of the course by which individuals (or groups of individuals) perceive their lives as stressful is important, there is a benefit to understanding the particular attributes that are generally the best predictors of perceived stress. By varying the sample across many trees in random forests, it is possible to identify predictors that may generalize to other samples. In other words, the conditional permutation importance provides important information for understanding the factors that are most salient to perceived stress, in this case, loneliness. Later life may be a segment of the lifespan that is particularly ripe for changes in social relationships. For example, death of family members or friends limits the number of people in our social networks; changes in health restrict involvement in activities that promote social engagement; and a move to a new residence can make gathering with others more difficult. It should be noted, however, that loneliness is not simply physical isolation; it is more than just time spent alone or the number of contacts that people have with others (Fischer & Phillips, 1982; Hawkley, Burleson, Bernston, & Cacioppo, 2003; Jones, 1982; Wheeler, Reis, & Nezlek, 1983; for review see Heinrich & Guillone, 2006). "*Loneliness*, … may be best described as an internal assessment of the meaning derived from social exchanges" (p. 5; Russell & Bergeman, 2010), and feelings of loneliness reflect the quantity and/or quality of unmet social needs (Peplau & Perlman, 1982). Much research has shown that social dynamics can serve as both a source of the stress and as a coping or resilience mechanism (Bergeman et al., 2010). It is clear from both the regression tree and random forest analyses, however, that loneliness is especially detrimental, and is related to elevated perceptions of stress.

Limitations

Much discussion in the stress literature has centered on the notions of objective and subjective measures of stress (Monroe, 2008). Perceived stress, the outcome here, is certainly a subjective measure. On the surface, life events checklists and counts of physical symptoms appear to be objective measures of exposure, however, the reporting of these indicators are intertwined with appraisal processes as well (Dohrenwend, 2006; Monroe, 2008) and so may best be described as subjectively-identified stress exposure (Duggal et al., 2000). From this perspective, the measures utilized in the current study document both the self-nominated exposure as well as the perceived severity of conditions across social, health, financial, and neighborhood domains. In addition, the analyses were limited to the stress measures available in the NDHWB, and different trees might result if additional measures were included. On the positive side, this multi-domain subjective data available for these analyses provides important information on the contexts of individual lives and how these components may put people at differential risk for perceiving their lives as stressful.

Recursive partitioning analyses are very sensitive to the characteristics of the sample, both a drawback and benefit of these methods. The random forests analyses produced 500 trees, which displayed many different patterns depending on which participants and predictors were sampled. It is impossible to interpret the specific patterns in this many trees, however, the random forests provide further evidence for the importance of loneliness, financial strain, and neighborhood strain as consistent predictors of perceived stress. The optimal tree examined is one of many possibilities produced by these analyses, but the one with the lowest cross-validated relative error. As a visual depiction, it underscores the intricate and node-specific relationships in the present sample and directs our attention towards the factors that may underlie perceived stress. More importantly, it highlights the varied pathways, delineating possible, but different, contributors to perceived stress. Understanding these differences is fundamental to targeting appropriate interventions. That is, for people like X, we should pay special attention to changing financial circumstances; whereas for person Y, it might be most effective to enhance social integration. It is important to note,

however, that although it is tempting to read trees as flow charts that describe processes in action, the causal processes underlying the stress appraisal are complicated and necessitate longitudinal data to examine empirically.

Future Directions & Conclusions

Although perceived stress is commonly employed as a predictor, little research has focused on the contextual stress factors that are related to these perceptions. The current study identified loneliness, neighborhood, and financial strain as particularly important correlates of this often used construct. Beyond simply assessing correlational relationships among these indicators or their individual correlations with perceived stress, the tree analyses provide intricate combinations of contexts that better contribute to our understanding of individual differences. Although someone's level of perceived stress gives information on the extent to which he or she generally feels overwhelmed, the contexts underlying this appraisal may not be the same across people even those with similar levels of perceived stress. In other words, people perceive their lives as stressful for different reasons. Public health interventions often use demographic characteristics to target their interventions. The highest perceived stress in this sample was found among those who reported some of the lowest income, however, some participants in this high stress node also reported mid-range and high incomes. These people, who also report feeling extremely stressed compared to the rest of the sample, would have been missed in an intervention using solely socio-economic status as a targeting tool. Intervention and prevention strategies need to be designed to take this equifinality of pathways into account. Finally, the mixing of quantitative and qualitative data can allow insights into complex developmental phenomena (Yoshikawa, Weisner, Kalil, & Way, 2008). Regression trees, random forests, and the interviews each provided a different vantage point for understanding stress in later life. The result is a rich, albeit exploratory, examination of the antecedents and concomitants of stress.

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Figure 1.

Regression tree diagram: Regression of perceived stress scores onto contextual risk domains. PSS: Perceived Stress Scale; Neighbr: neighborhood strain; Fin. Str.: financial strain; Life Ev.: life events. Standardized scores are reported. Nodes display level of splitter variable, node size, and average perceived stress relative to entire sample. Terminal nodes are indicated by circles and include number of interviewed participants which fell into that node.

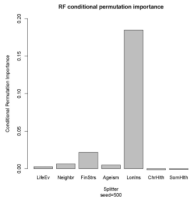

Figure 2.

Example conditional permutation importance table. LifeEv: life events, Neighbr: neighborhood strain, FinStr: financial strain, Lonlns: loneliness, ChrHlth: chronic health problems, SomHlth: somatic health problems.

Table 1

Demographic Characteristics of the Full and Interview Samples

	Full Sample		Interview Sample	
	N	%	N	%
Total N	282	--	26	--
Gender (Missing = 4)				
Female	169	61	16	62
Male	109	39	10	38
Marital Status (Missing = 3)				
Married	129	46	9	35
Divorced	65	23	8	31
Widowed	61	22	4	15
Single	21	8	4	15
Separated	3	1	1	4
Race (Missing = 3)				
Caucasian	234	84	18	69
Black/African American	29	10	7	27
Hispanic/Latin American	9	3	0	--
Asian/Pacific Islander	2	1	1	4
Native American/Aleutian Islander	1	<1	0	--
Other	4	1	0	--
Education (Missing = 2)				
Grade School (grades 1–6)	1	<1	0	--
Middle School (grades 7–9)	5	2	0	--
High School (grades 10–12)	110	39	11	42
Vocational Education	17	6	1	4
Some College Classes	61	22	7	27
College Degree	46	16	4	15
Post College Professional Degree	23	8	2	8
Graduate, Medical, or Law Degree	18	6	1	4
Annual Household Income (Missing = 7)				
Less than $7,500	3	1	0	--
$7,500 to $14,999	49	18	7	27
$15,000 to $24,999	50	18	7	27
$25,000 to $39,999	72	26	8	31
$40,000 to $74,999	71	26	2	8
$75,000 to $99,999	18	7	1	4
$100,000 or more	12	4	1	4

Note. Number of people missing refers to the Full Sample; demographic data for the Interview Sample is complete.

Table 2

Means, Standard Deviations, and Correlations of Variables in the Full Sample (N=282)

	M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Perceived Stress	29.12	5.84	1.00								
2. Life Events	2.28	2.58	**0.26**	1.00							
3. Neighborhood Strain	20.77	5.48	**0.35**	**0.19**	1.00						
4. Financial Strain	0.003	3.02	**0.36**	**0.24**	**0.35**	1.00					
5. Ageism	2.53	2.71	**0.31**	**0.32**	**0.23**	**0.16**	1.00				
6. Loneliness	34.69	9.24	**0.55**	**0.23**	**0.38**	**0.28**	**0.27**	1.00			
7. Chronic Health	2.02	1.53	**0.18**	**0.21**	**0.17**	**0.22**	**0.28**	**0.24**	1.00		
8. Somatic Health	2.48	2.12	**0.26**	**0.19**	**0.17**	**0.25**	**0.29**	**0.29**	**0.57**	1.00	
9. Age	68.84	5.20	−0.09	0.08	−0.07	0.02	0.04	−0.09	**0.16**	0.02	1.00

Note. Financial Strain is comprised of standardized items. The scales for Life Events, Ageism, Chronic Health, and Somatic Health reflect counts of exposure or symptom reports. Raw (unstandardized) scores are reported here, with the exception of Financial Strain; Analyses use standardized scores. Significant correlations are bold.

Table 3

Demographic Characteristics by Terminal Node; Values are Percentages.

Node	**8**	**12**	**13**	**10**	**11**	**6**	**7**
	N=24	**N=76**	**N=41**	**N=27**	**N=67**	**N=21**	**N=26**
Gender (Missing = 4)	(0)	(0)	(1)	(0)	(3)	(0)	(0)
Female	63	55	60	56	61	48	92
Marital Status (Missing = 3)	(0)	(0)	(0)	(0)	(3)	(0)	(0)
Married	41	53	47	59	41	53	27
Divorced	23	24	29	11	27	24	19
Widowed	24	22	12	22	23	19	31
Single	12	1	12	8	6	4	19
Separated	0	0	0	0	3	0	4
Race (Missing = 3)	(1)	(0)	(1)	(0)	(0)	(0)	(1)
Caucasian	83	83	80	93	87	86	76
Black/African American	4	8	15	7	12	5	20
Hispanic/Latin American	9	5	3	0	1	5	0
Asian/Pacific Islander	0	3	0	0	0	0	0
Native American/Aleutian Islander	0	1	0	0	0	0	0
Other	4	0	2	0	0	4	4
Education (Missing =1)	(0)	(0)	(0)	(0)	(1)	(0)	(0)
Grade School (grades 1–6)	0	1	0	0	0	0	0
Middle School (grades 7–9)	4	1	0	4	1	0	4
High School (grades 10–12)	25	26	37	44	55	38	50
Vocational Education	8	4	5	0	14	0	4
Some College Classes	13	28	27	19	14	29	23
College Degree	21	20	15	18	12	14	15
Post College Professional Degree	12	12	11	11	3	5	0
Graduate, Medical, or Law Degree	17	8	5	4	1	14	4
Annual Household Income (Missing =7)	(1)	(2)	(0)	(1)	(2)	(0)	(1)
Less than $7,500	0	0	0	0	2	5	4
$7,500 to $14,999	13	4	17	4	31	10	52

Node	8	12	13	10	11	6	7
	N=24	N=76	N=41	N=27	N=67	N=21	N=26
$15,000 to $24,999	9	9	32	8	29	14	16
$25,000 to $39,999	35	30	29	19	25	19	20
$40,000 to $74,999	17	45	17	42	12	33	4
$75,000 to $99,999	9	8	3	19	1	14	0
$100,000 or more	17	4	2	8	0	5	4

Note. Number of people missing refers to the full sample. Values in parentheses indicate the number of people missing on that characteristic in each node.

Table 4

Descriptive Statistics by Terminal Node

Node	**8**	**12**	**13**	**10**	**11**	**6**	**7**
	N=24	**N=76**	**N=41**	**N=27**	**N=67**	**N=21**	**N=26**
Perceived Stress	23.6	26.2	28.8	26.1	31.3	32.9	37.7
	(4.3)	(4.7)	(4.3)	(3.6)	(4.5)	(5.3)	(4.2)
Loneliness	27.3	27.7	28.3	36.2	37.0	50.3	51.9
	(3.9)	(3.5)	(3.1)	(2.7)	(3.1)	(5.4)	(6.2)
Financial Strain	−1.3	−2.0	2.4	−3.2	1.7	−0.1	2.6
	(2.7)	(1.5)	(1.7)	(1.0)	(2.4)	(2.6)	(3.6)
Life Events	0	2.1	2.7	1.9	2.4	3.1	3.7
	--	(1.2)	(1.8)	(1.5)	(3.5)	(3.0)	(3.9)
Neighborhood Stress	17.4	19.2	20.6	17.6	22.7	19.3	28.3
	(4.4)	(4.8)	(4.8)	(5.1)	(4.6)	(2.6)	(5.0)
Ageism	1.4	2.1	2.2	1.8	2.9	3.5	4.2
	(1.2)	(2.3)	(2.1)	(2.2)	(2.6)	(3.0)	(4.6)
Chronic Health	1.3	1.7	2.0	1.5	2.4	2.8	2.5
	(1.2)	(1.4)	(1.3)	(1.4)	(1.4)	(2.0)	(1.8)
Somatic Health	1.3	2.0	2.5	2.2	2.8	3.2	3.8
	(1.7)	(1.7)	(1.9)	(1.6)	(2.6)	(2.0)	(2.2)

Note. Means and standard deviations (in parentheses) of raw scores, with the exception of Financial Strain which is standardized, on each variable by node.