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Abstract: *Living with chronic co-morbidities implies long-lasting, always present conditions associated with highly variable health trajectories. In this study, ecological momentary assessment was used to explore nine older women's experiences of living with co-morbidities. Each participant completed a daily diary, which focused on 10 variables related to energy, pain, effort expended, and an overall health rating, for 21 days. Hierarchical linear modeling was used to explore intra-individual variation in daily health experiences and health-related burden, and determine the extent to which health-related burden was related to daily health experiences. Each of the daily health experience variables significantly predicted health-related burden. Over half of the variation was attributed to the predictor variables. These findings reveal the dynamic nature of living with multiple chronic conditions and demonstrate the utility of daily diaries for measuring fluctuating states of health in community-dwelling older women.*

Key Words: *Co-morbidity, Health-related Burden, Hierarchical Linear Modeling, Theoretical Model Testing*

Ecological Momentary Assessment of Older Women's Health

Today's older adults reap a variety of benefits from a longer life span, but they may be faced with a multitude of health-related challenges in their later years (Williams & Botti, 2002). Paterson, Russell, and Thorne (2001) reported that adults with multiple chronic conditions develop personalized approaches to chronic disease management. Focus group studies have shown that some elders with comorbidity learn to effectively cope with unwelcome changes in their health and daily activities (Loeb, 2006; Loeb, Penrod, Falkenstern, Gueldner, & Poon, 2003), demonstrating what Miller (2000) refers to as positive adaptation.

The Theoretical Model: Staying in Control

Coping processes are described in Penrod, Gueldner, and Poon's (2003) model of *Staying in Control* (see Figure 1), in which a sense of control over one's health status is accomplished through a flow of dynamic responses to perceived health threats experienced in day-to-day life. These threats may manifest as direct physical symptoms (e.g., experiencing a painful flare-up of arthritis), psychological concerns (e.g., dwelling in the uncertain silence of osteoporosis without new fracture), or impaired functional health (e.g., having an acute bout of heart trouble that renders normal daily activities impossible).

In the early phase of the theory-building project, a screening tool was designed to evaluate the self-reported frequency of common chronic conditions and the perceived impact of each condition on everyday life. The list of chronic conditions was based on an exhaustive literature review conducted by Poon and colleagues (Dowzer, Basford, Booth & Poon, 2000). An expert panel of geriatric clinicians provided more colloquial terms for these conditions and validated that the conditions were most commonly seen in practice. The clinicians added urinary/bladder problems due to the frequency of complaints among older adult patients. The resulting list of chronic conditions and the impact scale used in the preliminary screening study are illustrated in Table 1.

The model of *staying in control* was derived through focus groups exploring the phenomenon of living with co-morbidities from the older adults' perspective. Using a sampling frame established through preliminary screening (n = 122), each group was carefully segmented to maximize within-group variation in both the number and the impact of ten common chronic conditions of old age (Loeb, et al., 2003). This strategy promoted a group

Table 1. Preliminary Screening: Impact Rating of Common Chronic Conditions.

Chronic Conditions Included in Screening Survey.
- Heart Trouble
- Arthritis
- High Blood Pressure
- Diabetes
- Hearing Problems
- Lung Problems
- Osteoporosis
- Problems with Vision
- Urinary or Bladder Problems
- Cancer
- Stroke

Participants were asked to rate each of the following conditions using the following scale:

- No, my doctor never mentioned this to me (Assigned Value: 0)

- Yes, but I don't think much about it (Assigned Value: 1)

- Yes, I pay attention to my treatment, but I don't think about it too much (Assigned Value: 2)

- Yes. I think about it pretty often and I pay close attention to my treatment (Assigned Value: 3)

- Yes. I think about it nearly all the time and do all I can to feel better or get through the day (Assigned Value: 4)

dynamic of contrast (i.e., more or fewer conditions with greater or less perceived impact on daily life) in the midst of commonality (i.e., all were experiencing co-morbidities). Penrod, Guledner, and Poon (2003) provide an in-depth discussion of the preliminary survey used to define segmentation across groups. Within-group analyses provided a series of individual snapshots of older

Figure 1. Living with Multiple Chronic Conditions: Staying in Control (adapted from Penrod et al., 2003).
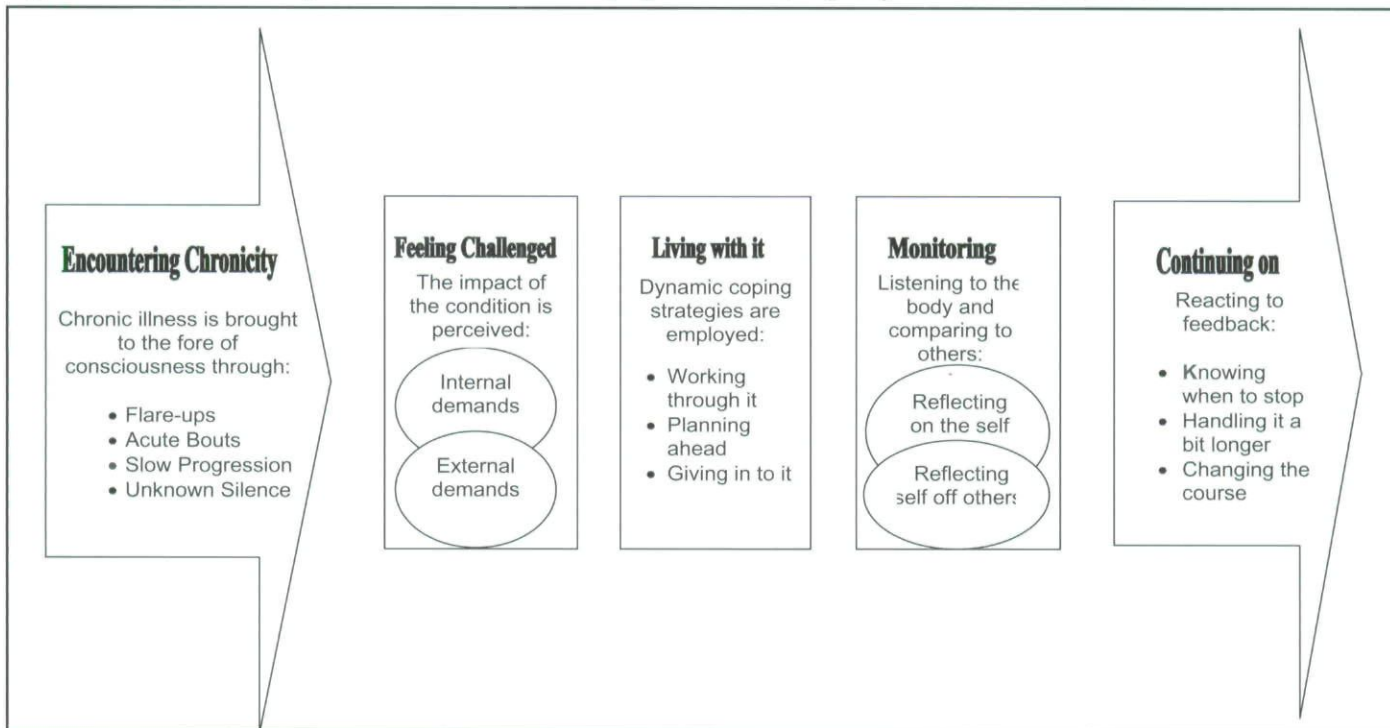
adults who were coping with multiple chronic health conditions, while across-group analyses revealed similarities in the coping with these conditions.

Ecological Momentary Assessment

Although the theoretical model (see Figure 1) fits the experiences of older adults with co-morbidities and is congruent with coping literature, empirical knowledge of the intra-individual variation in day-to-day life has not been reported. One promising method for shedding light on how older adults with chronic illness manage life on a day-to-day basis is using daily diaries, which allows researchers to capture "life as it is lived…in a way that is not possible using traditional designs" (Bolger, Davis, & Rafaeli, 2003, p. 579). Through repeated self-reports, it is possible to capture personal accounts of how people think, feel, and behave on an ongoing basis within their natural context, promoting what Brunswick (1949) termed ecological validity. Shiffman and Stone (1998) refer to this method of data collection as ecological momentary assessment.

Ecological Momentary Assessment permits the researcher to examine fluctuations of phenomena over time (Stone, Shiffman, & DeVries, 1999). Cognitive distortion or recall bias is minimized because the amount of time elapsed between an experience and the reporting of the experience is reduced (Bolger et al., 2003; Stone et al., 1998). Diaries have been successfully used in health and illness research for over 70 years, with the data obtained serving either as a stimulus for enhancing recall during interviews or as the primary data source in studies. The use of diaries in social science and health research and in clinical practice has increased markedly in recent years (Schumacher et al., 2002). The method is particularly well-suited for dynamic research phenomena.

The purpose of this study was to explore the utility of daily diaries for providing data about the attitudes, opinions, current feelings, and state of health of older women with co-morbidities over a period of 21 consecutive days. Through repeated sampling, our aim was to examine a) intra-individual variations in daily health experiences and health-related burdens perceived by women with multiple chronic health conditions, and b) the

extent to which daily health experiences are correlated with health-related burden.

Methods
Sample

Prior to initiating the study, human subjects approval was obtained from the University Office for Research Protections. Participants for this study were solicited through a letter mailed to 38 women who had agreed to be contacted for follow-up in an earlier study of living with comorbidity (Loeb et al., 2003; Penrod et al., 2003). The letter explained the nature and scope of the study, detailed requirements for data collection, the duration of the study, and a modest incentive ($50 at completion). Telephone conversations were used to answer questions raised by potential participants and to confirm their willingness to participate in this study. Inclusion criteria were a) age 55 or older, b) with at least two chronic health conditions, c) community-dwelling, and d) able to read and write in English. Recruitment efforts produced a final sample of nine community-dwelling women, ranging in age from 61 years to 83 years ($X = 72.1$ years), who reported three to nine chronic conditions ($X = 5.7$).

Instrument

The daily diary instrument was designed to accommodate the needs of older adults. Language difficulty was scored at less than an eighth-grade reading level. Print size was a minimum of 14 point font, most often bolded for increased contrast. The diary tool was pre-tested for 5 days with 3 older adults who met the study inclusion criteria. Based upon their feedback, the tool was legible, intuitively logical, and easy to complete; therefore, no revisions were made.

The daily diary tool included 10 items that were analyzed in this study. Seven of the scaled items focused on daily health experiences; these included a) a question focusing on action (i.e., degree of motion), which displayed a continuum with a pair of resting, untied shoes at the lower end, and a pair of tied shoes that were running on the upper end (Gueldner et al., 2005); b) an item measuring optimism through two pictures displayed at polar ends of a continuum with clouds covering the sun on the lower

end, and a full sun on the upper end (Gueldner et al., 2005); c) a question inquiring how much good happened to the respondent that day; d) a question asking how rested the person felt that day; e) an inquiry instructing participants to rate how much energy they felt that day; f) a question asking participants to rate their overall health that day, and g) an item asking participants to report the amount of pain they experienced that day. Three items focused on daily perceptions of health-related burden. These items explored participants' thinking about health conditions, effort spent to get through the day, and sense of burden (due to health conditions). Each item was structured as a 7-point visual scale. For each of the aforementioned items (with the exception of pain), higher scores represented higher degrees of action, optimism, good, rested, energy, health thinking, effort, and burden. Pilot testing confirmed that participants intuitively interpreted the right side of the scale to indicate "better" or improved states; therefore, for the variable pain, scores were reversed and higher scores represented lower levels of pain (i.e., improvement).

Procedure

An initial home visit was arranged with each participant to obtain informed consent, conduct a baseline interview, and provide instructions and materials needed for completing the daily diary (Keleher & Verrinder, 2003). The baseline interview included items that were the same as for the 21-day daily diary, except that participants were asked to focus retrospectively on the past three weeks. This pre-diary activity provided an opportunity for participants to work through the tool independently while a member of the research team observed and was available to answer questions.

Each participant was given a Participant's Packet that included: diary entry sheets labeled with the date and day of the week (individualized according to the participant's start date); a large manila envelope marked with inclusive dates in large letters; and a pencil. End of day sampling was used: Participants were instructed to make their entries daily, before bedtime over a 21-day period. On the evening of the initial home visit, participants began a three-week period of daily data collection, using the diary tool to focus on each day. Upon completion of each diary entry, participants were asked to simply place the entry sheet into the manila envelope. At the conclusion of each week, an investigator visited the participant briefly at home to retrieve the weekly envelope and to deliver the next week's materials.

There were a total of four face-to-face visits and 21 daily telephone reminders (made between 4 and 7 p.m.) to each of the participants. During the few instances when participants were not home when an investigator called, a reminder message was left on the participants' answering machine. The visits and phone calls were purposefully brief, carefully focused on the research protocol, yet cordial. This regular contact with the researchers was designed to minimize missing data (Keleher & Verrinder, 2003). A meeting date for the subsequent week was established at the conclusion of each visit (which ranged in duration from 15-30 minutes). At the final visit, researchers conducted a process assessment to gather data on the burden imposed by the protocol. Even though this protocol entailed a significant investment of researcher time, it was effective in minimizing missing data. In fact, out of 189 daily diary data points for the 9 subjects, only 1 subject failed to complete one daily diary form. The information obtained from these daily entries is the focus of this report.

Data Analyses

Hierarchical linear modeling (HLM) (Raudenbush & Bryk, 2002) in SAS Proc Mixed was conducted to explore intra-individual variation in daily health experiences and health-related burden and to determine the extent to which health-related burden was correlated with daily health experiences. Intra-class correlation coefficients (ICCs) were examined for each of the daily health experiences and health-related burden variables (see Snijders & Bosker, 1999). The ICC describes the proportion of between-

person over total variation in a variable. Higher ICC values indicate higher proportions of between-person variation; lower ICC values indicate higher proportions of within-person variation. For example, the variable pain had an ICC of .48, indicating that approximately 48% of the variation in this variable was due to between-person differences. The remaining 52% was related to within-person differences.

Intercept-only multivariate models (i.e., empty or without predictors) were estimated to examine the covariation of daily health experiences. These models are similar to those discussed by Snijders and Bosker (1999), where multiple dependent variables are estimated within a single three-level model (also see Sliwinski, Hofer, & Hall, 2003; equations and detailed descriptions of the models are available from the authors upon request). In practical terms, results from these models describe the extent to which the overall levels of each physical health construct (e.g., optimism, physical reality, and health related burden-see below) were related between persons (i.e., correlations among the random intercepts), and the extent to which daily measured variables correlated within-persons, across time (i.e., correlations among the time-specific residuals).

In this study, three sets of variables were examined using multivariate models. The first set included variables focused on action, optimism, and how much good happened (referred to together as *optimism*). The second set included the rested, energy, and pain variables (referred to together as *physical reality*). The third set was comprised of thinking, effort and burden variables (referred to together as *health-related burden*). For example, the correlation of residuals among the physical reality variables (i.e., set two) provides one way of describing the relationship between the extent to which participants were in pain on a given day, how rested they felt, and how much energy they reported having relative to their average levels of pain, rest and energy (within-person relations) and relative to other participants in the sample (between-person relations). A second analysis determined the effects of daily health experiences on predicting daily perceptions of health-related burden within a random intercept model. For interpretation purposes, each of the final daily predictors, including optimism, physical reality, pain, and overall health, was centered at the mid-point of the scale (4 in the scale of 1 to 7). *See endnote.*

Results

Findings from the process assessment completed at the last meeting with each participant revealed the protocol did not induce a significant burden for the participant. All participants rated the daily diary form to be easy to complete, taking only 20 minutes or less to accomplish each evening. The daily phone calls were described as welcomed, but "not necessary." All of the participants described a patterned routine that enhanced their successful completion rates; for example, keeping the forms and envelope at their bedside. The influence of such patterned behavior on completion was strong, as some participants described using their "system" on overnight trips during the study. Despite this routine, only 1 of the 9 participants reported that filling out the diary at the end of the day influenced how much or how often she thought about her health, commenting that "it was a helpful review of my physical, emotional, and spiritual events of the day." This participant reported that she kept a daily journal as part of her routine health promotion activities; therefore, the diary instrument was seen as an extension of this process.

Within and Between-Person Variation

Multi-colored line graphs were used to plot each participant's responses to each item over the twenty-one days of data collection. Within and between-person variability was graphically evident as EEG-like tracings of all participants' responses to each variable. These tracings were visually analyzed by the researchers. Intra-class correlation coefficients (ICCs) were then calculated to quantify the between and within-person variability. The ICCs for

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	3.07‡ (.28)	3.81‡ (.25)	3.85‡ (.22)	4.03‡ (.16)	3.82‡ (.18)
Optimism		-.66‡ (.07)	-.42‡ (.09)	-.38‡ (.08)	-.30‡ (.08)
Physical reality			-.29† (.08)	-.20* (.07)	-.16* (.07)
Pain				-.42‡ (.05)	-.34‡ (.05)
Overall health					-.42‡ (.10)
Between-person variation (intercept covariance)	.65	.46	.37	.16	.21
Within-person variation (residual covariance)	1.14	.75	.71	.50	.45
ML deviance (# of parameters)	579 (3)	501 (4)	488 (5)	419 (6)	401 (7)
AIC	584	510	500	437	422
BIC	585	510	501	437	422
N of observations	188	188	188	188	188

$^*p < .01$; $^†p < .001$; $^‡p < .0001$.
Note: Maximum Likelihood (ML) deviance tests were based on separate analyses using ML, rather than REML. AIC = Akaike Information Criteria; BIC = Bayesian Information Criteria.

variables measured on a daily schedule reflect a large portion of within-person variation (pain, ICC = .48; action, ICC = .61; optimism, ICC = .37; good, ICC = .40; rested, ICC = .39; energy, ICC = .38; overall health, ICC = .04; think, ICC = .29; effort, ICC = .32; and burden, ICC = .36).

Significant positive within-person correlations were found between the residuals of the optimism-related variables of action, optimism, and good (r's ≥ .59, p < .0001). For the physical reality variables, significant positive within-person correlations were found between rested and energy (r = .76, p < .0001); yet pain (a variable we anticipated would be related) did not correlate as strongly (within-persons) with these other two variables (rested, r = .22; energy, r = .24; p's < .01). Finally, for the health-related burden variables, significant positive within-person correlations were found among think, effort, and burden (r's ≥ .60, p < .0001). In summary, reports of the optimism variables correlated, the health-related burden variables correlated, and the rested and energy variables (representing physical reality) correlated. For example, on a day where high action was reported, high optimism and good happenings were typically reported, and on a day when burden was reported as high, think and effort were typically high.

Prediction of Health-related Burden

The extent to which daily health experiences predicted levels of daily health-related burden was examined. Daily health experience predictors were grouped based on theoretical assumptions underpinning the study and on the residual correlation analysis. The action, optimism, and good variables were aggregated to form a composite measure of the construct representing optimism. Rested and energy were aggregated to represent physical reality. Pain was used as a single predictor (because, as noted earlier, it did not correlate with rested and energy as expected). Overall health was separated from other variables as a distinct construct. In the models predicting health-related burden, each of the predictors was transformed into two variables representing between- and within-person variation. Both predictors were included in the models so that within-person variation could be estimated while controlling for between-person variation. Between-person variation was represented with a persons' average across all 21 days, while within-person variation was represented by a persons' deviation from their overall average on a given day.

As summarized in Table 2, few of the between-person variables were significant predictors of health-related burden, likely due to our small sample size. In contrast, each of the within-person daily health experience variables significantly predicted health-related burden. Specifically, as the combined measure of optimism increased by one unit, the composite health-related burden score decreased by approximately one third of a standard deviation; as the composite score for physical reality increased by one unit, health-related burden decreased by a little more than one tenth of a standard deviation; as pain went down by a unit, health-related burden decreased by one third of a standard deviation; and as overall health increased by one unit, health-related burden decreased by another third of a standard deviation.

To further examine the practical influence that predictors (e.g., optimism, physical reality, pain, and overall health) had on daily health-related burden, the proportion reduction in the variance terms was calculated (also known as pseudo R^2 [Singer & Willett, 2003]). The pseudo R^2 for daily burden was .61, indicating that 61% of the within-individual variation in daily burden was accounted for by the daily health predictors (see the reduction in within-individual variation values, as indicated in models 1-5 of Table 2, in the "within person variation" row). In essence, this pseudo R^2 value tells us that the daily health experiences of the respondents of this study accounted for most of the within-person change over time in daily health-related burden. In addition, a maximum likelihood (ML) deviance test with eight degrees of freedom indicated that Model 5 had significantly better fit over Model 1, suggesting a better model fit with the predictors in the model (see successively smaller ML deviance values in models 1-5 of Table 2). In summary, these results indicate that persons' levels of optimism, their physical reality, their overall health status, and the amount of pain they felt on a given day predicted the amount of burden they felt in relation to their health problems.

Discussion

In this study daily diaries were used to explore the dynamic states of health in community-dwelling older women with multiple chronic illnesses. Multilevel analyses revealed significant intra-individual variation across time, in measures of optimism, physical reality, and health-related burden; over 60% of the variation in most daily diary variables was due to intra-individual variation across days. This finding is not surprising given that there were only nine study participants providing 21 days of health-related data. However, this high percentage of intra-individual variability suggests a significant level of daily variation in health experiences in persons with multiple chronic illnesses. In addition, results revealed that within-person fluctuations in certain variables were related across days. Specifically, variables representing optimism, physical reality, and health-related burden all co-varied within persons.

Multi-level models were used to estimate the extent to which daily health experiences were associated with health-related burden. Results indicated that each of the daily health experience variables (i.e., optimism, physical reality, pain, and overall health) significantly predicted health-related burden. More than

half of the within-person variation in daily burden was accounted for by these predictors. With regard to the research design, the daily diary approach was successful in a) providing detailed data of health-related experiences from persons with multiple chronic conditions, b) collecting longitudinal data in a relatively short period of time, and c) collecting several data points with remarkably little missing data.

Theoretical Implications: Staying in Control Model

Results supported the notion that self-ratings and perceptions of the demands imposed by daily activities are highly variable, extending our understanding of the dynamic course of the chronic illness experience over time. These findings are consistent with the theoretical assertions made in the *Staying in Control* model (see Figure 1) (Penrod et al., 2003). For example, the theory purports that "feeling challenged represents the ways that comorbidity had an impact on the lives of [older adults] as they sensed demands throughout the flow of everyday life," and "their bodies posed internal challenges as they worked to manage a daily routine" (Penrod et al., 2003, p. 197). This study revealed the nature of encountering comorbid chronic health conditions in everyday life by explaining the variability of specific internal demands (e.g., limitations in movement, pain, and lack of energy) sensed by the participants.

Despite wide fluctuations in day-to-day self-assessments of optimism, pain, and the physical reality of life with chronic illnesses, the women in this study reported a relatively small degree of change in overall ratings of health (see ICC, mean, and standard deviation of "overall health"). The dynamic variability of burden scores indicates that these women monitored their progressive response to both demands and implemented adaptive strategies. Perhaps the relative stability of overall health was attributable in part to the success of coping strategies implemented by these older women in order to work through, plan ahead to manage, or give in to their presenting health concern. Consistent with the *Staying in Control* model, the daily diaries of these older women with co-morbidities indicated that they continued on (Penrod et al., 2003), maintaining a relatively steady state of health while simultaneously responding to, managing, and attempting to stay in control of multiple health conditions.

The small sample size in this study did not permit an exploration of between-person relationships. The measures used in this study were not standardized measures because few if any such daily measures exist. Future research is needed to establish standardized measures designed to capture daily variation and explore the discrete, responsive strategies used to successfully manage, or stay in control of, one's dynamic responses to complex chronic health conditions. By way of strengths, the current study revealed dynamic intra-individual variations in chronic health challenges across a 3-week period. Modern statistical analyses allowed for non-independence of longitudinal data, and provided unique descriptions of individual variation across time.

Conclusions

This study explored older adults' daily experiences of living with multiple chronic conditions by focusing on specific variables related to dynamic states of health and examining intra-individual variations in response to comorbidity. The methodological utility of a daily diary tool was established. Future research examining daily diaries of larger groups of persons with multiple chronic illnesses is needed to examine between-person variation in addition to the intra-individual variation revealed in this study. The complexity of this phenomenon demands that nurse-scientists apply advanced analytic techniques to expand conceptual understanding and ultimately improve care for older adults living with multiple chronic conditions.

Endnote: *Equations for the analysis of the effects of daily health experiences on daily burden within a random intercept model are available upon request. Contact the corresponding author.*

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