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Dynamic structural equation modelling evaluating the progressively lowered stress threshold as an explanation for behavioural symptoms of dementia

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Abstract

Aim: To evaluate the progressively lowered stress threshold (PLST) conceptual model as an explanation for behavioural symptoms of dementia and test several of its hypothesized propositions. The PLST model suggests that due to impairments in coping, persons living with dementia have a reduced threshold for stress and respond with more behavioural symptoms of dementia as stress accumulates throughout the day.

Design: Intensive longitudinal design.

Methods: A sample of $N = 165$ family caregivers completed brief daily diary surveys for 21 days between the dates of 7/2019 and 8/2020, reporting on a total of 2841 days. Dynamic structural equation modelling was used as the analytic technique to examine the impact of caregiver and care recipient environmental stressors on the diversity of behavioural symptoms of dementia to account for the nested data structure and autoregressive relationships.

Findings: Results show direct relationships between environmental stressors and diversity of behavioural symptoms of dementia that same day and the following day.

Conclusion: Findings provide support for the PLST model propositions. Further, findings suggest an extension to the conceptual model is warranted given evidence of an exposure/recovery trajectory and the lagged effects of stress exposure on behavioural symptoms of dementia presentation.

Impact: This study tested whether a commonly used nursing model does in fact explain the occurrence of behavioural symptoms of dementia. The main findings support using the model as an intervention framework and suggest the model should be adapted to consider recovery trajectories. Since behavioural symptoms of dementia represent complex and dynamic temporal phenomena, traditional longitudinal assessments and analyses are an insufficient measurement modality for testing models. Findings inform the design of environmental-modification type interventions for

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behavioural symptoms of dementia management and the methods to evaluate such interventions.

KEYWORDS
behavioural symptoms of dementia, caregiver stress, daily diaries, dynamic structural equation modelling, geriatric nursing, elder abuse, elder neglect

1 | INTRODUCTION

Most persons living with Alzheimer's disease and related dementias (ADRD) experience behavioural symptoms of dementia (BSD) at some point during their illness. However, most patients do not experience all types of BSD nor experience them in a predictable pattern (Cerejeira et al., 2012; Fauth et al., 2006). As reported by family caregivers, the most prevalent BSD include apathy, depression and agitation, while the most distressing BSD include delusions, agitation and irritability (Fauth & Gibbons, 2014). BSD are predictive of many poor outcomes for both the person with ADRD and their caregivers, such as falls, nursing home placement, caregiver burden, caregiver depression and a caregiver's use of abusive and neglectful actions towards the care recipient (Feast et al., 2016; Ornstein et al., 2013; Ornstein & Gaugler, 2012; Pickering et al., 2020; Sato et al., 2018; Toot et al., 2016). Yet, identifying causes of BSD remain a significant knowledge gap limiting the ability to provide tailored interventions (Kolanowski et al., 2018).

There is a need for novel methods to elucidate the hypothesized mechanisms of benefit behind interventions for BSD, particularly as evidence of the effectiveness for existing interventions is mixed about their ability to reduce BSD frequency and severity in community settings (Butler et al., 2020; Griffin et al., 2015; Laver et al., 2016). Since BSD represent complex and dynamic temporal phenomena, traditional longitudinal assessments and analyses are an insufficient measurement modality for testing models. For example, Fauth's seminal study demonstrated when data are aggregated to make group-level inferences about changes in BSD occurrence, the group mean is stable over 3 months; however, when data were analysed over time in the individual, there is significant variability in the rate of change (Fauth et al., 2006). Intensive longitudinal approaches, such as daily diary studies, can help address the knowledge gap on BSD determinants because these methods allow for more ecologically valid testing of dynamic temporal processes while limiting bias associated with retrospective self-report (Robbins & Kubiak, 2014; Scollon et al., 2003). Accordingly, the purpose of this paper is to evaluate the potential theory-based causal mechanisms for BSD more precisely than prior research through the use of intensive longitudinal methods as well as a novel modelling technique that emphasizes the strengths of the intensive longitudinal methods. The theory-based causal mechanisms were derived from the progressively lowered stress threshold model (PLST) (Hall & Buckwalter, 1987).

2 | BACKGROUND

The PLST model posits that because of a diminished ability to cope, persons living with ADRD have a reduced threshold for stress and respond with more BSD as stress accumulates and exceeds their "threshold" for stress tolerance (Hall & Buckwalter, 1987; Richards & Beck, 2004; Smith et al., 2004). The PLST model further suggests that various environmental stressors can negatively impact a person with ADRD (Hall & Buckwalter, 1987; Smith et al., 2004). For example, stressors can include changes in routine, caregiver or environment, or mismatch of caregiver expectation and care recipient ability. Physical stressors include illness or physiological needs (e.g. toileting, pain, etc.). Stress can also arise from unpleasant or aversive stimuli such as the invasion of personal space, conflict with the caregiver and loss of situational control (Ragneskog et al., 1998). More recent developments of the model suggest a circadian nature to a person with ADRD's stress tolerance, with a higher stress threshold in the morning versus the evening (Smith et al., 2004). While the PLST model propositions have not yet been evaluated, some have nevertheless developed, and tested, interventions based on the model. These intervention approaches are designed to assist caregivers in modifying environmental conditions that create stressors for the person living with ADRD to reduce BSD. For example, proposed strategies include creating a structured routine, removing mirrors to prevent misinterpretation of reflections and installing toilet seats in contrasting colours to make them easier to see (Gerdner et al., 2002). While these PLST interventions have positively impacted caregiver outcomes (e.g. stress appraisals), the relationship between the PLST interventions and reduction in the frequency of BSD is mixed (Gerdner et al., 2002; Robinson et al., 2016; Söylemez et al., 2016).

3 | AIMS

This paper evaluates the mechanisms driving BSD as proposed by the PLST conceptual model. Based on the PLST proposition that BSD is a stress reaction, we hypothesize that exposure to stressors in daily life will directly correlate with the number of different BSD types (e.g. BSD diversity) a care recipient expresses that same day. Additionally, we hypothesize there are bi-directional relationships between stressors, and that the influence of stress on the care recipient with dementia will compound over time, representing the PLST. Lastly, as the model is based on the tenet that

persons with ADRD have a reduced ability to manage stress and regulate responses, we propose an extension to the PLST model that hypothesizes that once a stress threshold is exceeded and BSD are escalated, there is a delay in the return to a baseline state. In other words, we propose that the BSD-stress relationship has a temporal 'spillover' process, with exposure to stressors also impacting the next day's BSD diversity.

4 | METHODS

4.1 | Design

This study uses an intensive longitudinal design and participant data from the first wave of an ongoing multi-time series longitudinal study about daily stressors, activities and family caregiving outcomes in ADRD. Enrolled participants completed a baseline survey followed by 21-days of brief daily diary surveys responding to questions about their environmental, social and caregiving experiences.

4.2 | Participants

Participants included self-identified caregivers aged 18 years or older who provide unpaid care or assistance to a spouse/common-law partner, parent, or grandparent (or in-law, age 60+ years) with mild cognitive impairment or dementia as indicated by the AD8 (Galvin et al., 2006). Care consists of help with at least two Instrumental Activities of Daily Living or one Activity of Daily Living. Participants must co-reside with their care recipient, have reliable access to the Internet, and speak/read English or Spanish. Social and news media were used to recruit participants across the USA. Both paid advertising and outreach through community organizations directed interested persons to a study website for enrolment. Best practices for online recruitment and research were followed to ensure the integrity of the sample and data (Kramer et al., 2014; Tarzia et al., 2017; Teitcher et al., 2015). The participants were a convenience sample of community-dwelling ADRD caregivers.

4.3 | Data collection

Data were collected between the dates of 7/2019–8/2020. All data collection occurred online by email or by phone via an interactive voice response system (IVR). After completing the baseline survey, participants began receiving the daily diary surveys each day for 21 days. Participants had between 7 am and 12 pm each day to complete their survey. Based on participants' preferences reminders were sent via text, email and/or phone to increase compliance. Participants received $40 for completing the baseline survey and $2 per diary survey sent via an Amazon e-gift card to their registered study email address.

4.4 | Measures

Data about the caregiver and care-recipient demographic characteristics were collected on the baseline survey, including caregiver's age, sex, race, ethnicity, education and relationship to the care recipient, care recipient's age and gender. Caregivers' depressive symptoms were measured using Patient Health Questionnaire (PHQ-9) (Kroenke & Spitzer, 2002). Care recipients' limitations in their activities of daily living were measured using the Katz Index of Independence in Activities of Daily Living (Katz, 1983). The daily diary surveys severed as the data source for the measures in the model. In this analysis, we consider stressors that directly involve the care recipient, as well as their caregivers' experience of stressors, since caregivers are an essential feature of the environment (Hall & Buckwalter, 1987; Smith et al., 2004).

4.4.1 | Care recipient's stress exposure

Since care recipients were not included as participants in this study, objective environmental stressors were included. Abusive (physical and psychological aggression) and neglectful behaviours by the caregiver can be considered aversive environmental stressors for the person with ADRD. Caregivers were asked to respond yes or no to whether they performed behaviours (listed below) representing abuse and neglect. For the analysis, care recipients' stress exposure was operationalized by combining the caregivers' answers to daily measures about their use of neglectful, psychological and physically aggressive behaviours.

Care recipient's exposure to neglect was measured as caregiver responses to the following questions: (1) 'skip care or not help with their [care recipient's] personal hygiene or going to the bathroom even though [their] relative needed help? Such as brushing teeth, bathing or doing laundry?', (2) 'skip care or not help at a mealtime even though [their] relative needed help? Such as cooking the food or helping [their] relative use a fork'., (3) 'ignore reasonable requests for help from [their] relative?', (4) 'leave [their] relative alone for any period of time even though [they] thought someone should be there to supervise or help them?' The measure for neglect was generated by summing dichotomous responses.

Care recipient's exposure to psychological aggression was measured as caregiver responses to endorsing these behaviours: (1) 'curse, yell, shout at, or speak to [their] relative in a way [they] know is not fair or appropriate', (2) 'threaten to abandon or put [their] relative in a nursing home'. Care recipient's exposure to physical aggression was measured as caregiver responses to (1) 'pinch, push, shove, or grab [their] relative; twist their arm or hair or throw something at them that could hurt', (2) 'bite, hit, kick, punch, choke, or burn [their] relative' and (3) 'bruise, scratch, or otherwise physically injure [their] relative in any way' These dichotomous response options were then summed. The final measure involved summing the scores from neglect, psychological aggression and physical aggression into a global index score representing the care recipient's stress exposure (score could range from 0 to 9).

4.4.2 | Caregiver perceived stress

Caregiver stress was also considered an environmental stressor for the care recipient (Smith et al., 2004). Caregivers were also asked about their daily stress levels about caregiving: 'How stressed were you about the caregiving responsibilities for your relative that you had to do?' Response options ranged from 1 = 'not at all stressed', to 5 = 'very much stressed', with 0 = 'not applicable'.

4.4.3 | Diversity of behavioural symptoms of dementia

Participants endorsed the presence or absence of eight different behavioural symptoms of dementia (BSD) observed in the day, informed by prior daily diary studies (Fauth et al., 2006; Pickering et al., 2020). These behaviours included restlessness (e.g. following caregiver around, pacing, fidgeting, or inability to sit still), mood changes (e.g. acting fearful, upset, sad, or crying), resisting care (e.g. refusing help to change clothes or take medications), property destruction (e.g. breaking appliances, clogging toilets or fixing things that were not broken), disinhibition (e.g. doing or saying embarrassing things in public or making sexual remarks they would not normally), verbal behaviours (e.g. yelling or calling people names), physical behaviours (e.g. kicking, hitting or throwing things) and any other behaviours caregivers found bothersome. The measure for BSD diversity was generated by summing how many unique behaviours the participant observed on a given day (scores could range = 0–8).

4.5 | Ethical considerations

Informed consent was obtained from all individual participants before they began the study surveys, in accordance with the IRB approved human subjects protocol. A data broker was used to ensure anonymity of the research data. Study procedures were considered exempt by the Institutional Review Board (IRB).

4.6 | Validity, reliability and rigour

A benefit to daily diary surveys is that it offers enhanced ecological validity and reduced recall bias (Robbins & Kubiak, 2014; Scollon et al., 2003). The item for caregiver's perceived stress is based on prior work (Pickering et al., 2020), and consistent with stress measurement of caregivers in other daily diary research intended to capture within-person variations across days (Almeida, 2016). The measure for abusive behaviours is based on the valid and reliable conflict tactics scale (Straus et al., 1996), and abusive and neglectful behaviours items used for the daily diary surveys are based on prior work (Pickering et al., 2020; Sullivan et al., 2012). ADRD caregivers' self-report of abusive and neglectful behaviours has been demonstrated as valid compared to expert judgement (Wiglesworth et al., 2010). To capture the diversity of behavioural symptoms of dementia, individual items were chosen from established scales to represent discrete non-overlapping symptoms and re-phrased to ask about just the past day, if needed, and based on prior work (Pickering et al., 2020). The scales include the daily record of behaviour (Fauth & Gibbons, 2014), the neuropsychiatric inventory (Cummings et al., 1994) and the repetitive behaviours scale revised––compulsive behaviours subscale (Lam & Aman, 2006).

4.7 | Analysis

A two-level dynamic structural equation model (DSEM) was used to examine the relationships posited by the PLST between BSD diversity and environmental stressors, including care recipient's stress exposures and caregiver perceived stress reported in the daily diaries. Because the same participant reports multiple daily observations, multilevel modelling is necessary to account for the serial nested data structure (Hayes, 2006; Peugh, 2010). Although this team's previous work has used generalized linear mixed modelling to address the intraindividual variance of nested data (Pickering et al., 2020), this approach is less robust when examining lagged effects due to bias in its estimates of the autoregressive relationships (i.e. Nickell bias) (Nickell, 1981). DSEM overcomes this bias while offering other advantages for the analysis of intensive longitudinal data including modelling the lagged relation of a single subject with a large number of repeated measures, modelling of multiple individuals while allowing for individual differences in the parameters, and modelling of multiple outcome measures, latent measures and mediation effects (McNeish & Hamaker, 2020). Furthermore, DSEM relies on Bayesian estimation routines, making it more robust when missing responses and unequal time intervals exist (Zhou et al., 2019). Bayesian estimation is also robust to non-normally distributed, allowing for flexibility of skewed data (Martin & Williams, 2017; McNeish & Hamaker, 2020).

DSEM allows for examining multiple interrelated hypotheses. It can produce main effects, which in this paper refer to the direct relationship between two measures captured on the same day. DSEM can also model several dependent measures, which leads to examining bi-directional relationships between two outcome measures (Armstrong et al., 2019). Because it can estimate autoregressive effects, it can identify a single measure's stability over time and produce cross-lagged effects to identify relationships between different measures over time (Hamaker et al., 2018; Selig & Little, 2012). These model specifications account for dynamic daily changes over time using multilevel data (Asparouhov et al., 2018; Hamaker & Wichers, 2017; McNeish & Hamaker, 2020), which allows for more thorough ecologically valid testing of the PLST conceptual model. To achieve a parsimonious model in which the analysis aligned with the PLST conceptual model, multiple and more general stressors were avoided to minimize multicollinearity (which could cause issues with convergence even with Bayes) and risk over-fitting the model (Jaya et al., 2019; Kline, 2016).

Figure 1 illustrates the hypothesized relationships between measures that we tested in the DSEM: (1) main effects of care recipient stress exposure (β coefficient) and caregiver perceived stress ($\beta 2$ coefficient) on the number of different BSD types on the same day (BSD diversity); (2) the directional effects of caregiver perceived stress on care recipient stress exposure and vice versa ($\beta 3$ and $\beta 4$ coefficients); (3) autoregressive effects of BSD diversity (i.e. previous day's behaviour (t−1) predicting today (t)'s behaviour, φ coefficient), care recipient's stress exposure (φ2 coefficient) and caregiver perceived stress (φ3 coefficient); (4) the cross-lagged effects of yesterday's stressors on today's BSD diversity (*cross lag* [*CL*] and *CL 2* coefficients). Overall, within-person components in our model included our two main effects, two bidirectional effects, three autoregressive and two cross-lagged relationships. All effects are estimated at the between-person level.

The analysis was performed in *Mplus* version 8.4 (Muthén & Muthén, 2018), which uses a Bayesian Markov Chain Monte Carol (MCMC) estimation routine that accounts for model complexity (Asparouhov et al., 2018; McNeish & Hamaker, 2020). Default specifications in *Mplus* for the Bayes estimator include 2 MCMC chains; a max iteration of 50,000; a burn-in iteration of 1; a convergence criteria of 0.100D-05; and a uniform prior of N(0,∞). All measures were treated as continuous. Missing data in DSEM are handled by the MCMC algorithm, in that missing data for an individual at a specific time-point is dealt with by (a) the neighbouring observation; (b) the autoregressive parameter at the current iteration of the MCMC algorithm (Hamaker et al., 2018; Sarkka et al., 2004). Before running the DSEM analysis, we checked for but did not find outliers and multicollinearity of predictors and lagged measures. The correlation was below the $r < 0.80$ cut-off (data not shown), indicating no multicollinearity problems. Following the Bayesian framework, a hypothesis is supported when the estimate falls in a credible interval (CI) that does not contain 0 (similar to confidence intervals from a frequentist perspective). While there are no 'significance tests', by setting our CI to 95% we can be sure that the actual values lie in this interval and is non-null.

5 | RESULTS

Table 1 provides the sample demographic of 165 caregivers and their care recipients. Most caregivers were female (90.3%), White (75%) and with a mean age of 53 years (SD = 13). About 54.5% of caregivers were children of a person with ADRD. Most caregivers had at least some college or vocational school experience (42.4%), with one-third having at least a 4-year college degree (32.7%). Most care recipients were identified as white (76%), with both sexes equally represented in the sample (female = 52.7%; male = 47.3%) with mean age of 77 (SD = 8). Caregiver participants reported on a total of 2841 days of caregiving (mean number of daily diaries per participant = 17.2 out of 21, SD = 4.34, range = 1–21). Only 624 (18%) of daily diaries were missing. Across all participants, the mean of BSD diversity was 4.05 (SD = 2.81), meaning that on average four out of eight different dementia-related behaviours were present on a given day during the 21-day observation period. Care recipients' stress exposure was on average 0.21 (SD = 0.82) out of nine, and the caregivers' perceived stress was on average 2.23 (SD = 1.23) out of five.

Table 2 describes the results for the multilevel DSEM. The current model explained 51.51% of the within-person variability in BSD diversity, 22.0% of the within-person variance in care recipient's stress exposure, and 30.5% of the within-person variability in caregiver perceived stress.

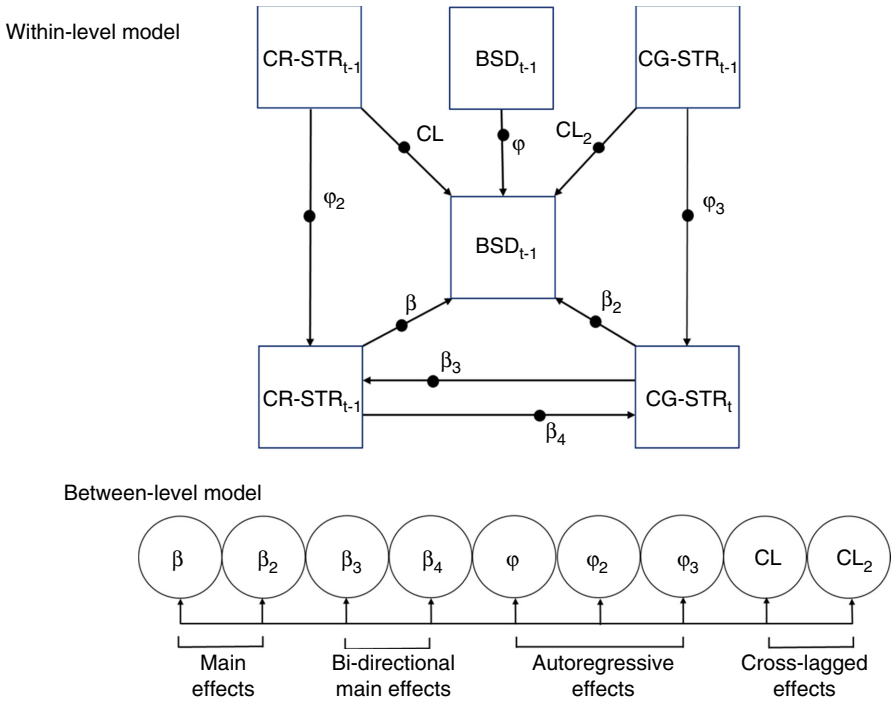

FIGURE 1 Path diagram of multilevel DSEM. Note: The means and variances of BSD, care recipient stress (CR-STR) and caregiver stress (CG-STR) are not shown to focus on the parameters of interest in the model

TABLE 1 Demographic characteristics of caregivers and care recipients (N = 165)

	Mean (SD, range) or *N* (%)
Caregiver characteristic	
Age	53 (13, 20–87)
Female	149 (90.3)
Race	
White	125 (75)
Black or African American	27 (16)
Other	13 (7.8)
Hispanic	17 (10.3)
Caregiver's relationship to care recipient	
Spouse or partner	49 (29.7)
Parent	90 (54.5)
Grandparent	23 (13.9)
Missing	3 (1.8)
Education	
High school or GED	16 (9)
Some college, vocational school or associate degree	70 (42.4)
4-year college	54 (32.7)
Professional degree	23 (13.9)
Missing	2 (1.2)
Depression symptomology (PHQ-9)	7 (6, 0–25)
Care recipient characteristic	
Age	77 (8, 60–98)
Female	87 (52.7)
Race	
White	126 (76.3)
Black or African American	29 (17.5)
Other	10 (6)
Hispanic	14 (8.4)
Number of impairments in ADL	3 (2, 0–7)
BSD diversity	4.05 (2.81, 0–8)
Care recipient stress exposure	0.21 (0.82, 0–9)
Caregiver stress	2.23 (1.23, 0–5)

Abbreviations: ADL, activity of daily living; BSD = behavioural symptoms of dementia; GED, general education development; 'Other' race includes Asian, Native Hawaiian or Pacific Islander, more than one.

5.1 | Main effects on BSD

The main effects we examined first were two hypotheses that stress affects BSD diversity. We found a positive relationship between care recipients' stress exposure and BSD (β = 0.30, 95% CI = 0.14 to 0.47). We also found a positive relationship between a caregiver's perceived stress and BSD diversity ($\beta 2$ = 0.31, 95% CI = 0.20–0.41). These two findings illustrate that care recipient stress exposure and caregiver perceived stress will both independently increase the number of BSD types observed in a day, supporting our first hypotheses about the concurrent effects of environmental stress.

5.2 | Bi-directional effects of stress

Our second set of hypotheses specified interaction between environmental stressors, which we tested using a bi-directional relationship between care recipient's stress exposures and caregiver's perceived stress. Again, we found a positive relationship with care recipient's stress exposure potentiating caregiver's perceived stress ($\beta 4$ = 0.34, 95% CI = 0.2–0.49). However, we did not find a relationship when the process was reversed. Accordingly, these two outcomes together suggest that while care recipient stress exposure can increase caregiver perceived stress on average, caregiver stress does not have the same reciprocal effect (e.g. PLST is a recursive rather than a non-recursive process).

5.3 | Autoregressive effects of BSD and environmental stress

The DSEM allowed us to test further the autoregressive 'carry-over' effects, which measured the strength of a participant's ability to remain stable from either a high or low state from the previous day. Autoregressive values closer to zero indicate an ability to return to baseline more quickly. In contrast, values closer to one indicate a carry-over effect from one day to the next, suggesting an issue with regulatory weakness (e.g. inability to process stressors) (De Haan-Rietdijk et al., 2016). First, we found an autoregressive relationship between the previous day's BSD diversity on current BSD diversity (φ = 0.45, 95% CI = 0.37–0.53), indicating that today's experience with BSD positively predicts BSD diversity on the next day. We also saw autoregressive effects of care recipient's stress exposure ($\varphi 2$ = 0.09, 95% CI = 0.01–0.16), indicating that the care recipient's stress exposure compounds from day to day but to a lesser degree (i.e. the $\varphi 2$ is closer to zero). Caregiver's perceived stress exhibited a similar autoregressive property ($\varphi 3$ = 0.24, 95% CI = 0.18–0.30), where stress perceptions from the previous day can further increase perceptions on the next day.

5.4 | Cross-lagged effects of environmental stress on BSD

Lastly, we tested for 'spillover' effects between stressors and BSD diversity by examining cross-lagged effects in our model. Spillover refers to one measures' relationship from the preceding observation (i.e. yesterday's state) on a different measure. We hypothesized that the previous day's stressors contributed to BSD diversity the following day. We saw a cross-lag relationship of care recipient's stress exposure on BSD diversity (*CL* = 0.39, 95% CI = 0.1–0.73). This suggests that on average the care recipient's exposure to stressors from

TABLE 2 Unadjusted estimates and 95% credible intervals for multilevel DSEM

Variable	Path symbol	Estimate	95% CI	Person specific mean
Average BSD across days	μ BSD	3.54	[3.16, 3.97][a]	[−0.03, 7.12]
Average CR stress across days	μ CR Stress	0.08	[0.06, 0.11][a]	[0.02, 0.14]
Average CG stress across days	μ CG Stress	2.24	[2.07, 2.41][a]	[0.21, 4.27]
Effect of CR stress today on BSD today	β CR-STR → BSD	0.30	[0.14, 0.47][a]	[−0.36, 0.96]
Effect of CG stress today on BSD today	$\beta 2$ CG-STR → BSD	0.31	[0.2, 0.41][a]	[−0.45, 1.06]
Effect of CG stress today on CR stress today	$\beta 3$ CG-STR → CR-STR	0.03	[−0.03, 0.09]	[−0.62, 0.68]
Effect of CR stress today on CG stress today	$\beta 4$ CR-STR → CG-STR	0.34	[0.2, 0.49][a]	[−0.56, 1.25]
Effect of yesterday's BSD on BSD today	φ $BSD_{(t-1)}$ → $BSD_{(t)}$	0.45	[0.37, 0.53][a]	[−0.26, 1.17]
Effect of yesterday's CR stress on CR stress today	$\varphi 2$ $CR\text{-}STR_{(t-1)}$ → $CR\text{-}SRT_{(t)}$	0.09	[0.01, 0.16][a]	[−0.37, 0.54]
Effect of yesterday's CG stress on CG stress today	$\varphi 3$ $CG\text{-}STR_{(t-1)}$ → $CG\text{-}SRT_{(t)}$	0.24	[0.18, 0.3][a]	[−0.24, 0.73]
Effect of yesterday's CR stress on BSD today	CL $CR\text{-}STR_{(t-1)}$ → $BSD_{(t)}$	0.39	[0.1, 0.73][a]	[−1.5, 2.28]
Effect of yesterday's CG stress on BSD today	$CL2$ $CG\text{-}STR_{(t-1)}$ → $BSD_{(t)}$	−0.12	[−0.21, −0.04][a]	[−0.48, 0.23]

Note: BSD = behavioural symptom of dementia type; CG = caregiver; CR = care recipient; CI = Credible Interval is used in Bayesian statistics instead of confidence interval in frequentist statistics; (t) = today's state; variable; (t-1) = lagged/yesterday's state.

[a]Relationship is considered non-null if 95% CI is below or above zero.

the previous day will increase the number of BSD types observed on the current day by approximately 40%. Interestingly, we saw a negative cross-lagged relationship of caregiver's perceived stress on BSD diversity ($CL2$ = −0.12, 95% CI = −0.21 to −0.04). Autoregressive coefficients with negative values represent back and forth shifting between scores above and below the baseline. This mixed effect suggests unstable processes or processes influenced by contextual reasons such as mood or outside factors such as socioeconomic status (Rovine & Walls, 2006). A negative coefficient suggests that, on average, a caregiver's perceived stress has an inconsistent relationship with BSD diversity from one day to the next (i.e. behaviour goes up or down).

6 | DISCUSSION

This paper's main findings, that exposures to environmental stressors are significantly related to an increase in BSD diversity the same day, provide strong support for several propositions in the PLST model (Hall & Buckwalter, 1987). While others have shown positive relationships between caregiver stress and increased BSD over longer longitudinal trajectories (Campbell et al., 2011), the PLST conceptual model is based on a daily time scale suggesting that as stress accumulates during the day, so too will care recipients' behavioural symptoms. Our findings show direct relationships between environmental stressors and BSD diversity that same day in an intensive, daily longitudinal investigation. This mismatch between the model's time scale and measurement protocols may explain why recent trials of PLST-based interventions have not found success in sustaining reductions in BSD. Accordingly, given the dynamic nature of these risk factors and outcomes, real-time assessments such as daily diaries represent a more precise measurement approach that future evaluate PLST and other environmental-modification interventions for BSD management should adopt.

Additionally, we expand on PLST by showing the temporality of the relationships between environmental stressors and BSD. While the original PLST model suggests a person with ADRD may be most sensitive to stressors as time accumulates throughout the day, the model has not fully considered the time it takes to return to a baseline state once a stress threshold is exceeded as evidenced by an increase in BSDs. Our findings show, on average, care recipient stress exposures (measured as caregiver's use of abusive and neglectful actions) have a stable positive 'spillover' relationship with a 40% increase in BSD diversity during the following day. This is a large effect (i.e. an additional 2 more types of BSD exhibited that day) considering the average amount of BSD types in a day is 4. This indicates the stress threshold is still exceeded the next day as evidenced by a continued, sustained increase in BSDs. Moreover, the caregiver's perceived stress as a source of environmental stress for the care recipient has an inconsistent effect on the following day's BSD diversity (i.e. BSD diversity increases or decreases). This inconsistency is likely driven by a within-person effect, or attributes/characteristics of the caregiver, such as coping style. For example, some caregivers may rely on coping techniques such as drinking alcohol excessively, which could perpetuate the environmental stress for the care recipient by being around an intoxicated caregiver and thus impact the next day's BSD. Alternatively, some caregivers could administer a *pro re nata* medication to the care recipient, which could lower BSD through sedation. Together, these findings suggest that (1) once the stress threshold is exceeded and BSD diversity increases, there is not necessarily a 'reset' the next morning, and (2) the timing of the recovery to baseline may be impacted by the severity of the stressor and secondary stressors. Therefore, we argue that future work in developing the PLST model considers this exposure/recovery

trajectory component in which the return to baseline stress-levels and normative behaviour is a more gradual recovery trajectory (Figure 2).

While our DSEM model explained 51.5% of the within-person variance in BSD, suggesting that these stressors are essential predictors, it is probable that other key, unmeasured processes contribute to BSD diversity. Future expansion of the PLST model could consider other factors such as caregiver coping styles or care recipient ADRD stage, which could interact with environmental stressors to influence the stress threshold and the return to baseline. The expansion of the model in these ways would enable more personalized approaches to PLST-intervention delivery.

The PLST intervention model suggests six principles for care to reduce stressors and thereby reduce BSD. A critique of the model is that it lacks specificity about the implementation of the six care principles (Richards & Beck, 2004). Given the immediate temporal nature of stressors and BSD shown in this analysis, future research should consider adjusting the PLST intervention approach to a just-in-time adaptive intervention (JITAI) format to provide tailored support by aligning the care principles with the caregiver/care recipient's immediate need. A recent meta-analysis of JITAI across a range of behavioural outcomes and populations found that compared to wait-list control and non-JITAI treatments, JITAI produce moderate to large effect sizes that persist (Wang & Miller, 2019). Since a recent meta-analysis of caregiver interventions found only small effect sizes of available interventions for managing BSD (Walter et al., 2020), JITAI is likely a more productive area for future research for BSD management.

Furthermore, these findings also have important theoretical implications for elder abuse and neglect in caregiving. Caregiver stress is thought to be a primary driver of abuse and neglect, though results have been correlative (Pickering et al., 2020). Thus, it is still unclear whether caregiver stress is a cause or an effect of BSD. As DSEM allowed us to examine bi-directional effects, we observed that care recipient stress exposures (i.e. exposure to caregivers' use of abusive or neglectful actions) directly positively impact the caregiver's perceived stress. We did not observe a reciprocal relationship in these models, meaning that caregiver stress is a consequence, not a cause of elder abuse and neglect in this model. For example, a caregiver may neglect bathing the person with ADRD because of care-resistive behaviours and then become stressed about not providing that care activity. Notably, previous daily diary and traditional longitudinal studies examining the relationship between caregiver stress and elder abuse and neglect have used BSD in their measure of caregiver stress (Pickering et al., 2020; Yan, 2014). Therefore, in general, caregiver stress may not lead to elder abuse and neglect in ADRD; instead, it is likely the stress related to the management of BSD that was driving previous positive correlative findings.

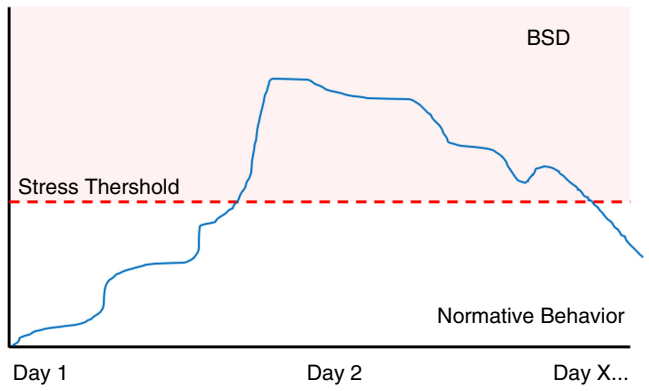

FIGURE 2 Exposure-recovery expansion to the PLST model. Note: Blue line indicates an individual with ADRD's stress exposure/recovery versus BSD occurrence trajectory over time

Another significant theoretical contribution is our finding on the relationship between elder abuse and neglect and BSD. For an act to constitute elder abuse and neglect, it needs to cause or increase the chance of harm (Hall et al., 2016). Due to a lack of data on the direct relationships between actions and harm, some scholars have adopted a 'caseness' criteria by counting psychological abuse as present only when a respondent indicates a certain number of events occurred over a specific time (e.g. 'Pillemer Criteria', 'Beach Criteria') (Beach et al., 2010; Dong, 2014; Pillemer & Finkelhor, 1988). Additionally, others have posited a severity framework for intervention, with severity based on the number of types of abusive/neglectful acts and the frequency of those acts (Burnes et al., 2016). These positions are likely flawed as they suggest for abuse and neglect to trigger an intervention it must represent a chronic pattern of behaviours despite a lack of empirical or theoretical basis for the relationship between frequency of acts and the harm to the older adult. Contrary to this position, our findings demonstrate a direct, positive relationship between a single act of abuse or neglect and an increase in BSD diversity during both that same day and the next day. As per the PLST model, escalation in BSD represents an increase in the care recipient distress (i.e. harm). Therefore, an act of abuse or neglect, whether it is the first or tenth transgression in an ADRD caregiving environment, should be considered valid both in future scientific examinations and practice settings.

This study's strength is our measure of care recipient stress exposure, which includes various acts of elder abuse and neglect, encompassing a variety of environmental stressors including physical stressors to unmet needs, loss of situational control, acts that invade privacy and inappropriate and aversive stimuli. These acts represent many of the sources of stress suggested by the PLST and provide for a more objective measurement by focusing on whether a behaviour occurred rather than obtaining a subjective proxy-report of a care recipient's stress level. Notably, most ADRD family caregivers self-report engaging in abusive and neglectful actions (Pickering et al., 2020; Wiglesworth et al., 2010). Therefore, the relationship between abusive and neglectful behaviours and escalation of BSD both the same day and the next day indicates that prevention of caregiver reliance on abusive and neglectful behaviour is a crucial component of BSD management interventions. As there are no efficacious caregiver interventions to prevent abuse and neglect in ADRD, this too represents a significant area for future research.

In this analysis, power assessments are generated by both the number of daily surveys and the ratio of cases between levels. Due to the novel application of DSEM, literature about sample size is sparse, but recent Monte Carlo simulations have suggested that samples with many subjects and fewer time points perform better than fewer subjects with many time points. For DSEM, Schultzberg and Muthén (2018) have suggested a 150:25, 75:75 or 50:150 ratio for moderate to strong effects. In addition, Bayesian estimation are more appropriate in smaller sample studies because they do not rely on the same asymptotic assumptions in frequentist estimation (Hox & McNeish, 2020). Nevertheless, while clear guidance on sample size and power does not exist, this study with N = 165 participants reporting on n = 2841 days exceeds most recommendations about sample size.

6.1 | Limitations

A limitation of this study is it lacks additional measures representing environmental stressors, such as daily social isolation, sleep and physical environment (e.g. noise, temperature, location) in the analytic model to inform whether different types of environmental stressors contribute to an increase in BSD diversity. While the study's findings support for the PLST model, future work using latent constructs can better examine the differential relationships between types of stressors and BSD. Another limitation of this study was the analysis was limited to a 1-day time lag. For research to better inform interventions and evaluations, such as through JITAI, a better approximation of the exact temporal relationship between exposure and outcomes is needed (e.g. 2-day, 4-day, etc.). As diaries were completed once daily, we could not test the PLST proposition that the stress threshold is less vulnerable in the morning than in the evening. Finally, it is unclear how generalizable the study sample is given the lack of studies describing nationally representative samples of co-residing ADRD family caregivers for comparison.

7 | CONCLUSION

Our findings, based on data collected using intensitive longitudinal methods and analysed in a two-level dynamic structural equation framework, support several propositions of the PLST model as an explanation for BSD diversity among persons with ADRD, and an expansion of the model to capture the process of returning to baseline once a stress threshold is exceeded. Our findings also suggest future evaluations of PLST interventions would benefit from a more valid, real-time daily diary type assessment that can better approximate the relationships between caregiver behaviours/use of intervention strategies, environmental stressors and care recipient responses. Finally, this study can guide future studies because it employed an analytic technique, a multi-level DSEM, novel to nursing science. Without the DSEM framework, we would not have correctly estimated or tested several key relationships and hypotheses, such as how the previous day's BSD behaviours predicted today's behaviour. This analytic approach can be particularly beneficial to nurses investigating other areas of symptom science beyond BSD.

CONFLICT OF INTEREST

Authors have nothing to disclose.

AUTHOR CONTRIBUTIONS

All authors have agreed on the final version of this manuscript and fulfil the criteria for authorship set forth by the ICMJE.

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