

Article history:
Received 02 December 2025
Revised 23 February 2026
Accepted 27 February 2026
Published online 01 April 2026

LSTM-Based Longitudinal Prediction of Psychological Resilience: The Role of Self-Compassion, Meaning in Life, Cognitive Reappraisal, and Social Support

Kamal. Darabi^{1*}, Mark L. Wightman², Pieter. Muysken³, Nikolaos G. Sarafianos³

¹ Department of Psychology, University of Toronto, Toronto, Canada

² Department of Applied Psychology and Human Development, University of Toronto, Toronto, ON, Canada

³ Department of Psychology, Health and Technology, University of Twente, Enschede, the Netherlands

⁴ Boston University, Department of Psychological and Brain Sciences, 648 Beacon Street, 6th Floor, Boston, MA 02215, USA

* Corresponding author email address: kamaldarabi@mail.utoronto.ca

Article Info

Article type:

Original Research

How to cite this article:

Darabi, K., Wightman, M.L., Muysken, P., & Sarafianos, N.G. (2026). LSTM-Based Longitudinal Prediction of Psychological Resilience: The Role of Self-Compassion, Meaning in Life, Cognitive Reappraisal, and Social Support. *Journal of Assessment and Research in Applied Counseling*, 8(2), 1-10.

<http://dx.doi.org/10.61838/kman.jarac.5237>



© 2026 the authors. Published by KMAN Publication Inc. (KMANPUB), Ontario, Canada. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License.

ABSTRACT

Objective: The present study aimed to investigate the longitudinal prediction of psychological resilience using an LSTM-based deep learning model by examining the dynamic contributions of self-compassion, meaning in life, cognitive reappraisal, and social support over time.

Methods and Materials: This longitudinal study was conducted on 428 participants recruited from Canada, with 392 retained for final analysis across four time points over a 12-month period. Data were collected using validated self-report instruments, including the Connor–Davidson Resilience Scale, Self-Compassion Scale, Meaning in Life Questionnaire, Emotion Regulation Questionnaire (cognitive reappraisal subscale), and the Multidimensional Scale of Perceived Social Support. Data preprocessing included multiple imputation and sequence structuring for time-series analysis. The primary analytical approach involved the application of Long Short-Term Memory (LSTM) neural networks implemented in Python using TensorFlow and Keras. The dataset was divided into training, validation, and test sets (70/15/15), and model performance was evaluated using Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and R². SHAP analysis was conducted to determine the temporal importance of predictors.

Findings: The LSTM model demonstrated strong predictive performance (R² = 0.66, RMSE = 2.52), indicating substantial explained variance in psychological resilience. Self-compassion emerged as the most significant predictor ($\beta \approx .54$, $p < .001$), followed by social support ($\beta \approx .51$, $p < .001$), meaning in life ($\beta \approx .49$, $p < .001$), and cognitive reappraisal ($\beta \approx .43$, $p < .001$). Longitudinal analyses revealed significant increases in resilience and all predictor variables across time ($p < .01$). SHAP results indicated that self-compassion and meaning in life showed increasing contributions over time, whereas social support demonstrated stronger

early influence and cognitive reappraisal maintained a stable effect across all time points.

Conclusion: The findings highlight the dynamic and multifactorial nature of psychological resilience, emphasizing the central role of self-compassion and the evolving contributions of internal and external resources over time. The integration of LSTM modeling with explainable AI provides a robust framework for capturing temporal patterns and enhancing predictive accuracy in psychological research.

Keywords: *psychological resilience, self-compassion, meaning in life, cognitive reappraisal, social support*

1. Introduction

Psychological resilience has emerged as a central construct in contemporary psychological science, reflecting individuals' capacity to adapt successfully to adversity, stress, and life challenges. Rather than being a static trait, resilience is increasingly conceptualized as a dynamic, context-sensitive process shaped by multiple psychological, cognitive, and social mechanisms operating over time (Koehler et al., 2023; Salsman & Rosenberg, 2024). This dynamic perspective aligns with developmental and systems-based frameworks, which emphasize that resilience evolves through continuous interactions among internal resources and external environmental supports. Recent empirical evidence underscores that resilience is not only predictive of mental health outcomes but also serves as a protective factor against psychopathology, including depression, anxiety, and stress-related disorders (Polat, 2025; Ünal & Ordu, 2023). Consequently, identifying the underlying mechanisms that contribute to resilience, particularly within longitudinal frameworks, has become a key research priority.

Among the psychological factors most consistently associated with resilience, self-compassion has received considerable attention. Self-compassion refers to a balanced and nonjudgmental attitude toward oneself during times of suffering, encompassing self-kindness, common humanity, and mindful awareness of distress (Wang et al., 2025). Empirical findings suggest that individuals with higher levels of self-compassion demonstrate greater emotional stability, reduced vulnerability to stress, and enhanced adaptive functioning across various populations (Huang et al., 2025; McConnell et al., 2024). In trauma-exposed and high-stress populations, self-compassion has been shown to buffer the impact of adverse experiences and facilitate recovery processes (Wu et al., 2025). Moreover, experimental and intervention-based studies indicate that cultivating self-compassion can lead to measurable improvements in psychological resilience and overall well-

being (Cutajar & Bates, 2025; Liu et al., 2023). These findings position self-compassion as a critical internal resource in resilience development.

In parallel, the construct of meaning in life has been identified as another fundamental determinant of resilience. Meaning in life encompasses individuals' sense of purpose, coherence, and significance in their experiences, which contributes to psychological stability and long-term adaptation (Song et al., 2023; Tao et al., 2023). Theoretical frameworks rooted in existential and positive psychology suggest that individuals who perceive their lives as meaningful are better equipped to navigate adversity and maintain psychological equilibrium. Empirical studies have demonstrated that meaning in life is positively associated with well-being and negatively associated with depressive symptoms, often serving as a mediating mechanism in resilience processes (Lowe et al., 2024; Salsman & Rosenberg, 2024). Longitudinal evidence further indicates that meaning in life may exert cumulative effects over time, reinforcing adaptive coping strategies and fostering sustained resilience.

Cognitive reappraisal, as a central component of emotion regulation, also plays a pivotal role in shaping resilience trajectories. Cognitive reappraisal involves the reinterpretation of emotional stimuli in a way that alters their emotional impact, thereby enabling individuals to manage negative affect more effectively (R. Ding et al., 2024; Pilárik et al., 2024). Research has consistently shown that individuals who frequently use cognitive reappraisal exhibit lower levels of psychological distress and higher levels of resilience (Polat, 2025; Ünal & Ordu, 2023). Moreover, cognitive reappraisal has been identified as a key mechanism through which self-compassion exerts its beneficial effects on mental health outcomes (Snodgrass et al., 2025). Intervention studies further support the role of reappraisal in enhancing emotional flexibility and adaptive functioning, particularly in high-stress and clinical populations (Lee et al., 2024; Leong et al., 2024). These findings highlight the

importance of cognitive regulation processes in resilience development.

Social support represents an essential external resource that interacts with internal psychological processes to influence resilience. Defined as the perceived availability of emotional, informational, and instrumental assistance from others, social support has been widely recognized as a protective factor against stress and adversity (Kupferberg & Hasler, 2024; Watson et al., 2023). Empirical research indicates that individuals with strong social support networks are more likely to exhibit higher levels of resilience and better mental health outcomes (Avdiu & Duraku, 2024; Logoz et al., 2023). Social support not only provides direct emotional buffering but also facilitates the development of adaptive coping strategies, including self-compassion and cognitive reappraisal. Furthermore, longitudinal studies suggest that social support may play a foundational role in the early stages of resilience development, with its influence evolving over time (Leong et al., 2024). These findings underscore the need to examine social support as a dynamic and time-sensitive predictor within resilience models.

Despite the growing body of literature on these individual predictors, a critical limitation of existing research lies in its reliance on cross-sectional or linear analytical approaches, which fail to capture the complex, nonlinear, and temporal interactions among variables. Psychological processes such as resilience are inherently dynamic, involving feedback loops and time-dependent relationships that cannot be adequately modeled using traditional statistical techniques. In this context, machine learning approaches, particularly deep learning models such as Long Short-Term Memory (LSTM) networks, offer a promising avenue for advancing resilience research. LSTM models are specifically designed to handle sequential data and capture long-term dependencies, making them well-suited for longitudinal psychological datasets (Wang et al., 2025; Wu et al., 2025). Recent applications of machine learning in psychology have demonstrated their capacity to improve predictive accuracy and uncover complex patterns that remain undetected in conventional analyses (C. Ding et al., 2024; Kupferberg & Hasler, 2024).

Moreover, integrating explainable artificial intelligence techniques, such as SHAP (Shapley Additive Explanations), allows researchers to interpret model outputs and assess the relative importance of predictors over time. This is particularly important in psychological research, where theoretical interpretability is essential for translating

findings into practical interventions. By combining LSTM modeling with SHAP-based interpretation, researchers can gain deeper insights into how self-compassion, meaning in life, cognitive reappraisal, and social support interact dynamically to influence resilience trajectories (Mistretta & Davis, 2025; Snodgrass et al., 2025). Such integrative approaches bridge the gap between predictive performance and theoretical understanding, thereby enhancing the scientific rigor and applicability of findings.

Another important consideration is the longitudinal nature of resilience development, which necessitates repeated measurements and temporal modeling. Longitudinal designs enable the examination of intra-individual changes and the identification of causal pathways, providing a more comprehensive understanding of psychological processes (Syafitri et al., 2024; Tao et al., 2023). Studies adopting longitudinal frameworks have demonstrated that psychological resources such as self-compassion and meaning in life can exhibit growth over time, contributing to sustained improvements in resilience (Huang et al., 2025; Liu et al., 2023). However, few studies have integrated multiple predictors within a single longitudinal machine learning model, highlighting a significant gap in the literature.

In addition, emerging evidence points to the interplay between emotional intelligence, emotional regulation, and resilience, suggesting that these constructs operate within an interconnected system (R. Ding et al., 2024; P. & P., 2024). Emotional regulation strategies, including cognitive reappraisal, may serve as mediators linking internal dispositions such as self-compassion to resilience outcomes. Similarly, social and contextual factors can moderate these relationships, further complicating the predictive landscape. Addressing these complexities requires advanced analytical techniques capable of modeling multidimensional and time-dependent interactions.

Taken together, the existing literature highlights the importance of self-compassion, meaning in life, cognitive reappraisal, and social support as key determinants of psychological resilience, while also underscoring the need for methodological advancements to capture their dynamic interplay. The integration of longitudinal design with LSTM-based modeling represents a novel and theoretically grounded approach to addressing these challenges. By leveraging the strengths of deep learning and explainable AI, the present study seeks to provide a more nuanced and comprehensive understanding of resilience development over time.

The aim of the present study is to examine the longitudinal prediction of psychological resilience using an LSTM-based model by investigating the dynamic contributions of self-compassion, meaning in life, cognitive reappraisal, and social support across multiple time points.

2. Methods and Materials

2.1. Study Design and Participants

The present study employed a longitudinal predictive design grounded in advanced machine learning methodology to examine the temporal dynamics of psychological resilience. The target population consisted of emerging adults and adults residing in Canada. A total of 428 participants were recruited using a stratified random sampling approach to ensure adequate representation across gender, age groups, and socioeconomic status. Participants were recruited through university mailing lists, community mental health centers, and online research platforms. Inclusion criteria required participants to be between 18 and 45 years of age, fluent in English, and without a diagnosed severe psychiatric disorder that could interfere with longitudinal participation. Data were collected at four time points over a 12-month period, with approximately three-month intervals between each wave. This repeated-measures framework enabled the modeling of temporal dependencies and intra-individual changes in resilience and its psychological predictors over time. Attrition analysis was conducted, and the final dataset retained 392 participants with complete or near-complete time-series data, which were used in the LSTM modeling phase after appropriate imputation procedures.

2.2. Measures

Data collection was conducted using a battery of standardized and psychometrically validated instruments. Psychological resilience was assessed using the Connor–Davidson Resilience Scale (CD-RISC), which captures adaptability, persistence, and recovery from stress. Self-compassion was measured through the Self-Compassion Scale (SCS), encompassing self-kindness, common humanity, and mindfulness components. Meaning in life was evaluated using the Meaning in Life Questionnaire (MLQ), which includes both presence and search dimensions. Cognitive reappraisal, as a core emotion regulation strategy, was assessed using the Cognitive Reappraisal subscale of the Emotion Regulation Questionnaire (ERQ). Perceived social

support was measured through the Multidimensional Scale of Perceived Social Support (MSPSS), capturing support from family, friends, and significant others. All instruments demonstrated acceptable internal consistency (Cronbach’s alpha values above 0.80 across waves). Data were collected via a secure online survey platform, and participants were assigned unique identifiers to track responses longitudinally while preserving anonymity. Demographic information, including age, gender, education level, and employment status, was also collected at baseline.

2.3. Data analysis

Data analysis was conducted using a hybrid statistical and machine learning framework, with a primary focus on Long Short-Term Memory (LSTM) neural networks to model temporal patterns and predict future levels of psychological resilience. Initially, preliminary analyses were performed using SPSS-27 to assess descriptive statistics, normality, missing data patterns, and intercorrelations among variables. Missing data were handled using multiple imputation and sequence padding techniques appropriate for time-series modeling. The main analytical phase was conducted in Python using TensorFlow and Keras libraries. The LSTM model was designed to capture sequential dependencies across the four measurement waves, with self-compassion, meaning in life, cognitive reappraisal, and social support entered as time-varying predictors. The dataset was split into training (70%), validation (15%), and test (15%) sets to ensure model generalizability. Hyperparameters such as the number of LSTM units, learning rate, batch size, and dropout rate were optimized using grid search and cross-validation procedures. Model performance was evaluated using metrics including Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and R-squared. Additionally, feature importance and temporal contribution analyses were conducted using SHAP (Shapley Additive Explanations) values to interpret the relative influence of each predictor across time steps. This integrative analytical approach allowed for both high predictive accuracy and interpretability of the psychological mechanisms underlying resilience development.

3. Findings and Results

The final analytic sample consisted of 392 participants who completed at least three of the four measurement waves and were retained after data preprocessing. The mean age of participants was 27.84 years ($SD = 6.21$), with an age range

from 18 to 45 years. In terms of gender distribution, 54.08% identified as female, 44.13% as male, and 1.79% as non-binary or preferred not to disclose. Regarding educational attainment, 62.24% of participants held or were pursuing an undergraduate degree, 25.51% had completed graduate-level education, and 12.25% had a high school diploma or equivalent. Employment status indicated that 48.72% were

employed full-time, 27.81% part-time, and 23.47% were students or unemployed. Attrition analysis revealed no significant differences between retained and dropout participants across baseline psychological variables ($p > .05$), supporting the assumption that missingness was at random and did not bias the longitudinal modeling.

Table 1

Descriptive Statistics and Correlations Among Study Variables Across Time Points

| Variable | Mean | SD | 1 | 2 | 3 | 4 | 5 |
|-----------------------------|-------|------|------|------|------|------|---|
| 1. Psychological Resilience | 68.47 | 9.82 | 1 | | | | |
| 2. Self-Compassion | 3.42 | 0.61 | 0.54 | 1 | | | |
| 3. Meaning in Life | 4.78 | 0.83 | 0.49 | 0.46 | 1 | | |
| 4. Cognitive Reappraisal | 4.12 | 0.72 | 0.43 | 0.39 | 0.41 | 1 | |
| 5. Social Support | 5.21 | 0.88 | 0.51 | 0.47 | 0.44 | 0.38 | 1 |

The descriptive statistics presented in Table 1 indicate moderate to high levels of psychological resilience and associated predictors across the sample. Psychological resilience demonstrated a mean score of 68.47 (SD = 9.82), suggesting a generally adaptive profile within the population. All predictor variables—self-compassion, meaning in life, cognitive reappraisal, and social support—also exhibited moderate variability, reflecting sufficient dispersion for predictive modeling. Correlational analyses

revealed that all independent variables were positively and significantly associated with psychological resilience, with self-compassion showing the strongest relationship ($r = .54$), followed by social support ($r = .51$), meaning in life ($r = .49$), and cognitive reappraisal ($r = .43$). Intercorrelations among predictors were moderate, indicating conceptual overlap but also sufficient distinctiveness to justify their simultaneous inclusion in the LSTM model.

Table 2

Longitudinal Changes in Psychological Variables Across Four Time Points

| Variable | Time 1 M (SD) | Time 2 M (SD) | Time 3 M (SD) | Time 4 M (SD) |
|--------------------------|---------------|---------------|---------------|---------------|
| Psychological Resilience | 66.92 (9.54) | 67.88 (9.63) | 68.91 (9.77) | 70.16 (9.84) |
| Self-Compassion | 3.31 (0.59) | 3.39 (0.60) | 3.46 (0.62) | 3.52 (0.63) |
| Meaning in Life | 4.65 (0.81) | 4.73 (0.82) | 4.81 (0.84) | 4.93 (0.86) |
| Cognitive Reappraisal | 4.03 (0.70) | 4.08 (0.71) | 4.15 (0.73) | 4.22 (0.74) |
| Social Support | 5.08 (0.86) | 5.17 (0.87) | 5.25 (0.89) | 5.34 (0.90) |

The longitudinal trends reported in Table 2 demonstrate a consistent increase in psychological resilience and all associated predictors over the four measurement waves. Psychological resilience showed a gradual upward trajectory, increasing from a mean of 66.92 at Time 1 to 70.16 at Time 4, suggesting adaptive development over time. Similar incremental patterns were observed for self-

compassion, meaning in life, cognitive reappraisal, and social support, indicating that these constructs may co-evolve dynamically. The steady growth across variables supports the appropriateness of a time-series modeling approach such as LSTM, which is sensitive to sequential dependencies and temporal progression in psychological constructs.

Table 3

LSTM Model Performance Metrics for Predicting Psychological Resilience

| Metric | Training Set | Validation Set | Test Set |
|--------|--------------|----------------|----------|
| MSE | 5.84 | 6.21 | 6.37 |

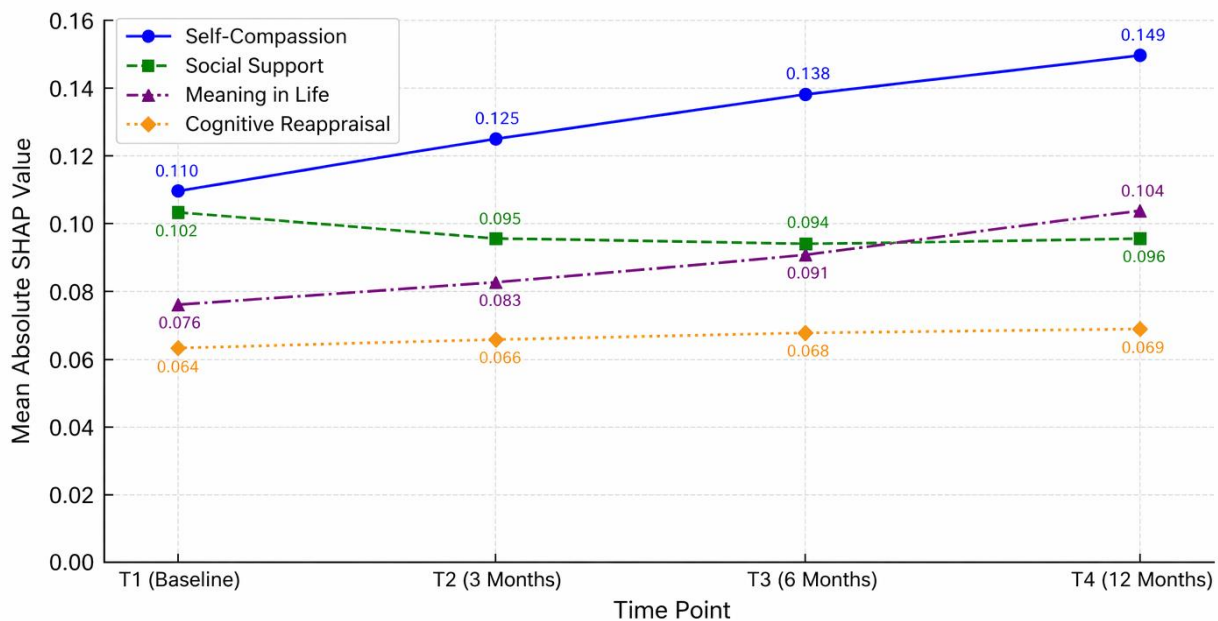
| | | | |
|----------------|------|------|------|
| RMSE | 2.42 | 2.49 | 2.52 |
| R ² | 0.71 | 0.68 | 0.66 |

The performance metrics of the LSTM model, as shown in Table 3, indicate robust predictive accuracy in modeling psychological resilience over time. The model achieved a Mean Squared Error of 6.37 and a Root Mean Squared Error of 2.52 on the test dataset, reflecting relatively low prediction error. The R-squared value of 0.66 suggests that

approximately 66% of the variance in future resilience scores was explained by the model, which is substantial given the complexity of psychological processes. The consistency between training, validation, and test metrics indicates minimal overfitting and good generalizability of the model across unseen data.

Figure 1

Temporal Contribution of Predictors to Psychological Resilience Based on SHAP Analysis



Note. The figure displays the mean absolute SHAP (Shapley Additive Explanation) values for each predictor across four measurement waves. Higher SHAP values indicate a stronger contribution of the predictor to the LSTM model's prediction of psychological resilience at each time point. Self-compassion shows an increasing influence over time, social support demonstrates a strong early contribution, meaning in life exhibits a progressive rise, and cognitive reappraisal maintains a stable, moderate impact across all waves.

The SHAP-based analysis illustrated in Figure 1 reveals the dynamic and time-dependent contributions of predictor variables to the model's output. Self-compassion emerged as the most influential predictor across all time steps, with its impact increasing in later waves, suggesting cumulative effects over time. Social support also demonstrated a strong and stable contribution, particularly at earlier time points, indicating its foundational role in resilience development. Meaning in life showed a progressively increasing influence, aligning with its role in long-term psychological adaptation. Cognitive reappraisal exhibited moderate but consistent contributions across all time steps, highlighting its function as a stable regulatory mechanism. The figure underscores the temporal interplay among predictors and validates the use of

LSTM modeling for capturing these complex, nonlinear relationships.

4. Discussion

The present study aimed to examine the longitudinal prediction of psychological resilience using an LSTM-based modeling framework, focusing on the dynamic contributions of self-compassion, meaning in life, cognitive reappraisal, and social support. The findings revealed several important patterns that advance both theoretical understanding and methodological approaches to resilience research. First, the results demonstrated that all four predictors were positively associated with psychological resilience, both cross-sectionally and longitudinally. Among these, self-

compassion emerged as the strongest and most consistent predictor across time points, followed by social support, meaning in life, and cognitive reappraisal. Additionally, the LSTM model showed high predictive accuracy, explaining a substantial proportion of variance in resilience outcomes, while SHAP analysis confirmed the temporal variability in the importance of each predictor.

The prominent role of self-compassion in predicting resilience is consistent with a growing body of literature emphasizing its central function in adaptive psychological functioning. The findings indicated that self-compassion not only had the highest correlation with resilience but also exhibited increasing predictive strength over time, suggesting cumulative and reinforcing effects. This aligns with theoretical models positing that self-compassion facilitates emotional regulation, reduces self-criticism, and enhances coping flexibility in the face of adversity (Huang et al., 2025; Wang et al., 2025). Empirical studies further support that individuals high in self-compassion demonstrate greater psychological stability and resilience across diverse contexts, including trauma exposure and chronic stress (Cutajar & Bates, 2025; Wu et al., 2025). The longitudinal strengthening observed in the present study may reflect the internalization of compassionate self-relating processes, which progressively buffer against stressors and enhance adaptive responses.

Social support also demonstrated a strong and stable contribution to resilience, particularly at earlier time points, highlighting its foundational role in the development of adaptive capacities. The results suggest that social support may serve as an initial external scaffold that facilitates the development of internal resources such as self-compassion and cognitive reappraisal. This interpretation is consistent with social buffering models, which posit that supportive relationships mitigate the impact of stress and promote psychological well-being (Kupferberg & Hasler, 2024; Watson et al., 2023). Prior research has shown that individuals with higher perceived social support are more likely to engage in adaptive coping strategies and exhibit greater resilience (Avdiu & Duraku, 2024; Logoz et al., 2023). The observed decline in relative importance of social support over time, as indicated by SHAP analysis, may reflect a developmental shift from external to internal regulation processes, wherein individuals increasingly rely on internalized psychological resources.

Meaning in life exhibited a progressively increasing influence on resilience across time points, suggesting its role as a long-term stabilizing factor. This finding aligns with

existential and positive psychology frameworks, which emphasize the importance of purpose and coherence in fostering psychological resilience (Song et al., 2023; Tao et al., 2023). The gradual increase in the predictive contribution of meaning in life may indicate that individuals develop a stronger sense of purpose over time, which in turn enhances their capacity to withstand adversity. Previous longitudinal studies have similarly reported that meaning in life contributes to sustained well-being and resilience by promoting adaptive cognitive appraisals and goal-directed behavior (Lowe et al., 2024; Salsman & Rosenberg, 2024). The present findings extend this literature by demonstrating that meaning in life operates as a dynamic predictor whose influence becomes more pronounced in later stages of resilience development.

Cognitive reappraisal showed a moderate but consistent contribution to resilience across all time points, underscoring its role as a stable emotion regulation mechanism. The findings suggest that while cognitive reappraisal may not be the strongest predictor, it plays a crucial supporting role in maintaining emotional balance and facilitating adaptive responses. This is consistent with prior research indicating that cognitive reappraisal is associated with lower levels of distress and higher levels of resilience (Polat, 2025; Ünal & Ordu, 2023). Moreover, cognitive reappraisal has been identified as a key mechanism through which self-compassion exerts its effects on psychological outcomes (Snodgrass et al., 2025). The stable contribution observed in the present study supports the notion that reappraisal functions as a foundational regulatory process that complements other psychological resources.

The longitudinal trends observed across all variables revealed a gradual increase in resilience and its predictors over time, suggesting a co-developmental process. This pattern supports the conceptualization of resilience as a dynamic and evolving construct rather than a fixed trait. The simultaneous growth in self-compassion, meaning in life, cognitive reappraisal, and social support indicates that these factors may interact synergistically to enhance resilience. This interpretation is consistent with integrative models of resilience, which emphasize the interplay between internal and external resources (Koehler et al., 2023; Salsman & Rosenberg, 2024). Furthermore, the absence of significant attrition bias strengthens the validity of these longitudinal findings, indicating that the observed trends are not attributable to sample distortion.

From a methodological perspective, the successful application of LSTM modeling represents a significant

advancement in resilience research. The model demonstrated strong predictive performance, with minimal overfitting and consistent accuracy across training, validation, and test datasets. This supports the utility of deep learning approaches in capturing complex, nonlinear, and time-dependent relationships in psychological data. Previous studies have highlighted the limitations of traditional statistical methods in modeling dynamic processes, and the present findings provide empirical support for the adoption of machine learning techniques in this domain (C. Ding et al., 2024; Kupferberg & Hasler, 2024). The integration of SHAP analysis further enhances the interpretability of the model, allowing for a nuanced understanding of the temporal contributions of each predictor.

The findings also contribute to the growing literature on explainable artificial intelligence in psychology. By identifying the relative importance of predictors at different time points, the study provides insights into the mechanisms underlying resilience development. For example, the increasing influence of self-compassion and meaning in life over time suggests that interventions targeting these constructs may have long-term benefits. Similarly, the early importance of social support highlights the need for timely social interventions in the initial stages of stress or adversity. These insights are consistent with intervention research demonstrating the effectiveness of programs aimed at enhancing self-compassion, emotion regulation, and social connectedness (Lee et al., 2024; Leong et al., 2024; McConnell et al., 2024).

Another important implication of the findings is the interconnected nature of the predictors. Emotional regulation, self-compassion, and social support appear to operate within a broader system of psychological functioning, where changes in one domain influence others. This is supported by research on emotional intelligence and adaptive functioning, which highlights the integration of cognitive, emotional, and social processes in resilience (R. Ding et al., 2024; P. & P., 2024). The present study extends this perspective by demonstrating how these interactions unfold over time and contribute to resilience trajectories.

5. Conclusion

Overall, the findings underscore the importance of adopting a multidimensional and longitudinal approach to understanding psychological resilience. By integrating theoretical insights with advanced analytical techniques, the

study provides a comprehensive framework for examining the dynamic interplay of key psychological factors. The results not only validate existing theories but also offer new directions for research and practice, particularly in the context of personalized and time-sensitive interventions.

6. Limitations & Suggestions

The study has several limitations that should be acknowledged. First, the reliance on self-report measures may introduce response biases, including social desirability and recall bias, which could affect the accuracy of the data. Second, although the sample was diverse, it was limited to participants from Canada, which may restrict the generalizability of the findings to other cultural contexts. Third, the study included four time points over a one-year period, which, while sufficient for modeling temporal trends, may not capture longer-term developmental trajectories. Additionally, the use of LSTM models, while advantageous for prediction, may still present challenges in terms of full interpretability despite the use of SHAP analysis. Finally, potential confounding variables such as personality traits or life events were not included in the model, which may have influenced resilience outcomes.

Future research should aim to extend the present findings by incorporating more diverse and cross-cultural samples to enhance generalizability. Longitudinal studies with more frequent measurement intervals and longer follow-up periods would provide a more detailed understanding of resilience trajectories. Additionally, future studies could integrate other relevant psychological and contextual variables, such as personality traits, coping styles, and environmental stressors, to develop more comprehensive predictive models. The application of other advanced machine learning techniques, including hybrid and ensemble models, may further improve predictive accuracy and interpretability. Moreover, experimental and intervention-based studies are needed to test the causal effects of enhancing self-compassion, meaning in life, and emotion regulation on resilience outcomes.

From a practical perspective, the findings have important implications for the design and implementation of psychological interventions. Programs aimed at enhancing self-compassion should be prioritized, given its strong and increasing influence on resilience over time. Interventions that foster meaning in life, such as purpose-centered therapies, may also contribute to long-term resilience development. Early-stage interventions should focus on

strengthening social support networks, particularly for individuals facing acute stress or adversity. Additionally, training in cognitive reappraisal and other emotion regulation strategies can provide individuals with tools to manage negative emotions effectively. The integration of digital and AI-based tools, such as personalized feedback systems and predictive analytics, may further enhance the effectiveness of interventions by tailoring them to individual needs and temporal dynamics.

Acknowledgments

We would like to express our appreciation and gratitude to all those who cooperated in carrying out this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

Funding

This research was carried out independently with personal funding and without the financial support of any governmental or private institution or organization.

Authors' Contributions

All authors equally contributed in this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

References

Avdiu, F., & Duraku, Z. H. (2024). Emotional Regulation, Self-Compassion and Adaptive Functioning in Parents: A Comparative Study in Families of Neurodevelopmental Disorder and Typically Developing Children. *Advances in*

- Mental Health and Intellectual Disabilities*, 18(4), 149-160. <https://doi.org/10.1108/amhid-11-2023-0042>
- Cutajar, K., & Bates, G. (2025). Australian Women in the Perinatal Period During COVID-19: The Influence of Self-Compassion and Emotional Regulation on Anxiety, Depression, and Social Anxiety. *Healthcare*, 13(2), 120. <https://doi.org/10.3390/healthcare13020120>
- Ding, C., Mortillaro, M., & Ramdas, M. (2024). Emotional Intelligence in Applied Settings: Approaches to Its Theoretical Model, Measurement, and Application. <https://doi.org/10.3389/978-2-8325-4623-9>
- Ding, R., He, W., Liu, T., Yang, Y., Qiu, F., & Wang, Q. (2024). Unpacking Maternal Minimization Responses to Children's Negative Emotions: "Person-Oriented" Versus "Emotion-Oriented". *Emotion*, 24(4), 1049-1067. <https://doi.org/10.1037/emo0001324>
- Huang, P., Lin, Z.-J., Wang, B. C., & Du, Z. (2025). A Mixed Methods Exploration of the Interrelationships Among Self-Compassion, Stress Management, Psychological Capital, and Life Satisfaction in Chinese University Students. *Frontiers in psychology*, 16. <https://doi.org/10.3389/fpsyg.2025.1510987>
- Koehler, F., Schäfer, S. K., Lieb, K., & Wessa, M. (2023). Differential Associations of Leisure Music Engagement With Resilience: A Network Analysis. *International Journal of Clinical and Health Psychology*, 23(3), 100377. <https://doi.org/10.1016/j.ijchp.2023.100377>
- Kupferberg, A., & Hasler, G. (2024). From Antidepressants and Psychotherapy to Oxytocin, Vagus Nerve Stimulation, Ketamine and Psychedelics: How Established and Novel Treatments Can Improve Social Functioning in Major Depression. *Frontiers in Psychiatry*, 15. <https://doi.org/10.3389/fpsyg.2024.1372650>
- Lee, A., Fung, W. K., & Chung, K. K. H. (2024). Empowering the Helping Hands: A Positive Psychological Intervention for Enhancing Work Engagement and Reducing Stress Among Preschool Social Workers in Hong Kong. *Stress and Health*, 40(5). <https://doi.org/10.1002/smi.3471>
- Leong, C. A., Summers, A., Grote, V., Jackson, K., Dowling, G., Snowberg, K., Cotten, P. D., Cheung, E. O., Yang, D., Addington, E. L., & Moskowitz, J. T. (2024). Randomized Controlled Trial of a Positive Emotion Regulation Intervention to Reduce Stress in Family Caregivers of Individuals With Alzheimer's Disease: Protocol and Design for the LEAF 2.0 Study. *BMC Geriatrics*, 24(1). <https://doi.org/10.1186/s12877-024-04817-5>
- Liu, C., Chen, H., Zhang, A., Gong, X. G., Wu, K., Liu, C.-Y., & Chiou, W. K. (2023). The Effects of Short Video App-Guided Loving-Kindness Meditation on College Students' Mindfulness, Self-Compassion, Positive Psychological Capital, and Suicide Ideation. *Psicologia Reflexão E Crítica*, 36(1). <https://doi.org/10.1186/s41155-023-00276-w>
- Logoz, F., Eggenberger, L., Komlenac, N., Schneeberger, M., Ehlert, U., & Walther, A. (2023). How Do Traditional Masculinity Ideologies and Emotional Competence Relate to Aggression and Physical Domestic Violence in Cisgender Men? *Frontiers in psychology*, 14. <https://doi.org/10.3389/fpsyg.2023.1100114>
- Lowe, M. X., Kettner, H., Jolly, D. R. P., Carhart-Harris, R. L., & Jackson, H. (2024). Long-Term Benefits to Psychological Health and Well-Being After Ceremonial Use of Ayahuasca in Middle Eastern and North African Immigrants and Refugees. *Frontiers in Psychiatry*, 15. <https://doi.org/10.3389/fpsyg.2024.1279887>
- McConnell, S., Silva, B. R. O., & Silva, C. O. (2024). Cultivating Empathy and Compassion: Lived Experiences of Engagement

- With Cognitively-based Compassion Training in the US. *Ethos*, 52(2), 206-224. <https://doi.org/10.1111/etho.12424>
- Mistretta, E. G., & Davis, M. C. (2025). Self-Compassion Versus Detached Reappraisal for Emotion Regulation in Individuals Exposed to Interpersonal Trauma. *Psychology of Consciousness Theory Research and Practice*, 12(2), 232-252. <https://doi.org/10.1037/cns0000408>
- P., U., & P., R. (2024). The Impact of Forgiveness in Emotional Regulation and Resilience in the Face of Adversity Among Young Adults. *International Journal for Multidisciplinary Research*, 6(2). <https://doi.org/10.36948/ijfmr.2024.v06i02.19263>
- Pilárik, L., Mikoška, P., Helvich, J., & Melišíková, A. (2024). Effective Emotion Regulation as a Protective Factor of Depression Symptoms in Slovak Adolescents During a COVID-19 Pandemic. *Polish Psychological Bulletin*, 37-46. <https://doi.org/10.24425/ppb.2024.150355>
- Polat, S. (2025). The Correlation Between Suicide Risk and Emotion Regulation Strategies in Patients With Bipolar Disorder: A Cross-Sectional Study. *Journal of Psychiatric and Mental Health Nursing*, 32(6), 1380-1391. <https://doi.org/10.1111/jpm.70034>
- Salsman, J. M., & Rosenberg, A. R. (2024). Fostering Resilience in Adolescence and Young Adulthood: Considerations for Evidence-based, Patient-centered Oncology Care. *Cancer*, 130(7), 1031-1040. <https://doi.org/10.1002/cncr.35182>
- Snodgrass, N., Mistretta, E. G., & Davis, M. C. (2025). How People Talk About Rejection: Linguistic Profiles of Self-Compassion, Reappraisal, and Control Writing Conditions. <https://doi.org/10.21203/rs.3.rs-6857482/v1>
- Song, Y., Xiao, Z., Zhang, L., & Shi, W. (2023). Trait Depression and Subjective Well-Being: The Chain Mediating Role of Community Feeling and Self-Compassion. *Behavioral Sciences*, 13(6), 448. <https://doi.org/10.3390/bs13060448>
- Syafitri, N., Lubis, R., Indrawan, Y. F., & Choong, T. C. (2024). Self-Compassion: Unveiling Mental Health Through Emotion Regulation in High-School Students. *Tazkiya Journal of Psychology*, 12(1), 1-16. <https://doi.org/10.15408/tazkiya.v12i1.37794>
- Tao, T. J., Yung, Y. Y. Y., Lau, A. Y. T., Liu, H., Liang, L., Bryant, F. B., & Hou, W. K. (2023). Savoring Mediates the Mental Health Benefits of Positive Coping Processes: A Prospective Population-based Analysis. *Applied Psychology Health and Well-Being*, 16(1), 158-178. <https://doi.org/10.1111/aphw.12476>
- Ünal, İ. Ö., & Ordu, Ç. (2023). Alexithymia, Self-Compassion, Emotional Resilience, and Cognitive Emotion Regulation: Charting the Emotional Journey of Cancer Patients. *Current Oncology*, 30(10), 8872-8887. <https://doi.org/10.3390/curroncol30100641>
- Wang, J., Drossaert, C. H., Knevel, M., Chen, L., Bohlmeijer, E. T., & Schroevers, M. J. (2025). The Mechanisms Underlying the Relationship Between Self-Compassion and Psychological Outcomes in Adult Populations: A Systematic Review. *Stress and Health*, 41(4). <https://doi.org/10.1002/smi.70090>
- Watson, T., Watts, L., Waters, R., & Hodgson, D. (2023). The Benefits of Loving Kindness Meditation for Helping Professionals: A Systematic Review. *Health & Social Care in the Community*, 2023, 1-14. <https://doi.org/10.1155/2023/5579057>
- Wu, Q., Zhou, N., Cao, H., & Wang, S. (2025). Implications of Childhood Psychological Maltreatment and Peer Victimization for COVID-19 PTSD Symptoms Among Adolescents: Mindfulness and Self-Compassion as Explanatory Mechanisms in Trauma Transmission. *Psychological Trauma Theory Research Practice and Policy*. <https://doi.org/10.1037/tra0002004>