

Brief report

Psychometric phenotypes of quality of life in community-dwelling older adults: A multivariate segmentation and Monte Carlo validation of the FRAG model[☆]

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ABSTRACT

Traditional biomedical paradigms frequently associate aging with an inevitable narrative of systemic decline, often neglecting the intrinsic capacity of older adults to optimize their quality of life (QoL) through psychological strengths. Grounded in Contextual Behavioral Science and the FRAG framework, this study aimed to identify heterogeneous QoL profiles in community-dwelling older adults and cross-validate their structural stability through computational simulation. A sample of Spanish community-dwelling older adults (N = 579, mean age = 69.37 years, 59.2% women) completed standardized instruments assessing QoL, gratitude, resilience, experiential acceptance, and psychological distress. A hierarchical cluster analysis using Ward's method was executed based on standardized psychometric scores. To evaluate parameter convergence and model stability against sampling noise, a single parametric Monte Carlo stochastic simulation (N = 1000) was parameterized using the empirical statistical moments and the Mersenne Twister algorithm. The cluster analysis identified a robust three-profile structure, distinguishing two vulnerability cohorts from a "functional excellence" phenotype. The Monte Carlo simulation confirmed excellent replication with parameter convergence metrics below 0.05. A subsequent univariate ANOVA revealed that continuous QoL scores differed significantly across the three empirical profiles, (2, 576) = F(2, 576) = 147.74, p < .001, $\eta^2p = .339$. Experiential acceptance and gratitude emerged as the primary discriminant anchors of functional excellence, whereas baseline resilience exhibited negligible weight. These findings support the systematic integration of acceptance- and gratitude-based interventions within psychogeriatric community care to foster intrinsic capacity.

Introduction

Global demographic aging represents a profound structural transformation, demanding an urgent transition from traditional welfare models toward evidence-based strategies that optimize quality of life (QoL). However, gerontology has systematically operated under a deficit-based

paradigm that associates old age with dependency and loss. This restrictive biomedical framework treats physical functioning as the sole determinant of well-being, ignoring response shift, the individual's intrinsic capacity to recalibrate internal standards when facing adversity [1].

In contrast, the present study adopts a psychosocial perspective grounded in human need satisfaction, where QoL is conceptualized as a

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multidimensional construct of self-actualization decoupled from the mere absence of pathology and operationalized via the CASP–12 scale [2]. Late-life emotional well-being is frequently threatened by a high prevalence of anxiety and depression, generating a vulnerability spiral where affective symptoms and low autonomy reciprocally reinforce each other [3].

From Contextual Behavioral Science, the impact of these stressors depends on how individuals respond to internal experiences; while psychological inflexibility and experiential avoidance anchor older individuals in a loop of distress, psychological flexibility acts as a core regulatory mechanism [4]. Within this framework, quality aging is operationalized through the FRAG model, a system of synergistic strengths, including resilience, acceptance, and gratitude, that preserves existential integrity despite functional decline [5]. Given the substantial interindividual variability in the mobilization of these resources, this study aimed to identify heterogeneous phenotypic profiles of aging using multivariate segmentation, validate their structural stability through a stochastic Monte Carlo simulation, and examine how these derived profiles differentiate functional excellence from vulnerability using a continuous, unbinned model of QoL.

Methods

Participants

A non-probability snowball sampling strategy was initially used to recruit community-dwelling older adults aged 60 and older across Spain via senior centers and digital platforms using Microsoft Forms. To ensure data integrity, the electronic platform required explicit written informed consent before accessing items, and the study protocol was approved by the institutional review board. The initial database (N = 665) was screened for missing values. Total missingness was exceptionally low (< 1.8%), meeting conservative methodological thresholds for Series Mean Imputation without structural distortion. Non-parametric box-plots were utilized as the diagnostic tool to identify and exclude 86 extreme outliers (participants scoring > 3 standard deviations below the mean in baseline strengths), yielding a final analytical sample of N = 579. Sociodemographic descriptors confirmed a mean age of 69.37 years (SD = 6.79, range 60–91), with 59.2% women, 62.5% married, and 43.9% reporting good perceived health status.

Instruments

Validated psychometric instruments were administered. Perceived QoL was measured using the 12-item CASP–12, which assesses control, autonomy, self-realization, and pleasure on a 4-point Likert scale, with higher scores indicating superior QoL (Cronbach’s $\alpha = .79$; [2]). Gratitude was assessed via the Spanish short-form Gratitude subscale of the Values in Action Inventory of Strengths, a 5-item instrument measuring emotional and cognitive components on a 5-point Likert scale, exhibiting excellent reliability (Cronbach’s $\alpha = .97$; [6]). Resilience was evaluated using the 4-item Brief Resilient Coping Scale (BRCS), utilizing a 5-point Likert scale to capture adaptive coping strategies in older cohorts (Cronbach’s $\alpha = .72$; [7]). Experiential acceptance was measured through the 7-item Acceptance and Action Questionnaire-II (AAQ-II), scored from 1 to 7, higher values represented greater

psychological acceptance (Cronbach’s $\alpha = .94$; [8]). Family functioning was evaluated using the 5-item Family APGAR Scale, assessing adaptability, partnership, growth, affection, and resolve on a 3-point Likert scale (Cronbach’s $\alpha = .80$; [9]). Psychological well-being was captured using the personal growth (7 items, Cronbach’s $\alpha = .65$) and purpose in life (6 items, Cronbach’s $\alpha = .67$) subscales of Ryff’s Psychological Well-Being Scales [10]. Finally, psychological distress was operationalized via the Hospital Anxiety and Depression Scale (HADS; [11]), yielding distinct 7-item subscales for anxiety (Cronbach’s $\alpha = .82$) and depression (Cronbach’s $\alpha = .62$).

Procedure

The [Omitted] University Institutional Review Board approved the protocol (Ref: [Omitted]). Participants provided written informed consent, ensuring confidentiality, anonymity, and penalty-free withdrawal. An online non-probability snowball sampling approach via Microsoft Forms recruited participants through senior organizations, community centers, and social media. Online surveys for subjective well-being show psychometric equivalence to traditional formats. Inclusion required being aged ≥ 60 years; self-reported major psychiatric or neurological disorders were grounds for exclusion. Digital forced-response items prevented missing data. Participation was voluntary, uncompensated, and lasted approximately 30 min.

Data analysis

Statistical analyses were executed in IBM SPSS Statistics (v.29.0). All continuous psychometric predictors were transformed into Z-scores within the analytical baseline to ensure equal geometric weight. A Hierarchical Cluster Analysis was performed using Ward’s method and squared Euclidean distance, identifying the optimal solution by examining the agglomeration schedule coefficients. To test model stability and cross-validate parameter convergence against sampling noise, a single parametric Monte Carlo stochastic simulation (N = 1000) was generated using the Mersenne Twister pseudorandom number generator. This synthetic population was parameterized based on the exact statistical moments (observed means and standard deviations) of the empirical sample. Subgroup sample sizes within the simulated population were allocated proportionally to mimic the precise prevalence rates of the original empirical sample (N = 579; Cluster 1 n = 491, Cluster 2 n = 56, Cluster 3 n = 32) into the expanded matrix (N = 1000; Simulated Profile 1 n = 848, Simulated Profile 2 n = 97, Simulated Profile 3 n = 55). Finally, to explicitly evaluate how the derived phenotypes correspond to overall well-being without losing statistical power through artificial categorization, a standalone univariate ANOVA was executed on the empirical sample (N = 579), utilizing the three-cluster solution as the independent factor and the continuous, raw CASP–12 QoL scores as the dependent variable. Effect sizes were interpreted using partial eta-squared.

Results

The hierarchical cluster analysis yielded a robust three-profile structure, distinguishing two vulnerability cohorts from one well-being phenotype (Table 1).

Table 1
Profiles of psychological strengths and distress: cluster solution characteristics and association with quality of life.

Profile / Cluster	N	Cluster Characteristics and Descriptive Profiles
Cluster 1	237	Moderately positive scores in Resilience, Personal Growth, and Purpose in Life, but characterized by low Acceptance (–.58) and low Gratitude (–.58).
Cluster 2	184	Negative values across almost all well-being dimensions. Notably characterized by high Loneliness (.58) as well as elevated Anxiety (.57) and Depression (.47) scores.
Cluster 3	158	Very high scores in Acceptance (.71) and Gratitude (.86). Demonstrates the lowest levels of Anxiety (–1.25) and Depression (–1.21).

Cluster 1 ($n = 491$; 84.8%) represented a "normative adaptive" profile, characterized by intermediate values across all psychological assets and low distress. Cluster 2 ($n = 56$; 9.7%) emerged as a "severe psychometric vulnerability" phenotype, defined by low acceptance, low gratitude, and elevated distress scores. Cluster 3 ($n = 32$; 5.5%) represented a phenotype of "functional excellence," characterized by exceptionally high scores in experiential acceptance and gratitude. Computational cross-validation via the Monte Carlo simulation ($N = 1000$) demonstrated highly consistent statistical estimates, with mean differences between the empirical and simulated parameters dropping below 0.05, confirming excellent replication and structural stability.

The analysis revealed highly significant differences in QoL levels across the profiles, $F(2, 576) = 147.74$, $p < .001$, $\eta^2p = .339$, demonstrating that profile membership accounts for 33.9% of the total variance in late-life QoL. Post-hoc comparisons via Bonferroni criteria confirmed that the functional excellence phenotype (Cluster 3) exhibited significantly higher continuous QoL scores compared to both the normative adaptive cohort (Cluster 1; mean difference = 5.67, $p < .001$) and the severe vulnerability cohort (Cluster 2; mean difference = 7.99, $p < .001$). Additionally, the normative adaptive cohort displayed significantly higher well-being than the severe vulnerability group (mean difference = 2.32, $p < .001$).

Discussion

These findings support a crucial paradigm shift in psychogeriatrics. While successful aging paradigms have historically overemphasized trait resilience as the primary engine of well-being [12], our empirical data reveal that baseline resilience exerts only a residual, non-

significant discriminant weight. This indicates that superior late-life QoL does not rely heavily on a proactive capacity to fight against adversity, but rather on the eudaimonic capacity to integrate life experiences and reconcile with one's life history.

Within this framework, experiential acceptance and gratitude function as pivotal transdiagnostic processes. From the perspective of Contextual Behavioral Science, the robust predictive weight of acceptance highlights psychological flexibility as a core mechanism [4]; it allows older adults to navigate physical decline or systemic loss without engaging in the experiential avoidance that characterizes the severe vulnerability cohort. Likewise, gratitude acts as an internal catalyst that steers individuals toward transcendence and purpose, enabling them to maintain values-oriented functioning [13]. When internal eudaimonic assets are highly developed, as seen in the functional excellence phenotype, they seem to buffer emotional distress and intercept the spiral of resource loss, supporting the World Health Organization's framework of Intrinsic Capacity [1].

Several limitations must be noted. The cross-sectional design precludes drawing strict causal inferences, and despite computational validation via Monte Carlo methods to test model stress, longitudinal studies are required to evaluate profile trajectories over time. Additionally, the sample was restricted to a Spanish cohort, necessitating cross-cultural invariance analyses to determine if these phenotypes remain stable across different cultural environments. In conclusion, this study validates the phenotypic structure of quality aging, demonstrating that eudaimonic assets surpass traditional trait resilience in predicting QoL. These results support the implementation of acceptance-based and gratitude-oriented interventions within primary care and community aging programs to systematically foster intrinsic capacity.

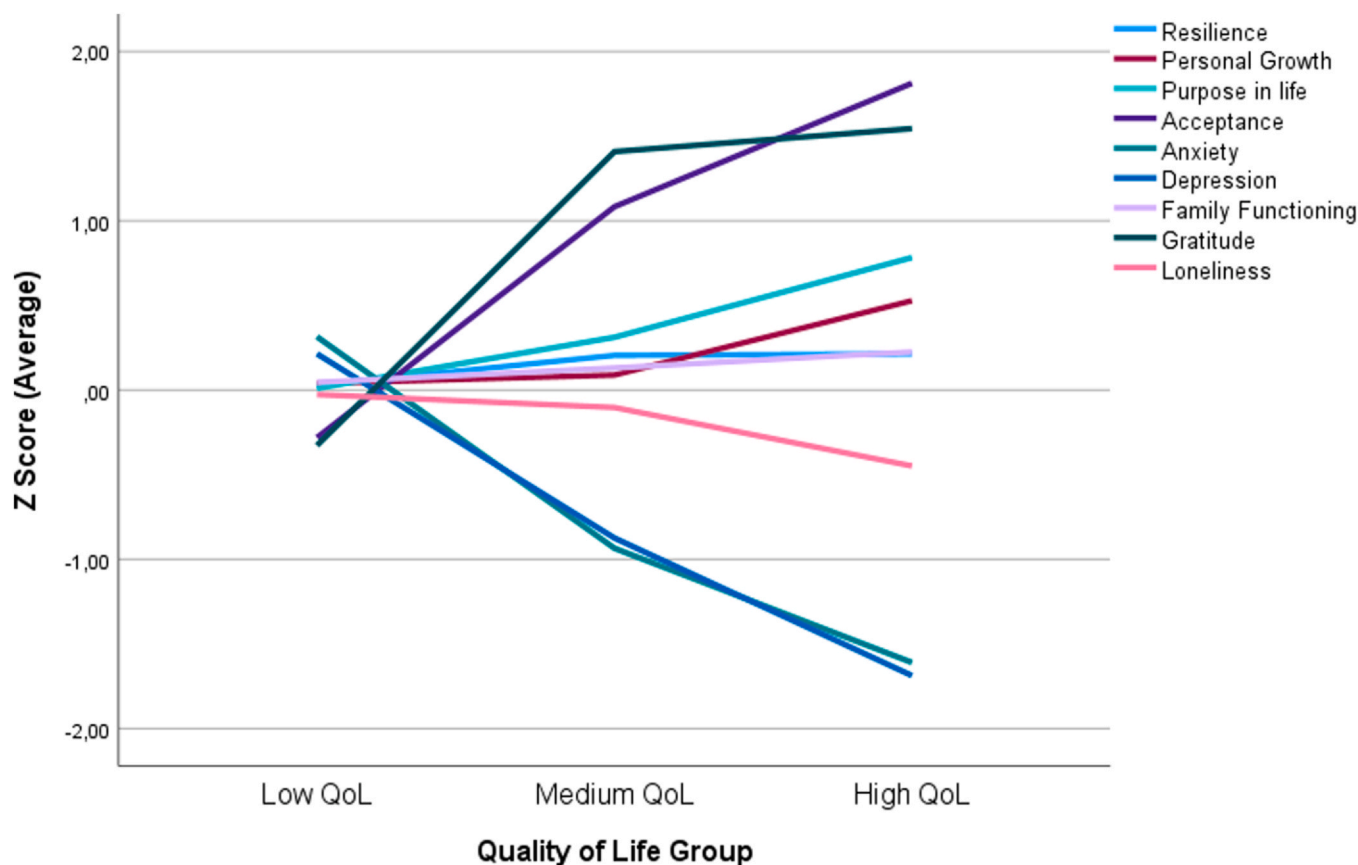


Fig. 1. Phenotypic Profiles of Psychological Strengths and Distress: Parameter Trajectories Across the Three Identified Quality of Life Clusters.

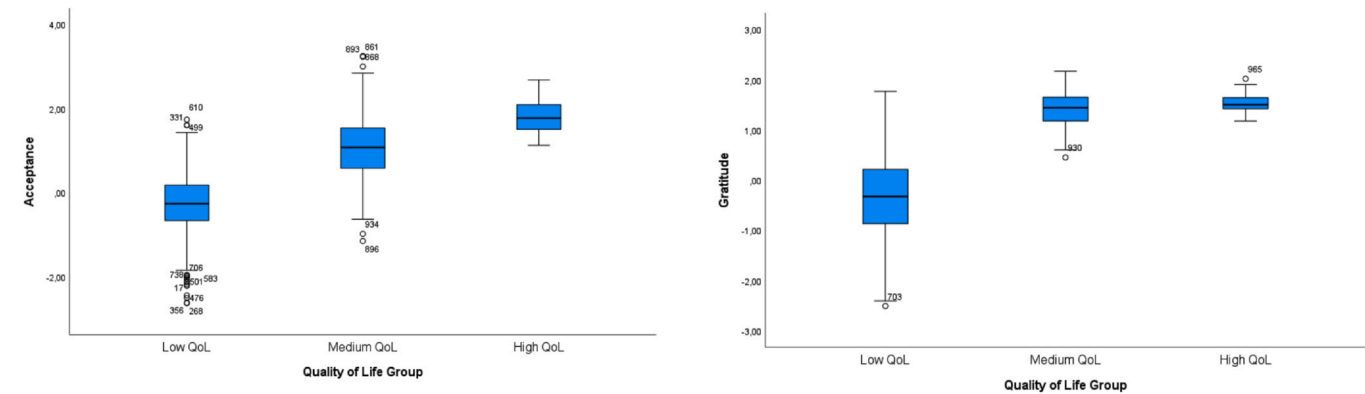


Fig. 2. Distribution of Eudaimonic Assets Across Quality of Life Clusters: Boxplots for Acceptance and Gratitude Scores.

Table 2
Comparison of observed sample means (N = 579) and Monte Carlo simulated means (N = 1000): parameter convergence and cluster profile stability.

Standardized Study Variables (Z-scores)	Original Sample Mean (N = 579)	Simulated Mean (N = 1000)	Mean Difference
Resilience	.0481	.0543	.0062
Personal Growth	.0296	.0701	.0405
Purpose in Life	.0778	.0819	.0041
Acceptance	-.0549	-.0342	.0207
Anxiety	.0834	.0874	.0040
Depression	.0371	.0033	.0338
Family Functioning	.1071	.0630	.0441
Gratitude	-.0807	-.0563	.0244
Loneliness	-.0605	-.0577	.0028

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CRedit authorship contribution statement

Cristina Noriega: Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Javier López:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Conceptualization. **Pérez-Rojo Gema:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Patricia López-Frutos:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization.

Data Availability Statement

Data analyzed herein are available in <https://osf.io/azx9j/>.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Gema Perez-Rojo reports financial support was provided by Spain Ministry of Science Innovation and Universities. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used Gemini to content organization and improve language and readability. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the published article.

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