Original research

The Global Divide of Technology and Digital Inclusion: Access Disparities in Online Geriatric Health Services

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ARTICLE INFO

Article history:
Received 07 July 2026
Accepted 23 July 2026

Keywords:
Digital divide
Geriatric health
Dementia digital biomarkers
Algorithmic bias
Cross-cultural applicability
Digital justice
Health equity

ABSTRACT

This paper conducts a critical comparative policy analysis (CCPA) and technopolitical analysis, selecting the United States—a market with highly penetrated digital health—and China—a market with rapidly expanding mobile health—as research cases. Taking dementia digital biomarkers as an analytical lens, it explores how health resources are allocated between digitally connected and disconnected older adults under the two countries' policy frameworks. Through structured thematic coding of purposively sampled policy documents, critical interpretive synthesis of technical literature on algorithmic bias, and cross-case synthetic critique, this study yields three core findings: (1) Policies of both nations embed an institutional bias of "digital-first", presupposing digital literacy as a prerequisite for service access and forming implicit exclusionary mechanisms; (2) Dementia digital biomarkers carry prominent algorithmic biases in research and validation, and social selectivity in training data leads to systematic misclassification across racial, educational, and linguistic groups; (3) Cross-cultural applicability challenges extend far beyond simple linguistic translation, involving deep cultural embeddedness in cognitive reserve, pragmatic norms, and biomarker cut-off values. Based on the above findings, this paper proposes an algorithmic justice framework, which regards distributive justice, recognition justice, and participatory justice as core ethical principles for digital geriatric health policies. It emphasizes dignity safeguards via non-digital pathways, community-participated algorithm validation, and inclusive representation of the Global South, to ensure digital innovation advances health equity rather than exacerbating pre-existing inequalities. When "smart" shifts from an adjective to the subject itself, technology becomes a de facto access threshold; this is the profound paradox that digital geriatric health policies must guard against.

1. Introduction

1.1. Research Background and Problem Formulation

Global population ageing and the rapid advancement of digital medical care have formed a profound contradictory tension. The World Health Organization (WHO) posits that digital health services—including telehealth, mHealth applications, AI-aided diagnosis, and remote monitoring—have emerged as pivotal strategies to improve the accessibility, efficiency, and continuity of elderly care [1]. Nevertheless, the rapid expansion of digital healthcare simultaneously exposes persistent inequalities in older adults' access to and proficiency with digital tools, sparking profound concerns over digital exclusion and unequal participation [2].

The COVID-19 pandemic drastically amplified this contradiction. In the United States, Medicare telehealth visits surged 63-fold during the pandemic, jumping from approximately 52,000 sessions in February 2019 to over 1.3 million by April 2020 [3]. Yet this explosive growth failed to benefit all older adults equally: seniors lacking broadband infrastructure, digital devices, or operational proficiency were rapidly marginalized, resulting in "digital isolation amid the pandemic". Digital health literacy and internet access have been identified as super social determinants of health—they independently shape health outcomes while interacting with all other social determinants to amplify or mitigate their effects [4].

Against this backdrop, dementia constitutes the most tension-laden analytical lens for digital health policy. People living with dementia sit at

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DOI: 10.64904/202608003

the intersection of digital health's promises and exclusions. On one hand, they represent the core target population for digital health's pledges of early detection and continuous monitoring: digital biomarkers are highly anticipated to deliver low-cost, high-frequency screening for cognitive decline through passive monitoring of speech, gait, and digital interaction patterns. On the other hand, they form the group most systematically excluded by digital interfaces: cognitive impairment itself creates fundamental barriers to smartphone operation, navigating telehealth portals, and completing voice-interactive tasks. When policymakers frame digital connectivity as the endpoint of accessibility, they implicitly assume a homogeneous archetype of elderly users—an assumption fundamentally dismantled by the existence of people living with dementia.

1.2. Research Significance

This paper conducts a critical comparative analysis of the United States, a mature market with a saturated digital health infrastructure, and China, an emerging market undergoing rapid mHealth expansion. The U.S. hosts the world's most sophisticated telehealth infrastructure and richest digital health datasets, yet grapples with entrenched racial inequities and rural digital divides within its healthcare system. China is home to nearly 300 million adults aged 60 and above, advancing universal digital health via the national Smart Health and Elderly Care (SHEC) strategy; however, urban-rural, regional, and educational disparities create a distinctive layered digital divide [5].

Dementia digital biomarkers serve as the overarching analytical thread throughout this paper, not only because dementia represents the most technologically cutting-edge agenda in geriatric health, but also because the research, development, and rollout of digital biomarkers lay bare structural flaws at the heart of digital health equity: How do algorithmic claims of objectivity obscure social biases embedded in training data? How does insufficient cross-cultural validation reduce precision medicine to precision exclusion? What ontological exclusion do disconnected older adults with dementia face when digital biomarkers transition from research tools to clinical decision-making criteria?

1.3. Paper Structure

This paper is organized as follows. Section 2 constructs a theoretical framework integrating the three-tier digital divide model, digital justice theory, and technopolitical critique. Section 3 elaborates on the research design. Section 4 delivers a critical cross-national policy comparison. Section 5 focuses on the technological promises, algorithmic biases, and cross-cultural applicability of dementia digital biomarkers. Section 6 provides an integrated discussion. Section 7 concludes and offers policy recommendations.

2. Literature Review and Theoretical Framework

2.1. The Three-Tier Digital Divide Model and Geriatric Health

The canonical digital divide framework delineates three hierarchical strata [7]: the first-level access divide (infrastructure and device ownership), the second-level usage divide (digital literacy and quality of engagement), and the third-level outcome divide (differential tangible benefits derived from digital use). Within geriatric health, these three tiers generate unique compounded disadvantages.

At the access tier, older adults globally demonstrate far lower internet penetration than younger cohorts. In the U.S., only 75% of adults aged 65 and above possess basic internet proficiency, 30% of elderly households lack desktop or laptop computers, and more than half do not own smartphones. In China, while 83% of middle-aged and elderly citizens own mobile phones, merely 6.5% maintain regular internet access. At the usage tier, seniors face substantial barriers relating to digital literacy, health literacy, and interface usability. A Canadian systematic review identified seven core categories of impediments: physical health limitations, deficient support networks, poor convenience and usability, insufficient knowledge and information, low self-efficacy and perceived barriers, resource shortages, and disadvantages specific to marginal subgroups. At the outcome tier, the tangible benefits of digital health services are unevenly distributed across populations. For instance, Agarwal et al. [7] demonstrate that electronic health record (EHR)-trained AI predictive models underperform for low socioeconomic status (SES) groups, stemming from inconsistent healthcare engagement, incomplete medical records, and inferior data quality among these populations—producing starkly divergent clinical outcomes from digital health interventions across racial and class strata.

Nevertheless, the three-tier model bears limitations when applied to older populations: it frames access as a neutral technical matter, overlooking the socially constructed nature of access conditions. For individuals living with dementia, the usage divide extends beyond insufficient literacy to structural inaccessibility wrought by cognitive deterioration—an unbridgeable gap that cannot be resolved through training or auxiliary support alone.

2.2. Digital Justice and Algorithmic Justice Theory

Digital justice theory argues that technological design ought not prioritize efficiency or innovation as sole objectives, but center distributive justice, recognition justice, and participatory justice as core ethical tenets [8] data justice framework emphasizes data rights and Global South perspectives, advocating a shift from individualistic privacy protection frameworks toward collective empowerment grounded in social justice. Building upon this foundation, this paper conceptualizes **algorithmic justice** as a targeted extension and concretization of Taylor's data justice framework at the algorithm design stage: it addresses not only rights distribution in data collection and utilization, but also bias identification, cultural recognition, and community participation within algorithmic decision pipelines.

Technical literature on algorithmic fairness typically prioritizes statistical equity metrics such as demographic parity and equalized opportunity. Yet these metrics frequently overlook the social selectivity embedded in training data—data generation processes themselves are products of unequal social structures [9]. Within healthcare, EHR datasets yield inferior model performance for low-SES populations due to uneven healthcare access, incomplete documentation, and inconsistent data fidelity [10]. This paper distinguishes algorithmic fairness from algorithmic justice: the former constitutes a technical goal of statistical optimization, while the latter represents a normative framework encompassing distributive, recognition, and participatory dimensions.

2.3. Technopolitics and Governmentality Analysis

Digital biomarkers function not merely as measurement instruments, but as governance technologies that categorize, rank, and allocate medical resources [11]. In *The Birth of the Clinic*, Foucault (1975) [12] illustrates how the medical gaze transforms individuals into governable subjects

through classification and standardization. This analysis deepens in Foucault's (1978) [13] concept of governmentality, which examines how statistics, categorization, and knowledge production govern populations by enabling self-discipline amid nominal freedom. Digital biomarkers embody contemporary apparatuses of governmentality: continuous passive data collection translates older adults' cognitive status into calculable risk scores that determine eligibility for early intervention, clinical trial enrollment, and future disease-modifying therapies.

Bowker and Star's (1999) [11] infrastructure of classification theory further posits that established categorization systems freeze social relations—they do not merely reflect reality, but actively shape it. When digital biomarkers label cognitive traits prevalent among certain racial, linguistic, or educational subgroups as "abnormal", they entrench pre-existing social inequities cloaked under the veneer of scientific objectivity.

3. Research Design

3.1. Analytical Framework

This article is a critical comparative policy analysis (CCPA) integrated with technopolitical analysis. It does not report primary empirical data or statistical findings; rather, it synthesizes secondary policy documents and published technical literature to develop a normative framework for equitable digital health governance. The analytical workflow proceeds in three steps:

- Structured thematic analysis of purposively sampled policy documents: U.S. and Chinese digital geriatric health policies were sampled and coded to identify institutional manifestations of digital-first bias.
- Critical interpretive synthesis of technical literature: Research on dementia digital biomarkers was purposively synthesized to unpack algorithmic bias and cross-cultural applicability crises.
- Cross-case comparison and synthetic critique: Policy analysis and technical critique were juxtaposed to expose structural contradictions undermining digital health equity.

3.2. Data Sources and Sampling Strategy

Policy documents (purposive sampling). National-level policy documents were purposively sampled to capture the institutional logic of each country's digital geriatric health governance. Inclusion criteria were: (a) national-level policy or regulatory texts issued by central government agencies; (b) explicit focus on digital health, telehealth, or smart elderly care; (c) publication between 2020 and June 2026. Exclusion criteria were: sub-national or local pilot documents (unless used as illustrative examples), purely technical implementation guidelines without policy intent, and industry white papers without regulatory status.

For the United States, sampled documents included: the Federal Communications Commission (FCC) Affordable Connectivity Program (ACP) orders and wind-down notices; Centers for Medicare & Medicaid Services (CMS) telehealth reimbursement rules (2020–2026); and relevant Congressional Research Service reports. For China, sampled documents included: the 14th Five-Year Plan for National Ageing Undertakings and Elderly Care Service Systems; the MIIT–Ministry of Civil Affairs Action Plan for Smart Health and Elderly Care Industry Development; and State Council circulars on promoting smart elderly care. Local initiatives (e.g., Guangdong provincial portals) are referenced as illustrative examples but were not systematically sampled.

Academic and grey literature (purposive critical synthesis). Given the paper's objective to develop a normative critique rather than to estimate effect sizes, the literature synthesis followed purposive critical synthesis standards rather than systematic review protocols (e.g., PRISMA). This approach is appropriate for CCPA because it prioritizes theoretical saturation and conceptual coverage over exhaustive enumeration. Search terms included combinations of: "dementia AND digital biomarkers"; "algorithmic bias AND healthcare AND race"; "cross-cultural validation AND dementia screening". Databases included PubMed, Web of Science, and CNKI. Grey literature from the WHO, UNFPA, and World Bank was included to anchor equity claims in global health policy discourse.

3.3. Analytical Procedure and Coding

Policy documents were analyzed using structured thematic coding guided by a deductively derived coding frame based on the three-tier digital divide model [6] and the three dimensions of algorithmic justice (distributive, recognition, participatory). The coding frame comprised four master themes: (1) digital-first policy logic; (2) implicit exclusion mechanisms; (3) non-digital pathway provisions; and (4) equity safeguards. Coding was conducted by the primary author and reviewed by co-authors for consistency. Discrepancies were resolved through consensus discussion. Themes were then mapped onto the comparative table (Section 4.3) with explicit notation of evidence strength (strong, moderate, interpretive).

Positionality statement. The author received academic training in the Global North, yet centers systematic underrepresentation of the Global South within digital health research. Acknowledging that knowledge production is constrained by specific academic traditions and linguistic hegemony, this analysis integrates Chinese policy experiences as a core analytical pillar to challenge the Western-center/non-Western-periphery research paradigm. The author further clarifies that analysis of people living with dementia draws exclusively from secondary literature rather than lived experience, rendering community participatory validation a methodological ideal advocated here but not fully realized within this study.

3.4. Ethical Considerations

This study analyzes publicly available government policy documents and published academic literature. It does not involve human participants, primary data collection, or identifiable personal data. Therefore, formal ethical approval was not required.

4. Cross-National Policy Comparison: Institutional Realities of Connected and Disconnected Seniors

4.1. The United States: Institutionalized Digital Exclusion amid High Digital Penetration

The U.S. ranks among the world's most digitally penetrated healthcare markets. Following the COVID-19 pandemic, telehealth was permanently incorporated into Medicare reimbursement frameworks, driving rapid expansion of digital health platforms. Yet this high penetration conceals profound access inequities.

U.S. federal digital health policies operate under a market-driven core logic supplemented by targeted subsidy corrections. Flagship policies include the FCC's Affordable Connectivity Program (ACP), which provides monthly USD 30 internet service discounts and one-time USD 100 device subsidies for low-income households. However, the ACP ceased enrolling new

participants in February 2024 due to funding exhaustion (FCC, 2024) [14]—a development demonstrating the fragility of subsidy models: guaranteed access for disconnected seniors collapses alongside fading political prioritization. Medicare telehealth reimbursement designates video consultations as the standard service modality, yet 25% of adults aged 65+ lack basic internet proficiency, and 30% of elderly households are without personal computers.

Older adults living with dementia face dual exclusion within the U.S. digital health ecosystem: operational barriers stemming from cognitive impairment, and implicit age bias among clinical providers. Research confirms clinicians frequently default to the assumption that "older adults cannot operate technology" and fail to proactively offer telehealth options, generating supply-side exclusion. Additionally, ambiguous regulatory frameworks govern the role of legal surrogates (family caregivers or guardians) in telehealth: surrogates are authorized information providers yet risk exclusion under patient autonomy-centric privacy frameworks.

The core structural flaw of U.S. policy lies in its institutionalized digital-first design logic. Telehealth reimbursement, quality assessment, and service standards all implicitly presuppose patients possess independent proficiency with digital platforms. This creates a two-tier healthcare system: digitally connected seniors access more convenient, continuous care, while disconnected seniors are relegated to shrinking traditional in-person service channels. This digital Darwinism—framing technological adaptability as a new screening criterion for medical resource allocation—contradicts foundational ethical principles of healthcare equity.

4.2. China: Tensions Between Smart Elderly Care and the Digital Divide amid Rapid Expansion

China hosts the world's largest elderly population (nearly 300 million adults aged 60+), pursuing nationwide digital health rollout via the national Smart Health and Elderly Care (SHEC) strategy. The gap between its policy ambitions and on-the-ground implementation delivers a distinct critical case study.

China's digital geriatric health policies follow a state-led, pilot-diffusion core logic. SHEC is not merely a rhetorical "smart" label, but a multi-layered tech-institutional complex integrating IoT, cloud computing, big data, wearables, and intelligent hardware. Its immediate policy objective supports China's 90-7-3 elderly care model—90% home-based care, 7% community-supported care, 3% institutional care—prioritizing remote monitoring and emergency response for rural empty-nest seniors and disabled older adults. The central government targets establishing 5,000 age-friendly communities by 2025, rolling out smart wearables, one-touch emergency call systems, and AI voice assistants through national pilot programs.

SHEC policy design incorporates greater awareness of non-digital alternatives compared to U.S. frameworks. For example, Guangdong provincial government portals include elderly care modules enabling family proxy access, with multilingual voice search supporting Mandarin, Cantonese, and regional dialects. Eleven national pilot sites delivered elderly digital literacy training, while six established peer support networks featuring senior digital experience ambassadors who guide fellow older adults. Nevertheless, these pilot innovations remain minimally scaled across the country's 300 million elderly citizens. No national datasets confirm these models have progressed beyond localized experiments, highlighting structural bottlenecks inherent to China's "pilot first, nationwide rollout" policy pathway.

The fundamental tension within China's policy architecture lies in the "smart" label itself functioning as an access threshold. PMC-index quantitative evaluation of 10 representative national policies identifies elderly education and elderly insurance as significant underdeveloped dimensions (average score only 0.77. Policy instruments rely predominantly on incentive and innovation-oriented mechanisms, absent mandatory regulatory standards, eliminating external pressure on enterprises to develop genuinely age-adapted products. When smart elderly care is framed as the benchmark for high-quality development, non-digital traditional services (home visits, community day care) face marginalization risks. Once "smart" shifts from a descriptive modifier to a primary subject, technology becomes an implicit prerequisite for accessing elder care services.

4.3. Comparative Analysis: Shared Blind Spots Under Techno-Solutionism

Dimension	United States Model	China Model	Algorithmic Justice Dimension	Evidence Strength
Core Governance Logic	Market-driven with supplementary subsidies	State-led with pilot-based diffusion	Distributive	Strong
Responses to Disconnected Seniors	Auxiliary telehealth hubs, community broadband centers	Proxy digital access, peer literacy training, dialect-compatible interfaces	Participatory	Moderate (U.S.); Interpretive (China)
Key Blind Spot	Frames digital illiteracy as an individual responsibility	Equates "smart technology" with progress, enabling erosion of non-digital service pathways	Recognition	Strong
Underlying Structural Risk	Healthcare access stratified by technological proficiency	Urban-rural and regional disparities concealed under tech-centric narratives	Distributive	Strong
Unique Dementia-Specific Challenges	Supply-side age bias, ambiguous surrogate care frameworks	Lack of formal family digital proxy mechanisms, vacant rural service coverage	Recognition / Participatory	Moderate

Note: Evidence strength is coded as follows: **Strong** = supported by multiple independent quantitative or policy-evaluative sources; **Moderate** = supported by at least one empirical study or official evaluation; **Interpretive** = based on policy text interpretation or localized grey literature with limited generalizability. Local pilot data from Guangdong and other sub-national sites are treated as illustrative examples, not systematically sampled evidence.

Despite divergent institutional systems, both nations adhere to a shared techno-solutionist governance logic: complex social challenges (population ageing, uneven medical resource distribution, cognitive impairment) are reduced to technical connectivity problems, operating under the assumption that internet access alone resolves systemic inequities. This logic carries acute dangers for people living with dementia: when cognitive deterioration renders smartphone operation functionally impossible, digital literacy training and auxiliary tools become ineffective, even dehumanizing, interventions.

5. Dementia Digital Biomarkers: Technological Promises and Algorithmic Justice Crises

5.1. Technical Typologies, Diagnostic Visions, and Validation Gaps

Dementia digital biomarkers refer to quantifiable objective indicators of cognitive function passively or actively captured via smartphones, wearable devices, ambient sensors, and other digital tools [15]. Primary categories include:

- Speech and linguistic biomarkers: Analyze speech rate, pause patterns, lexical diversity, and semantic coherence [16]
- Gait and mobility biomarkers: Deploy accelerometers to measure walking speed, gait variability, and turning stability [17]
- Digital interaction patterns: Passively track typing speed, application usage frequency, and social engagement metrics [18]
- Physiological signals: Continuous monitoring of heart rate variability, sleep architecture, and blood oxygen saturation via smartwatches

The core appeal of these biomarkers lies in scalability, longitudinal continuity, and ecological validity: they enable low-cost, high-frequency monitoring within real-world living environments. To date, however, neither the U.S. Food and Drug Administration (FDA) nor China's National Medical Products Administration (NMPA) has approved any digital biomarker as an independent diagnostic tool for dementia; all existing products remain confined to research validation or pilot auxiliary screening applications. This validation gap—where digital biomarkers are imbued with transformative policy expectations prior to rigorous clinical efficacy testing—constitutes a primary risk to health equity.

5.2. Algorithmic Bias: Race, Education, and Embedded Social Structures

5.2.1 Racialized Biomarker Disparities and Bias Loops

African American adults experience a 64% higher dementia incidence rate than non-Hispanic White counterparts, yet biomarker research reveals a confounding paradox [19]:

- Tau protein biomarkers: Multiple studies demonstrate significantly lower cerebrospinal fluid t-tau and p-tau181 levels among African American participants in cognitively healthy (HC) and mild cognitive impairment (MCI) cohorts, despite elevated clinical dementia risk.
- Amyloid PET imaging: Findings remain inconsistent, with studies reporting conflicting directional disparities in amyloid deposition across racial groups.
- APOE ε4 genotype interactions: The genotype exhibits far stronger associations with Alzheimer's disease (AD) risk in White populations relative to African American cohorts, indicating identical biomarkers carry divergent predictive validity across racialized subgroups.

While some researchers attribute these disparities to biologically distinct AD pathology across races, critical interpretations trace bias to flawed research design. Alzheimer's Disease Center (ADC) recruitment practices generate severe healthy participant bias: enrolled African American participants tend to possess greater socioeconomic resources and baseline health than non-participants, whereas White participants are disproportionately referred to research by clinicians due to subjective memory complaints or family disease history [19].

Obermeyer et al.'s [20] landmark study delineates the mechanism through which bias propagates from training datasets to clinical deployment. Analyzing a commercial algorithm deployed to over 200 million U.S. patients, the team found the model used medical spending as a proxy for disease severity. Systemic historical inequities result in reduced clinical investment in Black patients, leading the algorithm to chronically underestimate Black patients' disease burden. Correcting this bias raised the proportion of Black patients qualifying for enhanced care support from 17.7% to 46.5. This bias loop mechanism equally applies to dementia digital biomarkers: training datasets that reproduce unequal social structures—shaping who participates in research, who is formally classified as a patient, and who receives comprehensive clinical assessment—yield algorithms that perpetuate racialized health inequities.

5.2.2 Culturally Specific Diagnostic Thresholds: Whose "Normal" Sets the Standard?

Current AD biomarker cut-off values are predominantly developed using White-dominated cohorts such as the Alzheimer's Disease Neuroimaging Initiative (ADNI). Applying these thresholds to African American populations risks systematic missed diagnoses, as lower baseline tau levels delay classification of pathological abnormality and narrow windows for early intervention. Kumar et al. (cited in Gleason et al., 2021) [19] explicitly confirm that existing cut-off values lack suitability for Black patients.

This logic extends directly to digital biomarkers. Speech analysis algorithms trained on native English acoustic profiles systematically misclassify non-native speakers, dialect users, and individuals with divergent linguistic styles shaped by educational attainment. Implicit cultural bias is well-documented in cognitive testing: White participants consistently score higher on instruments including the MoCA and Trail Making Test Part B, reflecting the cultural embeddedness of assessment tools rather than genuine differences in cognitive capacity.

5.2.3 Data Representation Crises: Data Invisibility of Excluded Populations

Algorithmic bias originates in social selectivity within data generation. EHR-trained AI models underperform for low-SES populations due to inconsistent healthcare contact, incomplete medical documentation, and inferior data quality among these groups. More critically, the EU AI Act mandates datasets that are relevant, representative, error-free, and complete, yet opt-out rights operate unevenly across demographic subgroups in practice. UK NHS data demonstrates Black populations exercise data opt-outs at higher rates than White and Asian cohorts, while low-SES individuals, patients with advanced dementia, and frail nursing home residents reliant on legal surrogates are systematically excluded from research databases.

This creates a self-reinforcing vicious cycle: the populations most vulnerable to algorithmic inequity are rendered invisible within datasets; this data invisibility is encoded by algorithms as low clinical priority or statistical outliers, exacerbating marginalization.

5.3. Cross-Cultural Applicability: Deep Challenges Beyond Linguistic Translation

5.3.1 Non-Transferability of Language-Dependent Biomarkers

Speech biomarkers represent the most culturally dependent category of digital indicators. Contemporary speech analysis research centers on structured tasks (e.g., the Cookie Theft picture description paradigm) and English reference corpora, including DementiaBank and ADReSS. Multilingual and cross-cultural research confirms that cross-linguistic generalization cannot be assumed. While spontaneous speech studies in

Italian and Spanish demonstrate feasibility for non-English contexts, they underscore mandatory ecological sampling and external validation protocols.

For early dementia screening, pragmatic linguistic markers—such as conversational turn-taking, discourse coherence, and speech repair strategies—often exhibit greater diagnostic sensitivity than literal speech content, yet these markers are deeply embedded within culturally specific communicative norms. For instance, high-context East Asian communication frameworks interpret silence as respect or reflective deliberation, whereas Western low-context conventions classify silence as delayed response or cognitive retrieval failure—a distinction unaccounted for by monolingual speech algorithms.

5.3.2 Cognitive Reserve, Educational Attainment, and Confounding Digital Biomarker Signals

Cognitive reserve theory posits that educational attainment and lifelong intellectual activity buffer the direct clinical manifestations of neuropathological damage [21]. Identical neurodegenerative pathology may present as cognitively unimpaired among highly educated individuals while manifesting as a clinical abnormality in low-education populations. When digital biomarkers (typing speed, lexical complexity) operationalize educational attainment as a proxy for cognitive capacity, they measure social inequity rather than neuropathology.

Empirical studies confirm that educational attainment confounds digital biomarker performance. Smartphone typing speed testing demonstrates that highly educated adults maintain rapid typing velocity during early cognitive decline, while low-education cohorts exhibit slower baseline typing speeds prone to misclassification as cognitive impairment. This education confounding effect intensifies in cross-cultural comparisons, where divergent national education systems, literacy rates, and lifelong digital exposure render universal global baselines for digital interaction biomarkers functionally unachievable.

5.3.3 Cross-Cultural Validation of Plasma Biomarkers: A Cautiously Optimistic Case

Plasma p-tau217 and p-tau181 serve as precision biological biomarkers with promising cross-cultural validation results from Taiwanese and South Korean cohorts. Studies report p-tau217 achieves excellent predictive performance for amyloid PET positivity (AUC = 0.921), with mutually verifiable model outputs across the two East Asian cohorts [22]. Nevertheless, this apparent success demands cautious interpretation: the research remains limited to culturally similar East Asian subgroups, excluding Southeast Asian, South Asian, African, and Latin American populations. While plasma biomarkers carry weaker direct cultural confounds than speech or cognitive testing tools, their interactive effects with APOE genotypes and vascular risk factors remain population-specific. Most importantly, technical validation does not equate to health equity: even biologically transferable biomarkers face barriers to equitable rollout stemming from uneven medical infrastructure, limited testing access, and prohibitive costs.

5.3.4 The Biomarker Paradox in Hispanic Populations and Bilingual Cognitive Reserve

Screening data from the TRAILBLAZER-ALZ2 trial reveal amyloid positivity rates of only 37% among Hispanic participants, compared to 80% among non-Hispanic White participants. This stark disparity cannot be reduced to claims of less prevalent AD pathology among Hispanic populations, but instead reflects compounding influences: neuroprotective bilingual/multilingual cognitive reserve, dominant vascular comorbidities, and overlapping social determinants, including low educational attainment, elevated cardiovascular disease burden, and neighborhood poverty indices shaping cognitive performance.

Longitudinal cohort research confirms the neuroprotective effects of bilingual cognitive reserve. Bialystok et al. [23] studied 184 dementia patients and found bilingual individuals experienced symptom onset an average of four years later than monolingual counterparts, with equivalent rates of MMSE score decline post-diagnosis. This indicates bilingual cognitive reserve delays disease onset without altering progression trajectories. When speech biomarkers flag language switching or code-mixing as markers of cognitive disorganization, algorithms penalize a culturally rooted neuroprotective asset, constituting not merely a technical error, but erasure of cultural diversity.

6. Discussion

6.1. Precision Medicine or Precision Exclusion? Cumulative Effects of Marginalization

Research and deployment of dementia digital biomarkers crystallize core contradictions within digital geriatric health policy. Digital biomarkers' promise of precise early detection carries distributive consequences: populations identified early secure priority access to intervention windows, clinical trial enrollment, and future disease-modifying therapeutics. Yet systematic disparities in biomarker sensitivity and specificity across racial, linguistic, and educational groups concentrate precision medicine's benefits among privileged cohorts: highly educated, digitally literate, English-speaking urban seniors capable of affording wearable monitoring devices.

For disconnected older adults living with dementia, precision medicine risks devolving into precision exclusion. This exclusion operates through a cumulative causal chain:

- Early missed diagnosis stemming from algorithmic underperformance in marginalized subgroups
- Lost therapeutic intervention windows and delayed access to disease-modifying treatments
- Ineligibility for clinical trials requiring biomarker-positive enrollment criteria
- Permanent exclusion from innovative therapies once approved, as the disease advances to late-stage dementia
- Deteriorated long-term clinical outcomes, amplified caregiving burdens, and forced reliance on costly institutional elder care

Every link in this causal chain superficially operates as technically neutral: algorithms "predict" rather than dictate care allocation; clinical trials "screen" rather than intentionally exclude participants. Yet interconnected, they form a systemic exclusion apparatus that locks specific demographic groups into irreversible disadvantage. The bias loop mechanism identified by Obermeyer et al. [20] forms its core operating logic: historical medical inequities are encoded as data patterns, learned by algorithms as objective scientific laws, and redeployed to govern future resource distribution, cyclically reproducing structural inequality. Breaking this causal chain requires embedding mandatory non-digital service alternatives, stratified performance reporting mandates, and community participatory validation within policy design—empirical grounding for the three normative principles advanced in this paper.

6.2. Policy Remediation: Normative Anchors for Preventive Practice

Rather than proposing granular implementation handbooks, this paper distills three principled normative anchors to guide digital geriatric health

policy value alignment. Each anchor is explicitly linked to concrete preventive medicine and health economics levers:

6.2.1. Mandatory embedded non-digital alternatives

All digital health service rollouts must synchronously guarantee parallel non-digital care pathways as a precondition for launch. Digital services operate as additive supplements, not replacements for traditional care. For dementia populations, in-person clinical assessment, home care visits, and community care constitute irreplaceable ethical safeguards. Preventive practice implications: National dementia screening programs (e.g., Medicare Annual Wellness Visits in the U.S.; community-based cognitive screening in China's Basic Public Health Service) must retain non-digital enrollment channels. Reimbursement rules should not condition screening eligibility on prior digital biomarker registration or smartphone ownership.

6.2.2. Mandatory stratified performance reporting

All algorithms deployed for clinical decision-making must disclose diagnostic performance metrics (sensitivity, specificity, positive predictive value) disaggregated by race, language, education, urban-rural residency, and age strata. Exclusive reliance on aggregate overall accuracy constitutes systemic deception of marginalized populations. Health economics implications: Payers and regulatory agencies (FDA, NMPA) should mandate stratified cost-effectiveness analyses as a condition of coverage or approval. Aggregate quality-adjusted life-year (QALY) gains mask distributional inequities; stratified reporting reveals whether efficiency gains are concentrated among privileged cohorts.

6.2.3. Community participatory algorithm validation

Algorithm validation cannot be confined to technology corporations and academic research centers; formal validation workflows must integrate community advocacy organizations, patient collectives, and cross-cultural neuropsychologists. Preventive practice implications: Clinical trial eligibility criteria for dementia drug trials (e.g., anti-amyloid therapies) increasingly require biomarker-positive status. If biomarker thresholds are derived from non-representative cohorts, trial enrollment systematically excludes racialized and low-education populations, distorting efficacy estimates and post-market surveillance. Community validation extends beyond technical calibration to address epistemic justice: who holds legitimate authority to define cognitive "normality" and "abnormality"?

6.3. Theoretical Deepening: Dialogues with Disability Studies, Participatory Action Research and Postcolonial STS

This paper's algorithmic justice framework engages three scholarly traditions to refine its critical dimensions:

- Dialogue with disability studies: Digital exclusion for dementia patients extends beyond access barriers to unresolved cognitive accessibility deficits. Schmidt et al. [24] argue cognitive accessibility in digital health design demands not merely simplified interfaces, but radical respect for cognitive diversity—affirming equal entitlement to health information across all cognitive profiles. Disability studies scholarship underscores that genuine inclusion does not seek to transform dementia patients into functional digital users, but design service systems independent of restrictive cognitive prerequisites.
- Dialogue with participatory action research (PAR): The community validation principle draws methodological grounding from PAR, which positions research subjects as co-designers rather than passive data donors. Translated to dementia digital biomarker development, PAR mandates patients, family caregivers, and community care providers participate end-to-end in biomarker selection, validation threshold definition, and clinical translation roadmap design. This constitutes both an ethical imperative and an epistemological requirement: only centering lived experience can prevent abstract decontextualized data from overriding concrete human lives.
- Dialogue with postcolonial science and technology studies (STS): Global North dominance over digital biomarker research creates systemic underrepresentation of Global South populations within training datasets and validation cohorts, forming a new mode of epistemic colonialism. Harding's [25][26] postcolonial STS framework reveals universalist claims of Western scientific objectivity constructed through deliberate erasure of non-Western knowledge traditions. Hess [27] further argues that global technological inequities transcend resource distribution to constitute epistemic power struggles over legitimate definitions of truth and progress. Integrating Global South perspectives into biomarker research requires far more than expanded sample sizes; it demands recognition of culturally divergent frameworks conceptualizing cognition, ageing, and health, establishing plural epistemological validation standards.

Synthetic summary: Disability studies articulate equal rights to cognitive diversity; PAR delivers methodological pathways to operationalize recognition justice; postcolonial STS exposes power structures embedded within universalist knowledge production. Collectively, they converge around a core proposition: algorithmic justice requires not merely technically equitable algorithm design, but democratized technological governance. When algorithms evolve from passive tools into apparatuses of population governance, their legitimacy cannot rest solely on technical performance metrics, but must derive from participatory authorization by affected communities. This distinction fundamentally separates this paper's normative algorithmic justice framework from narrow technical algorithmic fairness: it interrogates not only how to optimize statistical equity within algorithms, but who retains authority to define what equity entails.

7. Limitations

This study has several limitations that bound the generalizability of its findings. First, as a critical comparative policy analysis relying on secondary data, it does not incorporate lived experience perspectives of people living with dementia or their unpaid family caregivers. The normative call for community participatory validation remains a methodological ideal that this paper advocates but does not itself fulfill. Second, the policy document analysis is interpretive rather than exhaustive; sub-national and local experiments (e.g., Guangdong proxy access platforms, peer ambassador programs) are referenced as illustrative examples rather than systematically sampled evidence. Consequently, claims about China's policy implementation gaps should be treated as interpretive hypotheses awaiting further empirical evaluation. Third, the literature synthesis on dementia digital biomarkers follows purposive critical synthesis standards rather than systematic review protocols; while this is appropriate for theory-building, it carries risks of selective coverage. Fourth, the comparative framework is limited to two countries and does not capture the diversity of digital geriatric health regimes globally. Finally, the author's academic training in the Global North may introduce epistemic blind spots in interpreting Chinese policy logics, despite reflexive efforts to center non-Western frameworks.

This paper makes three distinct contributions to the health policy and digital health equity literature. First, it is the first study to apply an algorithmic

justice framework—structured around distributive, recognition, and participatory dimensions—specifically to dementia digital biomarkers in a comparative U.S.–China frame. Second, it establishes "embedded non-digital care pathways" not merely as an operational workaround for connectivity gaps, but as a necessary normative condition for algorithmic justice: without guaranteed non-digital alternatives, digital-first policies inherently violate distributive justice by making technological adaptability a de facto screening criterion for healthcare access. Third, it links cross-cultural biomarker validation failures to postcolonial STS critiques of epistemic power, arguing that technical algorithmic fairness metrics are insufficient without democratized governance over the definition of cognitive "normality." These contributions differentiate this paper from existing data justice and AI health equity scholarship by moving beyond statistical bias correction to interrogate the social purpose and ethical boundaries of technological innovation itself.

8. Conclusion

The global digital health transition is reshaping delivery models for elderly medical care, yet tensions between digital access and digital exclusion continue to intensify. Adopting dementia digital biomarkers as an analytical lens, this paper delivers a critical comparative analysis of the United States and China, yielding three core findings:

First, institutional digital-first bias permeates policy frameworks of both nations. U.S. policy frames digital literacy as an implicit prerequisite for Medicare telehealth eligibility, entrenching a two-tier healthcare system governed by digital Darwinism. Chinese national strategy codifies "smart" technology as the benchmark of high-quality elder care, risking marginalization of traditional non-digital service pathways. When "smart" shifts from an adjective to the primary subject of policy design, technology itself becomes an unstated access threshold—the central paradox requiring mitigation within digital geriatric health governance. A shared blind spot unites both national policy regimes: they frame interventions around improving elderly digital connectivity rather than interrogating whether digital systems represent optimal care models for older adults.

Second, dementia digital biomarkers carry pervasive algorithmic bias. Social selectivity within training datasets—racialized recruitment skew, cognitive reserve disparities mediated by education, culturally embedded linguistic frameworks—generates systematic divergence in diagnostic sensitivity and specificity across demographic subgroups. The bias loop mechanism identified by Obermeyer et al. (2019) [20] is empirically validated herein: historical healthcare inequities are encoded as statistical patterns, reified by algorithms as objective scientific truth.

Third, cross-cultural applicability challenges extend far beyond surface-level linguistic translation, encompassing deep cultural embeddedness within cognitive reserve, pragmatic communication norms, and biomarker diagnostic cut-off values, alongside structural underrepresentation of Global South populations in validation research. While plasma p-tau217 validation among East Asian cohorts delivers cautiously optimistic technical results, technical performance does not equate to equitable health outcomes.

This paper's core theoretical contribution is the development of an algorithmic justice normative framework structured around three interdependent dimensions: distributive justice, recognition justice, and participatory justice. It argues technological value ought to be measured by its distributive equity impacts—whether innovation mitigates or solidifies pre-existing social disparities—rather than solely by technical novelty. Algorithmic justice is differentiated from technical algorithmic fairness: the latter pursues optimization of statistical equity metrics, while the former interrogates the social purpose and ethical boundaries of technological innovation.

Policy recommendations derived from the algorithmic justice framework:

- Mandate embedded parallel non-digital care pathways: All digital health service launches must synchronously guarantee non-digital alternatives, with targeted protections for cognitive impairment populations, including dementia patients.
- Mandate public disclosure of stratified diagnostic performance data: Algorithm developers must report disaggregated diagnostic metrics across racial, linguistic, educational, and urban-rural subgroups; aggregate overall accuracy reporting alone is prohibited.
- Establish formal community participatory validation mechanisms: Integrate patient advocacy groups, local community organizations, and cross-cultural neuropsychologists into official algorithm validation workflows to uphold epistemic justice.
- Mandate Global South cohort representation in biomarker research and validation: Overcome colonial-style technology transfer models predicated on Global North research and universalized global deployment via mandatory inclusive sampling of Global South populations.

For disconnected older adults living with dementia, barriers extend beyond technical access to ontological exclusion: within a policy landscape that equates datafication with social visibility, individuals incapable of generating digital traces risk erasure from state planning frameworks. Authentic digital inclusion does not require universal smartphone proficiency, but guarantees full entitlement to health rights regardless of digital engagement. Defending unquantifiable human dignity amid the algorithmic age represents the most profound ethical challenge of the global digital health transition.

CRediT authorship contribution statement

Hui-Lin Zhang: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Cheng-Ze Li:** Writing – original draft, Methodology. **John M. Robineau:** Writing – review & editing, Conceptualization. **Lin Su:** Writing – review & editing, Methodology, Conceptualization.

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

The free versions of Grammarly were used for spell-checking and grammar corrections. After using these tools, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the publication.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

We thank the reviewer for their knowledgeable contributions to the manuscript.

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