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COGNITIVE ERGONOMICS CHALLENGES IN OLDER ADULTS' EVERYDAY ACTIVITIES : A CRITICAL NARRATIVE REVIEW FOR AGE-FRIENDLY SMART CITY DEVELOPMENT

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Abstract

Cognitively accessible public signage and symbols are essential for supporting older adults' independence in age-friendly smart cities. Age-related changes in processing speed, working memory, and attention may create mismatches between information demands and cognitive capacities. This critical narrative review examines cognitive ergonomics challenges in older adults' everyday activities, emphasizing public signage and the effort behind successful task performance. Literature was retrieved from Scopus, ScienceDirect, PubMed, Google Scholar, and Garuda between August and October 2026, with 20 eligible sources synthesized thematically. The Cognitive Failures Questionnaire (CFQ), NASA-TLX, and symbol comprehension tests were critically examined for their complementary strengths and limitations. The proposed conceptual framework distinguishes low-effort success from compensated success, emphasizing that accuracy alone may overlook additional cognitive effort. Supplementary simulation data comprising 240 response time of 12 partisipants, observations showed an overall mean of 7.39 seconds. Directional signs recorded the longest mean response time (8.25 seconds), followed by Safety & Accessibility (7.68 seconds), Public Facility (6.87 seconds), and Traffic/Pedestrian (6.75 seconds). Response time complements performance assessment without directly measuring cognitive effort. Age-friendly smart city development should integrate task accuracy, response time, and cognitive effort into cognitive accessibility assessments. Limited Indonesian evidence warrants further context-specific validation.

Keywords: Age-friendly city, Cognitive ergonomics, Mental workload, older adults', Smart city

INTRODUCTION

According to Badan Pusat Statistik (2024), adults aged 60 years and older accounted for 12% of Indonesia's population in 2024. Population projections based on the 2020 Population Census indicate that this proportion will reach 20.31% by 2045 (Badan Pusat Statistik, 2023). The size of the older population is only part of the issue; living arrangements also play an important role. In an earlier survey of older adults without close family nearby, most respondents reported carrying out their daily activities alone or with a spouse, including visits to markets, places of worship, and other public facilities (Pakiding & Ardiyanto, 2023). Their independence therefore depends largely on whether the products, information, and services they use are designed to accommodate their capacities.

Meanwhile, smart city initiatives have encouraged the digitalization of public services in Indonesian cities. In Balikpapan, for example, the local government introduced the E-Link application to facilitate public reporting, complaints, and access to environmental information (Balikpapan Environmental Agency, 2025). Such initiatives offer opportunities to improve urban accessibility, including for older adults. However, the availability of digital services does not necessarily ensure that older adults can use them independently. A critical review of smart city assessment tools identified limitations in stakeholder engagement and the balanced representation of assessment indicators (Sharifi, 2019). From a cognitive ergonomics perspective, smart city evaluations should therefore consider not only technological availability but also users' ability to understand information and interact effectively with public services. The World Health Organization (2007) included communication and information among the eight domains of its age-friendly city framework, while Marston and van Hoof (2019) later proposed that technology be addressed explicitly across these domains. Balikpapan serves as a contextual example rather than a representative

case of all Indonesian cities. As this review does not systematically compare cities by population size, infrastructure, or digital maturity, the applicability of its findings across different urban contexts requires further investigation.

Accessibility in urban environments extends beyond the removal of physical barriers to include the cognitive demands associated with using public facilities, information, and services. An older adult may have no difficulty reaching a ticket machine but may still struggle to complete a purchase because of complex menu structures or visually similar confirmation and cancellation icons. Cognitive ergonomics addresses this fit between the information-processing demands of a task and the cognitive capacities of the user (Wickens et al., 2015). In earlier fieldwork involving Indonesian older adults, operating electronic devices and using public transport were identified among the activities that respondents found difficult. Reported coping strategies included postponing tasks, seeking assistance from family members or neighbors, and avoiding certain activities altogether (Pakiding & Ardiyanto, 2023). These challenges suggest that successful task completion alone may not fully reflect cognitive accessibility, as older adults may require additional time, effort, or compensatory strategies to achieve the intended outcome.

Existing reviews relevant to older adults' cognitive ergonomics provide complementary perspectives on aging and user interaction. Clinical and neuropsychological reviews describe age-related changes in cognitive functioning, particularly in processing speed, memory, and attention (Harada et al., 2013; Yang et al., 2023). From a gerontechnology perspective, Peek et al. (2014) identified factors influencing technology acceptance among older adults, including perceived benefits, concerns about technology, and social influence. Similarly, Lee and Coughlin (2015) developed an integrated framework of technology adoption that incorporates usability, accessibility, experience, and independence. Studies on sign and symbol comprehension provide a different perspective by examining users' ability to interpret visual information (Chan & Ng, 2010; Duarte et al., 2014). Although these studies offer complementary insights into cognitive capacities, technology adoption, and task performance, their analytical objectives differ. An integrative cognitive ergonomics perspective is therefore valuable for examining not only whether older adults successfully interpret public information but also the time, cognitive effort, and compensatory strategies potentially involved in achieving successful performance. This distinction is particularly relevant to evaluating the cognitive accessibility of public signage and information systems in age-friendly smart cities.

This critical narrative review integrates the literature on cognitive aging, technology use, and public signage comprehension to examine how cognitive capacities, task demands, and cognitive effort can be considered together in evaluating older adults' cognitive accessibility in everyday urban activities. Drawing on published literature, this review critically examines the complementary strengths and limitations of the Cognitive Failures Questionnaire (CFQ), the NASA Task Load Index (NASA-TLX), and symbol comprehension tests as cognitive ergonomics assessment instruments. The distinctive contribution of this review is a conceptual framework that distinguishes low-effort success from compensated success, recognizing that successful task performance does not necessarily reflect low cognitive effort. To complement the literature synthesis, a supplementary descriptive analysis focuses exclusively on response times obtained from a public signage comprehension simulation. Response time is considered a complementary indicator of task performance rather than a direct measure of cognitive effort. This integrated approach provides a basis for identifying research gaps and formulating cognitive ergonomics recommendations for the development of inclusive, age-friendly smart cities, particularly within the Indonesian context.

LITERATURE REVIEW

Cognitive Aging and Compensation

Aging does not affect all cognitive functions to the same degree. Vocabulary and general knowledge, often referred to as crystallised abilities, tend to remain stable until late in life, whereas processing speed, working memory, inhibition and divided attention decline gradually from early adulthood (Harada et al., 2013). Salthouse (1996)attributed much of this pattern to a general slowing of processing. When each mental operation takes longer, the products of earlier operations may no longer be available when later operations need them, so complex tasks are affected more than simple ones. Neuroimaging studies further show that Elderly often recruit additional brain regions to maintain their performance, a mechanism described as compensatory scaffolding (Park & Reuter-Lorenz, 2009). From a design perspective, this means that an older user who performs as well as a younger user may still be working harder to do so. The resources used for compensation are then no longer available for other demands occurring at the same time, such as watching for traffic or remembering a queue number.

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Mental Workload

Mental workload is generally understood as the relationship between task demands and the resources a person has available, rather than as a fixed property of a task. According to multiple resource theory, tasks draw on partly separate perceptual, cognitive and response resources, and workload increases when several demands compete for the same resource or exceed the resources available (Wickens, 2008). Longo et al. (2022)proposed a broader definition that also takes into account the individual's capacity, state and experience. Following this view, the same kiosk or pictogram may be easy for a 30-year-old and demanding for a 70-year-old, even if both eventually complete the task.

Figure 1 presents the conceptual framework developed in this review. The relationship between task demands and available cognitive capacity draws on established cognitive ergonomics principles (Wickens et al., 2015). Based on these principles, this review proposes four possible outcomes: low-effort success, compensated success, assisted success, and task failure. Low-effort success refers to independent task completion with relatively little effort, whereas compensated success involves independent completion through additional effort or compensatory strategies. Assisted success occurs when the intended goal is achieved with external assistance, while task failure occurs when the goal is not achieved. Thus, failure to complete a task independently does not necessarily indicate failure to achieve the intended goal. Response time, perceived workload, repeated information checking, and observable compensatory strategies may help distinguish low-effort success from compensated success. These outcomes represent the author's conceptual synthesis, and no classification thresholds are proposed because the framework has not yet been empirically tested.

The CFQ, NASA-TLX, and SCT provide complementary information at different levels and timescales. The CFQ captures self-reported cognitive failures in everyday life, NASA-TLX assesses perceived workload following a task, and SCT evaluates task-specific symbol comprehension. Response time provides an additional indicator of task performance. Together, these measures can help interpret task performance in relation to everyday cognitive experiences and perceived workload. However, they assess different constructs rather than a common cognitive capacity and cannot, by themselves, establish compensatory mechanisms. In this review, the three instruments are examined through published literature, while response time is analyzed descriptively using supplementary simulation data.

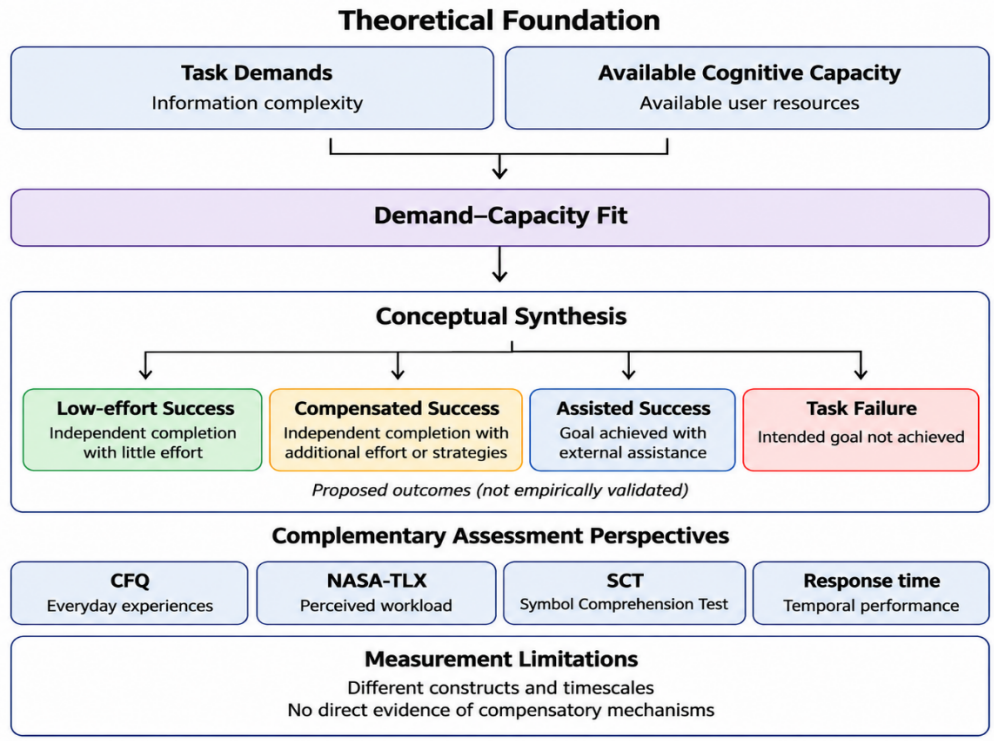

Figure 1. Conceptual framework of demand-capacity fit and complementary assessment measures.

METHOD

This article adopts a critical narrative review approach, which extends beyond summarizing existing literature to critically evaluating evidence and developing conceptual contributions (Grant & Booth, 2009). This

approach was selected to integrate perspectives from neuropsychology, sign design, and urban studies, with an emphasis on conceptual synthesis rather than quantitative aggregation. The Scale for the Assessment of Narrative Review Articles (SANRA) was used as a guide during manuscript preparation (Baethge et al., 2019). Its six assessment aspects guided the justification of the review's relevance, clarification of its objectives, description of the literature search, appropriate referencing, scientific reasoning, and presentation of relevant findings. SANRA was used to guide manuscript quality rather than to assess the methodological quality of individual studies. The literature search, selection, synthesis, and critical appraisal procedures are described separately.

Literature searches were conducted between August and October 2026 using Scopus, ScienceDirect, PubMed, Google Scholar, and Garuda, with the final search conducted on 30 October 2026. Search terms were entered through the general search interfaces without additional field-specific restrictions. The search strategy consistently combined three keyword groups representing population, phenomenon, and context using AND, while alternative terms within each group were combined using OR. An example of the Boolean search string is ("older adults" OR "elderly") AND ("cognitive ergonomics" OR "mental workload" OR "cognitive failure" OR "usability" OR "symbol comprehension" OR "wayfinding" OR "safety sign") AND ("smart city" OR "age-friendly" OR "public service" OR "household device").

The search included journal articles and conference proceedings published in English or Indonesian from January 2000 through January 2026. For Google Scholar, the first 20 results of each search query were examined using relevance-based ranking, although the sorting settings were not formally documented. Reference lists and citing publications were also examined to identify additional relevant sources. Publications before 2000 were considered when they introduced foundational theories or assessment instruments that remain relevant to the review, such as the original CFQ and NASA-TLX publications. Additional sources, including master's theses, international standards, and national statistical reports, were considered when they provided relevant theoretical, methodological, or contextual information.

The eligibility criteria distinguished between direct and supporting evidence. Direct evidence included studies examining adults aged 60 years or older and comparative studies across age groups that reported findings specific to older adults, particularly regarding cognitive aspects of technology use, public information, signage, and everyday activities. Supporting evidence included studies involving other age groups, theoretical frameworks, instrument development and validation, design principles, standards, and relevant contextual information. Studies involving younger adults, students, workers, or experts were included when they provided relevant methodological, theoretical, or design-related insights rather than direct evidence of older adults' cognitive performance. Studies focusing exclusively on clinical diagnosis, medical treatment, or physical ergonomics without relevance to the review objectives were excluded. Existing literature reviews were retained only when they provided relevant theoretical or conceptual contributions. The master's thesis by Pakiding (2024), which primarily investigated ergonomic challenges and musculoskeletal risk factors, was retained solely to provide contextual information on the everyday activities and ergonomic challenges of Indonesian older adults. It was not treated as direct evidence of cognitive performance. Findings from different population groups were interpreted within their respective research contexts to avoid unsupported generalizations to older adults. .

The selected publications were examined based on their research objectives, participant characteristics, assessment methods, research contexts, and key findings, where applicable. The literature was organized narratively according to its relevance to the review objectives and the relationships between findings across publications, without applying a formal thematic coding procedure. The first three stages of literature selection were conducted collaboratively by all three authors, with differences in interpretation resolved through discussion and majority agreement. The fourth stage, final selection, and literature synthesis were conducted by the first author. The conceptual framework presented in Figure 1 was developed collaboratively by all three authors based on the literature synthesis. Critical appraisal was conducted qualitatively by considering study design, sample size, participant characteristics, assessment methods, research context, and methodological limitations. Potential selection, measurement, and cultural biases were considered when interpreting the findings, particularly regarding participant representativeness, measurement limitations, and cultural differences. Differences in findings were examined in relation to variations in study characteristics and research contexts. Greater emphasis was placed on evidence directly relevant to older adults and the review objectives. Findings from different populations and cultural contexts were interpreted cautiously to avoid unsupported generalizations to Indonesian older adults. No formal risk-of-bias assessment or numerical quality scoring was conducted.

A total of 49 publications were initially identified through the literature search. After removing seven duplicate publications, 42 publications remained for title and abstract screening. Of these, 32 publications were

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retained for full-text assessment, and 27 were considered eligible for further evaluation. The primary reasons for exclusion were an emphasis on clinical or medical aspects and insufficient relevance of existing literature reviews to the objectives of this review. Following the final assessment, 20 publications were selected for critical review and narrative synthesis.The 20 selected publications comprised both empirical and non-empirical publications. Additional references, including foundational theories, textbooks, instrument publications, international standards, national statistics, and master's theses, were used to support theoretical, methodological, and contextual discussions. These supporting references were distinguished from the publications included in the main synthesis.

RESULTS AND DISCUSSION

Heterogeneity of Cognitive Aging in Design Research

A recurring weakness in design research is treating older adults as a homogeneous group despite differences in age, education, technology experience, and reading habits. Cognitive aging is generally gradual and uneven, and most older adults using public facilities do not have clinical cognitive impairment (Harada et al., 2013). Therefore, design should focus on whether interface demands exceed users' available cognitive capacity rather than assuming impairment based on age alone.

Familiarity helps compensate for slower processing, with symbol comprehension influenced by familiarity, concreteness, and the relationship between images and their meanings (Mcdougall et al., 1999; Ng & Chan, 2007). As a result, replacing established signage with a new visual style may reduce comprehension among older residents by removing familiar cues.

Areas of Everyday Difficulty

Three areas of everyday difficulty emerge from the reviewed literature. The first involves the use of everyday electronic devices, including smartphones and tablets. Vaportzis et al. (2017) identified a lack of clear instructions and fear of making mistakes as barriers to tablet use among older adults. Salman et al. (2018) identified 27 usability problems in smartphone interfaces through expert evaluations complemented by user testing with older adults, highlighting the importance of considering both interface design characteristics and actual user performance. Sonderegger et al. (2016) further highlighted discrepancies between subjective usability evaluations and actual task performance among older adults.

In the Indonesian context, Pakiding and Ardiyanto (2023) examined the independence of 30 older adults aged 60–80 years in Yogyakarta using the Katz and Lawton questionnaires. The findings indicated that most participants maintained independence in various everyday activities. Although cognitive performance was not directly assessed, limitations in everyday activities may involve both physical and cognitive challenges. Taken together, these studies suggest that independence and perceived usability alone may not fully reflect cognitive accessibility. Evaluations of everyday technology should therefore consider interface demands, available cognitive capacity, task performance, and the time and effort potentially required to complete a task.

The second area concerns digital public services. Technology adoption among older adults is influenced by perceived usefulness, ease of use, cost, social support, confidence, and computer self-efficacy (Charness & Boot, 2009; Czaja et al., 2006; Lee & Coughlin, 2015; Peek et al., 2014). Although these studies provide insights into technology acceptance and use, they offer limited evidence regarding the cognitive demands experienced during specific public service interactions. Tasks such as completing digital forms, navigating self-service kiosks, and using municipal applications may require information processing, working memory, and decision-making. The application of general technology adoption findings to digital public services in this review represents a conceptual interpretation rather than direct empirical evidence. Further task-specific assessments are needed to determine whether digital public services accommodate older adults' cognitive capacities and support independent task completion.

The third area concerns public signage and wayfinding. Older adults may encounter difficulties when interpreting signs while walking or navigating environments characterized by noise, limited lighting, or time pressure. Wayfinding difficulties may involve spatial processing demands, while symbol familiarity, visual characteristics, age, and education may influence signage comprehension (Deng et al., 2025; Duarte et al., 2014; Jamshidi et al., 2020; Wu et al., 2022). However, differences in participant characteristics, research settings, and assessment procedures limit direct comparisons across studies. Evidence obtained from younger adults, occupational groups, or specific healthcare environments may not directly represent older adults' performance in everyday urban settings. These differences highlight the importance of considering both user characteristics and contextual demands when evaluating the cognitive accessibility of public signage.

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Table 1 presents ten representative studies selected for their relevance to the three areas of everyday difficulty and their associated assessment approaches. These studies provide direct evidence involving older adults, supporting evidence from other population groups and expert evaluations, and contextual evidence concerning everyday independence. The table provides a focused comparison of relevant evidence rather than an exhaustive presentation of the 20 publications included in the critical narrative synthesis. Differences in study characteristics, assessment methods, findings, and limitations provide a basis for critical interpretation.

Table 1. Representative empirical and supporting evidence on cognitive ergonomics challenges in older adults' everyday activities

Study and domain	Setting and sample	Design and measures	Key findings	Critical note
Vaportzis et al. (2017) Electronic devices	UK; n=18; 65–76 years	Three focus groups; thematic analysis of tablet-use experiences	Lack of instructions and fear of mistakes were barriers.	Direct qualitative evidence; self-reported experiences.
Salman et al. (2018) Electronic devices	Malaysia; 5 experts, 8 older users; ages pending	SMASH heuristic evaluation (severity 0–4) and smartphone user testing	27 usability problems; experts predicted 79.17% of user problems.	Expert and user evidence; small user sample.
Pakiding & Ardiyanto (2023) Everyday independence	Indonesia; n=30; 60–80 years	Survey; Katz ADL and Lawton IADL questionnaires	Independence: 97–100% (ADL); 73–100% (IADL).	Contextual evidence; no direct cognitive assessment.
Czaja et al. (2006) Technology adoption	USA; n=1,204; 18–91 years	Survey of technology use; attitudes and cognitive battery	Cognitive abilities, anxiety and self-efficacy predicted technology use.	Mixed-age evidence; not specific to public services.
Ng & Chan (2007) Public signage	Hong Kong; n=41; ages pending	Interpretation of 120 traffic signs; guessability and design-feature ratings	Semantic closeness and familiarity predicted guessability.	Supporting evidence; not specific to older adults.
Duarte et al. (2014) Public signage	Portugal; n=90; workers 21–62, students 18–28, cerebral palsy group 16–53 years	17 safety signs; ISO 9186 open comprehension test; oral responses	Comprehension varied across groups; workers and students generally scored higher.	Supporting evidence; older adults not the target population.
Wu et al. (2022) Wayfinding	China; design n=24 (73 ± 9.7 years); evaluation n=77 (>60 years); 3 experts	Participatory design; nine symbol pairs; judgment test (0–100%)	Six of nine redesigned symbols had higher estimated understandability.	Direct design evidence; judgment is not actual accuracy.
Gungor (2023) Public signage	Turkey; n=139 workers; mean 32.15 ± 4.8 years	22 safety signs; online multiple-choice test	Mean comprehension 66.6%; range 22.5–98.6%.	Occupational evidence; not representative of older adults.
Deng et al. (2025) Public signage	China; n=100; 50 aged 18–45 and 50 aged 65–80	42 healthcare symbols; accuracy, response time and feature ratings	Younger vs older: 74% vs 57%; 9.55 vs 11.92 s.	Direct comparative evidence; hospital context.
Devos et al. (2020) Assessment methods	USA; n=38; ≥65 years; mean 73.81 ± 5.23 years	0-, 1-, 2-back tasks; test–retest; raw NASA-TLX, ICA and ERP	ICC: NASA-TLX 0.71–0.81; ICA 0.56–0.73.	Direct methodological evidence; laboratory tasks.

The evidence summarized in Table 1 highlights the multidimensional nature of cognitive accessibility. Studies on technology use emphasize cognitive abilities, user experience, confidence, and interface characteristics, while signage studies highlight semantic closeness, familiarity, and visual design. However, differences in participant characteristics, task demands, and measurement formats limit direct comparisons across studies. For example, Gungor (2023) examined actual safety sign comprehension among industrial workers, whereas Wu et al. (2022) assessed estimated symbol understandability among older adults. Similarly, Pakiding and Ardiyanto (2023)

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assessed everyday independence without directly measuring cognitive effort. These differences should be considered when interpreting the relevance of existing evidence to older adults' everyday interactions.

Taken together, the reviewed studies indicate that no single assessment perspective adequately captures the different dimensions of cognitive accessibility. Everyday cognitive experiences, perceived workload, task accuracy, and response time provide complementary information about user interaction. Their integration may support a more comprehensive evaluation of the relationship between task demands and available cognitive capacity. However, the applicability of these assessment approaches to Indonesian older adults requires further context-specific investigation.

Strengths and Limitations of the Assessment Instruments

The Cognitive Failures Questionnaire (CFQ) measures the self-reported frequency of everyday lapses in perception, memory, and action, rather than objective cognitive ability (Broadbent et al., 1982). Its main strength is its focus on everyday experiences, with its factor structure examined across the adult lifespan (Rast et al., 2009). However, self-reported cognitive failures may be influenced by recall limitations and differences in exposure to everyday tasks (Carrigan & Barkus., 2016) Low failure scores may therefore reflect infrequent opportunities to experience difficulties rather than better cognitive functioning. Adapting the CFQ to public facilities and digital services could improve its contextual relevance, but changes in item wording and context may alter the construct being measured and limit score comparability with the original instrument. Such adaptation should include cognitive interviews, language comprehension testing, and evaluation of reliability and validity among the target population of Indonesian older adults. The frequency of public service use should also be considered when interpreting scores. Until these procedures are completed, the adapted CFQ should be regarded as a proposed instrument rather than a validated measure.

The NASA Task Load Index (NASA-TLX) assesses subjective workload across six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration (Hart & Staveland, 1988). It reflects perceived workload rather than objective task demands. Evidence of its measurement properties in older adults supports its consideration as a complementary assessment instrument (Devos et al., 2020). For future assessments of public service tasks, the raw, unweighted version is proposed for administration immediately after task completion. This version avoids the additional pairwise comparisons required by the weighted version, thereby simplifying the assessment procedure (Hart, 2006). However, its greater suitability for older adults remains to be established through direct comparative research. Individual dimension scores should be examined alongside the overall workload score (Galy et al., 2018), with particular attention to the interpretation and scoring direction of the performance dimension. Although older adults may report favorable usability perceptions despite poorer task performance (Sonderegger et al., 2016), this does not establish bias in NASA-TLX ratings. Whether similar response tendencies influence subjective workload ratings remains a hypothesis requiring empirical investigation.

To complement the critical narrative review, a supplementary descriptive analysis was conducted using response time data obtained from a public signage comprehension simulation involving 12 older adults aged 60–75 years. The simulation consisted of 20 public signs distributed equally across four categories: Traffic/Pedestrian, Public Facility, Directional, and Safety & Accessibility. Each participant was asked to verbally interpret the meaning of each sign. Response time was measured in seconds using a stopwatch, starting when the participant began viewing the sign and ending when the participant completed their verbal response. Time measurements were recorded separately for each sign and participant, regardless of whether the response was correct or incorrect.

A total of 240 response time observations were analyzed descriptively using mean, minimum, and maximum values for each signage category. The five signs with the longest mean response times were also identified for further discussion. Response time was considered a complementary indicator of temporal task performance rather than a direct measure of comprehension accuracy, cognitive effort, or mental workload. This supplementary analysis was intended to provide empirical insights into the temporal aspects of public signage interpretation and complement the conceptual discussion of cognitive accessibility in age-friendly smart cities.

Symbol comprehension tests assess whether users correctly interpret the intended meaning of graphical symbols. ISO 9186-1 (2014) provides a method for evaluating symbol comprehensibility, emphasizing understanding without supplementary explanatory text. However, the absence of explanatory text does not necessarily imply the absence of contextual information. Testing procedures also vary across studies (Arcia et al., 2019). Duarte et al. (2014) employed an open-ended comprehension test, whereas Gungor (2023) used a multiple-choice format. Wu et al. (2022) employed judgment tests to assess estimated symbol understandability rather than actual comprehension accuracy. These differences should be considered when interpreting and comparing results.

Open ended responses require predefined scoring criteria and consistent interpretation by evaluators to improve scoring reliability. From an ecological validity perspective, removing contextual cues may reduce comprehension, whereas controlled testing conditions with limited distractions may facilitate performance compared with real-world environments. These potential effects depend on the testing conditions and should not be assumed to occur in every study. Future assessments should consider complementary in situ testing, response time measurement, and observations of user behavior to evaluate signage accessibility under realistic conditions. Table 2 compares the purposes, strengths, limitations, and potential applications of the three assessment instruments.

Table 2. Strengths and limitations of cognitive ergonomics assessment instruments

Aspect	CFQ	NASA-TLX (raw)	Symbol comprehension test
Measure	Self-reported frequency of everyday cognitive failures	Subjective workload across six dimensions after a specific task	Task-specific symbol comprehension
Strength	Captures everyday cognitive experiences	Provides task-specific workload ratings across multiple dimensions	Assesses comprehension directly when participants interpret symbols
Limitation	Recall bias and differences in task exposure may affect responses	Subjective ratings and aggregate scores may obscure differences across dimensions	Testing conditions and response formats may affect comprehension scores
Interpretation	Supplementary individual-level information, not objective cognitive capacity	Perceived workload, not direct evidence of cognitive effort or compensation	Task-specific performance, not direct evidence of cognitive effort
Future use	Assess language suitability, reliability, and construct validity	Report individual dimensions and assess suitability for older adults and specific tasks	Use predefined scoring criteria, response time, and in-situ trials

Response Time as a Complementary Indicator of Cognitive Accessibility

To complement the critical narrative synthesis, a descriptive analysis of response time was conducted using data from a public signage comprehension simulation involving 12 older adults aged 60–75 years. Each participant interpreted 20 public signs distributed across four categories, resulting in 240 response time observations. Response time was recorded regardless of whether the interpretation was correct or incorrect. Figure 2 presents the mean response time across the four signage categories, providing supplementary evidence of temporal performance in public signage interpretation.

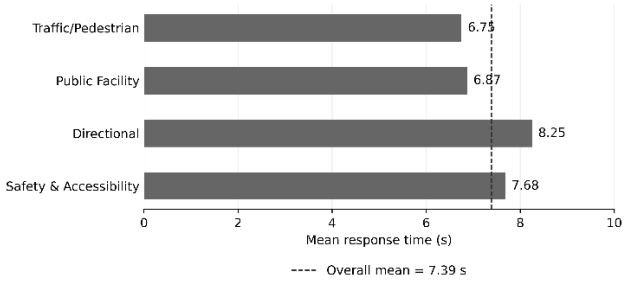

Figure 2. Mean response time across four public signage categories.

As shown in Figure 2, the overall mean response time was 7.39 seconds, with individual observations ranging from 2 to 27 seconds. Directional signs recorded the longest mean response time (8.25 seconds), followed by Safety & Accessibility (7.68 seconds), Public Facility (6.87 seconds), and Traffic/Pedestrian (6.75 seconds). The mean response time for Directional signs was approximately 22.2% longer than that for Traffic/Pedestrian signs. These descriptive findings indicate variation in temporal performance across signage categories. However, longer response times do not necessarily indicate greater cognitive effort or poorer comprehension.

Response time provides additional information about temporal performance that may not be captured by comprehension accuracy alone. Deng et al. (2025) examined both comprehension accuracy and reaction time in healthcare symbol interpretation, demonstrating the relevance of temporal performance in signage evaluation. Previous studies have also identified symbol familiarity, semantic closeness, and visual characteristics as relevant

factors in symbol comprehension (McDougall et al., 1999; Ng & Chan, 2007). These factors may provide a basis for investigating the observed differences in response time. However, their individual effects were not directly examined in the present simulation and require further investigation.

Within the proposed demand-capacity fit framework (Figure 1), response time represents a complementary dimension of task performance. Although response time alone cannot distinguish low-effort success from compensated success, it may help identify tasks that warrant further assessment. Integrating response time with comprehension accuracy, perceived workload, and observations of compensatory strategies may provide a more comprehensive evaluation of cognitive accessibility. Given the small sample size and simulation conditions, these findings should be interpreted as preliminary descriptive evidence rather than empirical validation of the proposed conceptual framework.

Implications for Age-Friendly Smart City Design in Indonesia

The reviewed evidence suggests the potential benefits of familiar, semantically meaningful symbols in age-friendly public signage (McDougall et al., 1999; Ng & Chan, 2007). Concise Indonesian labels may reduce ambiguity, although their effectiveness requires local validation. Directional signs recorded the longest mean response time (8.25 seconds) in the supplementary simulation, warranting further investigation without implying lower comprehension accuracy or greater cognitive effort. Digital public services should prioritize simple navigation, reduced memory demands, and consistent interfaces to support independent task completion (Fischer et al., 2020). These recommendations require further evaluation among Indonesian older adults.

This review proposes a cognitive accessibility evaluation involving public sign interpretation, facility navigation, queue number retrieval, and digital form completion. Researchers should record independent and assisted success, task failure, completion time, errors, and observable compensatory strategies. The raw NASA-TLX can capture subjective workload immediately after each task, while the CFQ can provide supplementary individual-level information on everyday cognitive failures. Integrating these measures may help distinguish low-effort success from compensated success and inform smart city indicators beyond infrastructure and service availability. Future studies should validate this approach among Indonesian older adults in real-world settings.

This review identified insufficient evidence supporting the validity of Indonesian-language CFQ and NASA-TLX for older adults in public service contexts. Instrument translation alone does not establish reliability, construct validity, or task-specific suitability. Future studies should examine these measurement properties and their contextual relevance. Table 4 summarizes the identified research gaps and proposed research directions.

Table 3. Research gaps and proposed directions for cognitive ergonomics in age-friendly smart cities

Gap	Why it matters	Suggested direction
Limited evidence on cognitive accessibility among Indonesian older adults	International findings may not reflect local language, education, and technology experience	Context-specific studies across Indonesian cities
Limited consideration of heterogeneity among older adults	Cognitive capacities and technology experience vary across individuals	Stratified sampling by age, education, and digital experience
Insufficient validation evidence identified in this review for Indonesian-language CFQ and NASA-TLX in the intended population and context	Translation alone does not establish reliability, construct validity, or task-specific validity	Assess translation suitability, conduct cognitive interviews, and examine psychometric properties and task-specific validity
Limited ecological validity of symbol comprehension tests	Environmental context and task conditions may influence performance	In-situ signage and wayfinding evaluations with response time and behavioral observation
Limited integration of task accuracy, response time, and cognitive effort	Accuracy alone may overlook compensated success	Integrate accuracy, response time, subjective workload, and observable compensatory strategies
Limited early involvement of older adults in design	Designs may overlook older adults' needs and capabilities	Involve older adults through participatory design from the concept stage

Language restrictions, limited Google Scholar screening, and the exclusion of inaccessible full-text publications may introduce selection bias. Reliance on international studies and non-older adult populations limits generalizability to Indonesian older adults, while methodological differences restrict direct comparisons. The

supplementary simulation involved a small sample and did not directly measure cognitive effort or compensatory mechanisms. Future studies should validate the proposed framework and recommendations in real-world Indonesian contexts.

CONCLUSION

This critical narrative review highlights mismatches between task demands and available cognitive capacity as a central challenge in older adults' interactions with household devices, digital public services, and public signage. International studies provide insights into these challenges, while Indonesian evidence primarily addresses everyday independence. The supplementary simulation showed that directional signs had the longest mean response time (8.25 seconds). However, response time alone cannot establish comprehension difficulties or greater cognitive effort. Further research should examine these challenges among Indonesian older adults under real-world conditions.

Methodologically, no single instrument fully captures these challenges: the CFQ may underestimate cognitive failures, NASA-TLX may not fully reflect workload, and symbol comprehension tests may overestimate or underestimate understanding. Combining these measures can provide a more comprehensive assessment. For age-friendly smart cities, services and signage should be evaluated based on task success, time, and effort, with priority given to safety and accessibility of information and older adults involved from the earliest design stages.

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