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Review article

# Online performance and interface design implications among older adults: A systematic review of eye tracking studies

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ABSTRACT

Eye tracking is a valuable tool for studying the online performance of older adults, but no review has systematically synthesised findings based on eye tracking data. This study fills that gap by conducting a systematic review of 14 relevant journal articles. It categorises and compares online performance in terms of viewing and interaction performance. Design implications are synthesised across icon design, image and text design, interaction design, and layout design. Findings suggest that older adults' online performance is influenced by various factors, as evidenced by the heterogeneous results across studies. This highlights the importance of considering perceived usefulness and ease of use in eye-tracking experiments and accounting for a range of factors affecting older adults. While most studies focus on individual design elements, future research should propose context-based design suggestions to address the holistic needs of older adults, thereby advancing the field with more comprehensive age-friendly design strategies.

## 1. Introduction

Digital technology plays a fundamental and positive role for older adults in social involvement and participation (Gatto and Tak, 2008; Hurme et al., 2010; Mason et al., 2012; Plaza et al., 2011; Woodward et al., 2010). It also facilitates intergenerational relationship improvements, such as enhancing contact with family members through social media (Holladay and Seipke, 2007; Sayago and Blat, 2010) and plays a significant role in reducing loneliness (Erickson and Johnson, 2011; Mason et al., 2012; Tsai et al., 2010; Yu et al., 2021), etc. However, there is still a gap in digital participation and access between the ageing and younger populations worldwide (Liu et al., 2021; Perrin, 2021). Digital participation, which refers to actively engaging with digital technologies such as the internet, social media, and online services (Seifert and Rössel, 2022), is essential for closing the digital divide. However, while 63 % of the global population is connected to the internet, 27 % of people in some developing countries remain offline (United Nations, 2023). Similarly, the China Internet Network Information Center (2024) reports that only 15.6 % of internet users in China are aged 60 and above, highlighting the limited digital engagement within this demographic. The challenge of how to integrate older adults into the digital age has become a common topic in the world.

Studies have verified that interface design would impact older adults in digital participation (Krayz Allah et al., 2021; Reneland-Forsman, 2018). Therefore, examining the online performance of user interfaces is crucial for understanding older adults' usage behaviour. This understanding facilitates the development of inclusive, age-friendly interfaces, ultimately promoting greater digital participation among this demographic. Previous studies have examined the user experience of older adults using various methods, primarily relying on subjective data. For example, focus groups (Arkkukangas et al., 2021; Lowndes and Connelly, 2023), interviews (Li and Luximon, 2020) and questionnaires (Barros et al., 2014) were used to understand their online performance. However, the limitation of these methods is that they rely heavily on subjective self-reports, which may cause reporter bias, such as social desirability bias (Cho et al., 2019). In order to capture the objective online performance of older adults, eye tracking, which has been utilised for years to comprehend human activities and to study human behaviours (Sharma and Dubey, 2014), could be an appropriate tool in exploring the online performances of older adults. In this research context, the term online performance refers to the overall capacity of interacting with interface design, instead of time and efficiency in completing the design task. This is because the research focuses on exploring the pain points of older adults in using the interface, so as to

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propose design implications for interface designers.

From a theoretical perspective, the information processing theory: Cognitive Load Theory (CLT) (Sweller, 1988) provides a robust framework for understanding the online performance of older adults through eye-tracking analysis. CLT focuses on the mental effort required to process information, referring to the overall cognitive resources utilised during information processing. Compared to Cognitive Resource Theory (CRT) (Fiedler, 1989) and the Dual Process Theory of Reasoning (DPT) (Evans, 2003) which also address cognitive resource allocation and processing, CLT offers clear instructional design principles that guide the development of age-friendly designs. These principles are particularly relevant for addressing cognitive impairments often experienced by older adults. Moreover, CLT is uniquely suited to be operationalised through eye-tracking studies, as it enables the measurement of objective metrics such as fixation durations, gaze patterns, and pupil dilation, which directly reflect cognitive load. In contrast, CRT and DPT are not inherently linked to such empirical approaches. Additionally, CLT has been extensively applied in HCI research to examine how users process information when interacting with digital interfaces (Al Siyabi and Al Minje, 2021; Mazza, 2017; Oviatt, 2006), making it a practical and effective framework for studying and improving interface designs for older adults.

The theory categorises cognitive load into three types: intrinsic load, which relates to the inherent complexity of the information being processed; extraneous load, which arises from external barriers, such as the poorly information presentation; and germane load, which refers to the cognitive effort made to facilitate the understanding of the information. From the design perspective, extraneous load was found to have the most significant impact on influencing the user experience of older adults, as it directly relates to how the interface is presented. The instructional design principles from CLT to mitigate the cognitive load, such as the split-attention effect, modality effect and redundancy effect (van Merriënboer and Sweller, 2005), could be highly relevant for developing age-friendly interface designs.

1. Split Attention Effect: This principle alters multiple sources of information into a single source that can be interpreted easily. For interface design, this involves integrating information into an easily comprehensible format.
2. Modality Effect: This principle highlights the benefits of using multimodal presentations, such as combining visual outputs (e.g., text or images) and auditory outputs (e.g., sounds) to enhance comprehension. For interface design, this principle can be helpful in overcoming physical limitations (such as visual or hearing impairments) among older adults by providing information through multiple channels, such as visuals, auditory and sensory outputs.
3. Redundancy Effect: This principle involves removing unnecessary information to avoid overloading the user's cognitive capacity. For interface design, it suggests avoiding cluttered layouts or repetitive instructions, which can increase extraneous cognitive load among older adults.

As previously stated, CLT is particularly suited to be used in eye-tracking studies. In eye tracking experiments, each metric plays a different role in understanding human behaviour. Two main eye tracking metrics are fixation and saccade (Bruneau et al., 2002). **Fixation** can be seen as a gaze that is relatively still (longer than 300 ms) (Djamasbi et al., 2007), which can be used to identify the location to which the human pays attention. **Saccades** occur between fixations that can be interpreted as eye movement shifts (Poole and Ball, 2004), which imply the interest direction of eye movement (Fig. 1). **Areas of interest (AOI)** refers to the predefined areas that interest researchers, which are often jointly analysed with fixations to see the attention distribution on a particular point or area. **Heat maps** can be used to illustrate the duration of gaze focus, with different colours determining how long that region was looked at (Špakov and Miniotas, 2007) (Fig. 2). Such metrics

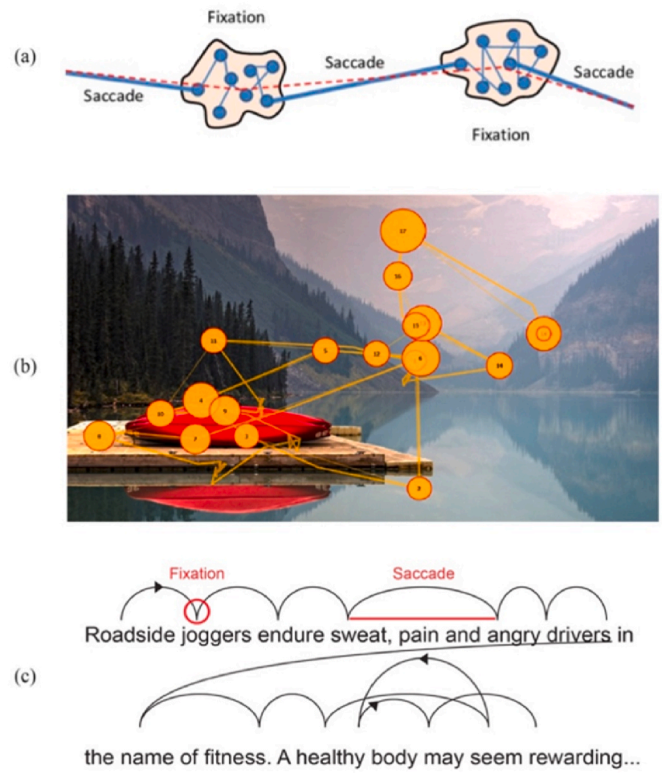


**Fig. 1.** Fixation and saccades examples, adapted from iMotion (2024).

could also be useful to see attention distribution and to infer participants' visual interest areas. **Pupil size and blink rates** are instinctive biological activities that relate to cognitive activity. For example, large pupils or a less frequent blink rate may imply a more cognitive burden to understanding information (Brookings et al., 1996; Bruneau et al., 2002; Pomplun and Sunkara, 2003). Overall, the combined use of eye tracking metrics can purposefully obtain data that explain human behaviour objectively, particularly in how older adults interact with products. For example, long fixation duration, or large pupil size on irrelevant interface components may indicate high extraneous load caused by the design. By linking these observations to CLT, researchers can identify and address specific usability issues to enhance the online experience for older adults. This approach helps identify potential design shortcomings, making eye tracking a valuable tool for understanding the specific needs of older adults. By addressing these needs, designers can enhance the user experience and improve the usability of digital products for this demographic.

Although the benefits of using eye tracking metrics in pertinent studies are revealed, the adoption of pertinent eye tracking studies remains fragmented, no existing reviews have been carried out in this field. This fragmentation hinders the synthesis of knowledge regarding the online performance of older adults from an eye-tracking perspective and limits the contribution to actionable design implications. Therefore, the overall aim of this systematic review is to address this gap by systematically reviewing relevant studies to explore the online performance of older adults and identify design implications that can assist designers in creating age-friendly interfaces in the future. The first objective is to uncover the online performance of older adults based on eye tracking results. The second objective is to identify the interface design implications. Further research gaps and future research directions are provided based on the above findings.


**Fig. 2.** Heatmap and AOI examples, adapted from iMotion (2024).

## 2. Methods

### 2.1. Review protocol

This systematic review follows the Preferred Reporting of Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (Page et al., 2021) as the items of this guideline are comprehensive and rigorous.

### 2.2. Information sources and search strategy

A systematic search was conducted using four databases, Web of Science (core collection), Scopus, ProQuest and Ovid (Medline) All. The initial search was conducted on September 11, 2023, followed by a second search on November 27, 2024 to update the review. In order to capture as comprehensive relevant studies as possible, the search strategy was structured using PI(C)OS (Table 1.) and the search string developed by the lead researcher (GL) was assessed by the senior researcher (TT). The following search string was finalised using a TOPIC search, which includes the title, abstract, and keywords.

"TS=(older or elder* or senior or aging or ageing) AND TS=(mobile or app or application or UI or interface or "user interface" or smartphone or cellphone or cell phone or phone or system or software or web or website or tablet or online or digit*) AND TS=("user experience" or usability or experience or cognit* load or develop* or visual or improve* or aesthetic or interact* or evaluat* or measure* or navigat* or estimate* or feedback or observ* or attent* or saccade or interest or fixation or perform* or "region of interest") AND TS=(eye track* or eye-track* or eye mov* or eye gaz*). Limits were set to only include English studies.

**Table 1**
PICOS search string.

| | | |
|---|---|---|
| **Population** | older OR elder* OR senior OR aging OR ageing | Combined PI(C)OS using 'AND' |
| **Intervention** | mobile OR system OR app OR application OR UI OR Interface OR "user interface" OR smartphone OR "cell phone" OR cellphone OR phone OR software OR web OR Online OR Digit* OR Website OR Tablet | |
| **Outcome** | "user experience" OR usability OR experience OR cognit* load OR develop* OR visual OR improve* OR interact* OR evaluat* OR measure* OR navigat* OR estimate* OR feedback OR observ* OR attent* OR saccade OR interest OR fixation OR perform* OR "region of interest" OR aesthetic | |
| **Study design** | eye track* OR eye-track* OR eye mov* OR eye gaz* | |

### 2.3. Eligibility criteria

To aid in the identification of papers relevant to the scope of the review, the following inclusion and exclusion criteria were used.

#### 2.3.1. Inclusion criteria

i. The age of participants must involve older adults aged over 65, and the participant information (age range, mean age) should be presented.
ii. The sample size of older adults must be more than 10 to ensure statistical power (Holmqvist, 2011).
iii. The study must focus on the interface of mobile or web platforms.
iv. The study must be published in English articles and can be accessed in the full-text version.

#### 2.3.2. Exclusion criteria

i. Articles do not involve older adults aged over 65 and do not show the age range.
ii. Articles that employ a small sample size (N < 10) in older adults.
iii. Articles that do not focus on the interface elements of mobile or web platforms.
iv. Articles that are not published in English articles or have no full-text access.

### 2.4. Selection process

PRISMA flow diagram was used to present the whole screening process (Fig. 3.). During the initial review on September 11, 2023, 13 eligible studies were found. During the process, both researchers participated in the first and second screenings, focusing on titles and abstracts only. Both researchers checked five random samples of screened records respectively and independently to make the screening more reliable than a single screening. Screening of full text was made by the lead author (GL), while discussions regarding potentially eligible studies were held with the senior researcher (TT). Discrepancy over the eligibility was discussed with TT until a consensus was reached. Data were extracted to include the characteristics of each study. The same

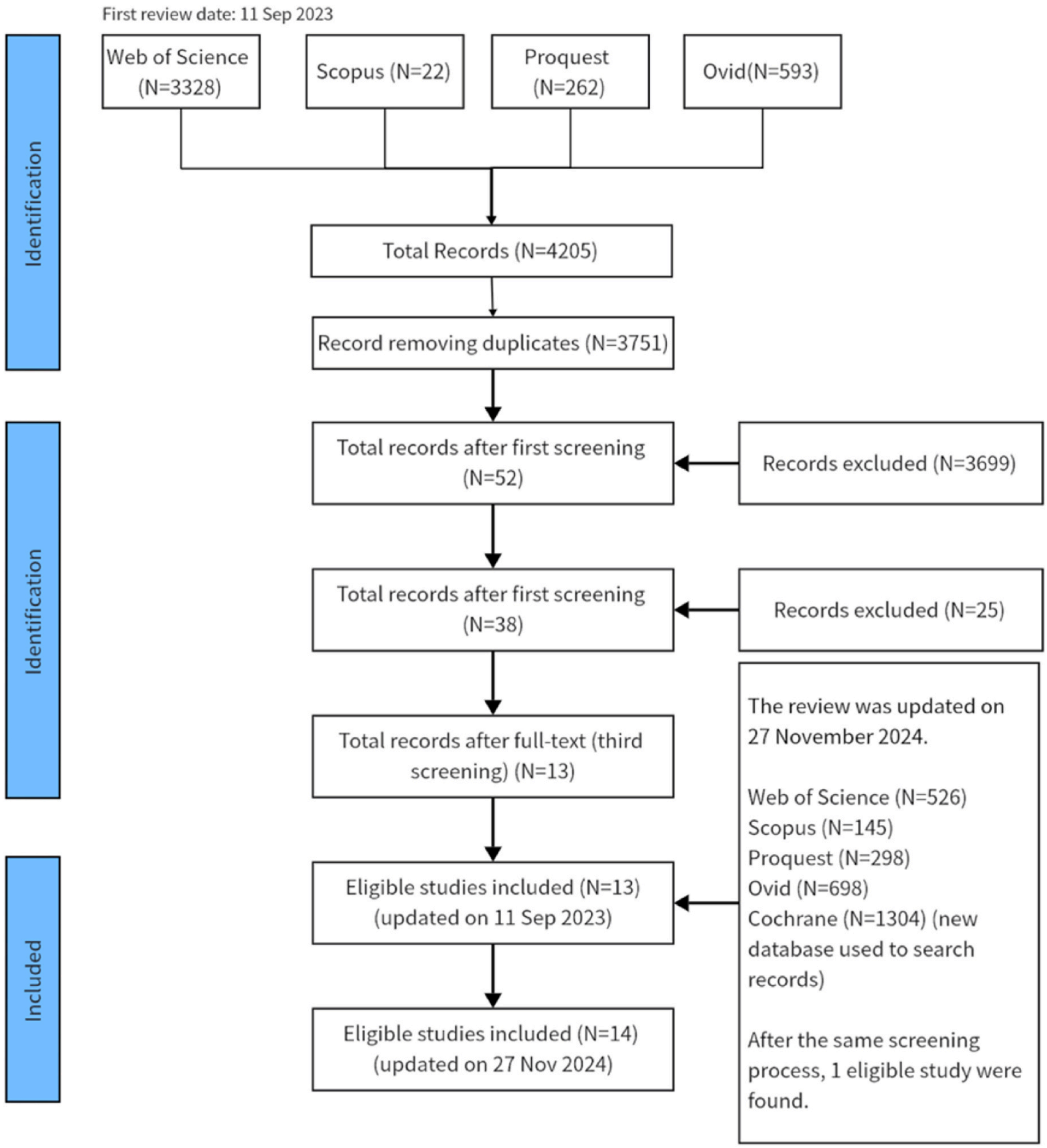


**Fig. 3.** PRISMA flow diagram.

process was applied during the updated review on November 27, 2024, which identified 1 additional eligible study. In total, this systematic review included 14 studies.

Overall, the characteristics of each study include study design, participants, method, settings and eye tracking results. Due to the heterogeneity of both interfaces and the use of eye tracking, it is not appropriate to conduct a quantitative synthesis. Thus, a qualitative synthesis was developed.

## 3. Results

### 3.1. Study selection

During the study selection process, 4205 records remained after removing duplicates from three databases. After the first screening (assessing the title of records) and the second screening (assessing the abstract of records), there were 38 relevant records identified as possibly eligible. By reading the full text of these 38 studies, 13 studies were eligible and included as review papers.

### 3.2. Study characteristics

The main characteristics of the included studies are summarised in Table 2. Overall, 10 out of 14 studies compared older adults with other user groups (e.g., young adults, middle age adults and older adults with mild cognitive impairment). The remaining four studies focused exclusively on older adults as a single user group (Hou et al., 2020; Hou and Hu, 2021; Zhou et al., 2022, 2023). Seven studies investigated older adults with web interfaces while seven recent studies examined eye movement with mobile interfaces. Regarding the characteristics of older adults, the sample size of older adults (excluding the comparison group) ranged from 13 to 42, and the mean age varied from around 58.4 to

**Table 2**
Main Characteristics of the included studies (N = number).

| Study | Year | Method | Participants (in eye tracking experiment) | | Aim | Setting |
|---|---|---|---|---|---|---|
| | | | Older adults | Comparison group | | |
| Yu et al. | 2024 | Experiment Questionnaire | Older adults = 15 Age range 45–75 Mean age 63 SD 6.1 | Youth adults = 15 Age range 18–45 Mean age 24.2 SD 1.8 | To analyse the influence of different navigations of smart home interfaces between older adults and young adults. | Mobile interface |
| Zhou et al. | 2023 | Experiment (Including EEG) Questionnaire | Older adults = 17 Age range 53–76 Mean age 63.25 8F:9M | Not applicable | To investigate the preferences of swiping direction of elderly-focused smart home user interfaces. | Mobile interface |
| Liu et al. | 2023 | Experiment Questionnaire | Older adults = 20 Age range 58–69 Mean age 64.1 SD 3.7 | Youth adults = 20 Age range 22–25 (M = 24, SD = 1) | To compare and investigate how different factors, including the style of icons, their level of concreteness, and the interplay between these elements impact the cognitive performance and cognitive load of users across various age groups. | Mobile interface |
| Wu et al. | 2022 | Experiment | Older adults (Cognitive normal) = 8 Age (SD) 62.13 (2.10) 4F:4M | Older adults (mild cognitive impairment) = 8 Age (SD) 61.25 (1.39) 4F:4M | To investigate the digital behaviour of older adults with and without mild cognitive impairment when processing different types of icons. | Mobile interface |
| Liu et al. | 2022 | Experiment | Older adults = 13 8F:5M Mean age 65.36, SD 3.95 | Young adults = 28 12F:16M, M = 22.75, SD = 2.52 | To explore how different visual cues in visualizations impact users' understanding of self-monitoring outcomes and to analyse how varying visualization styles influence users' visual attention. | Web interface |
| Zhou et al. | 2022 | Experiment (Including EEG) | Older adults = 16 Age range 55–76 Mean age 61.56 9F:7M | Not applicable | To investigate the visual behavior patterns of older adults while they perform visual searches and log in to four elderly-focused social service applications. | Mobile interface |
| Hou and Hu. | 2021 | Experiment Questionnaire | Older adults = 23 Age range 57–71 Mean age 62.04 ± 3.64 | Not applicable | To identify older adults' suitable combinations of text and pictogram sizes and to study the visual priortisation between pictogram and text. | Mobile interface |
| Hou et al. | 2020 | Experiment Questionnaire | Older adults = 20 Age range 57–70; Mean age 61.9 | Not applicable | To investigate comfort combinations of Chinese character spacing and size for older adults' experience. | Mobile interface |
| Beattie & Morrison. | 2019 | Experiment Questionnaire | Older adults = 23 Age range 60–75; 14F:9M | Young adults = 24 Age range 23–40 16F:8M | To study whether navigational layout would impact the online search behaviour of the user groups. | Web interface |
| Haesner et al. | 2018 | Experiment Questionnaire | Older adults = 20 Age range 61–93 Mean age 71 27F:23M | Older adults with MCI (mild cognitive impairment) = 19 | To understand the differences between older adults with MCI and without MCI regarding web navigational behaviour. | Web interface |
| Bergstrom et al. | 2016 | Experiment Questionnaire | Older adults = 20 Age range 62–72 Mean age 67 12F; 8M | Young adults = 9 Age range 20–25; 7F:2M Middle-age adults = 14 Age range 40–49; 8F; 6M | To investigate eye movement patterns among three user groups regarding web interface interaction. | Web interface |
| Bol et al. | 2016 | Experiment Questionnaire | Older adults = 42 Age range 65–88 Mean age 73.48 | Young adults = 55 Age range 21–64 Mean age 44.02 | To examine the relationship between attention and recall in terms of health information (text-only information, text with cognitive illustrations, or text with affective illustrations) among older adults and young adults. | Web interface |
| Bergstrom et al. | 2013 | Experiment Questionnaire | Older adults = 15 Age range 50–75 Mean age 58.4 | Young adults = 22 Age range 19–37 | To examine the age-related differences in website navigation, website performance and satisfaction. To provide design implications for website design. | Web interface |
| Etcheverry et al. | 2012 | Experiment Questionnaire | Older adults = 28 Age range 60–76 Mean age 66.6 | Younger adults = 27, Age range 18–28 Mean 21.4age | To understand the visual search strategies between older and younger adults. | Web interface |

73.48 (all included older adults aged above 65). The majority of older adults had certain Internet use experience and were recruited from senior universities or local communities. All studies reported eye tracking data, while 12 studies additionally collected self-report questionnaire data or EEG for a more complementary analysis (Beattie and Morrison, 2019; Bergstrom et al., 2013, 2016; Bol et al., 2016; Etcheverry et al., 2012; Haesner et al., 2018; Hou et al., 2020; Hou and Hu, 2021; Liu et al., 2023; Yu et al., 2024; Zhou et al., 2022, 2023). All studies were conducted in a lab or indoor context. The Tobii eye tracker series and its software platform were mainly used to collect eye movement data. The reported eye tracking experiments usually allowed participants to wear daily visual aids, such as glasses, however, participants who had eye conditions were normally excluded.

### 3.3. Quality assessment

In order to check the quality of the included studies, the rating tool developed by (Dybå and Dingsøyr, 2008) was selected as it is applicable for various types of studies and it was broadly applied in the field of software engineering (Yang et al., 2021). According to the checklist of the quality assessment, the reporting quality of these studies is relatively high (Appendix A). Among the included studies, ten studies scored above 8 out of 11. Four studies reached scores over 9. The findings and data analysis reached high scores in general, which reflected that the results of the included studies were relatively trustworthy. Another common issue of the included studies was the failure to report the researchers' own role and their potential bias regarding the whole research process. Nevertheless, the issue would not seriously influence the overall quality of the research.

### 3.4. Eye tracking performance

The main characteristics of the eye tracking performance are summarised in Table 3. Overall, this performance can be divided into viewing and interaction performance.

#### 3.4.1. Viewing performance

*3.4.1.1. Content searching.* Content searching refers to the process in which older adults complete tasks requiring them to locate specific information within an interface. All five studies that investigate content searching behaviour involve comparisons with young adults. Three studies focus on the performance of navigational information searching. Yu et al. (2024) employ fixation, gaze duration and saccade to compare the preferences of older adults in navigating different layouts. The results suggest that older adults prefer an interface layout with navigation positioned on the left side. Additionally, they favour low-complexity interactions, allowing content to be accessed with minimal steps. Etcheverry et al. (2012) design two web page layouts for the same content and explore the visual search strategy in information-finding tasks. They adopt mean fixation duration and AOI to see how difficult the searching tasks are. The results suggest that older adults might experience difficulties in finding navigation information. In addition, they tend to focus not only on task-related regions but also on peripheral areas. Beattie and Morrison (2019) tested four navigational layouts with equivalent web content types with older adults and young adults. The number of fixations, time to first fixation, AOI and gaze duration are employed to investigate the cognitive processing of the participants. The results imply that the left-periphery navigational layout may increase the satisfaction of older adults. Moreover, the use of top-peripheral navigation appears to negatively impact the online performance and satisfaction of both groups.

Another two studies emphasise the content information searching performance. Bergstrom et al. (2013) select five different websites to test the information search performance in comparison between older adults and young adults. They mainly adopt eye tracking metrics including the proportion of fixations, AOI, and time to first fixation to compare the age-related navigation performances between the two groups. The results show that older adults fixate more often on the central part of two websites, and fixate less on the peripheral top part (top side) of the website in one of the websites. Bergstrom et al. (2016) compare older adults, young adults and middle-aged adults using one website with eye tracking. The number of fixations, mean fixation duration, AOI, heatmap and gaze opacity are mainly used to investigate the visual patterns of these groups. The results show that older adults fixate less frequently on peripheral parts of the websites, which is in accord with the aforementioned study.

*3.4.1.2. Content reading.* Content reading focuses on the interpretation of the information designed from the interface. Two studies compare the comprehension of health information images between older adults and young adults with eye tracking (Bol et al., 2016; Liu et al., 2022). Bol et al. (2016) present participants with a medical information webpage (radiofrequency ablation) that includes text-only information, text with cognitive illustrations or text with affective illustrations. They adopt heatmap, gaze opacity and fixation duration to understand the attention distribution of reading the webpages between the participant groups. The results report that older adults spend less time reading the cognitive illustration webpage (explanatory visualization for medical treatment) compared to younger adults, though both groups were inclined to prioritise textual information. Liu et al. (2022) adopt the number of fixation, fixation duration, time to first fixation and AOI to compare older adults and young adults in reading four types of health information images (basic type, basic type with colour, basic type with colour and text, basic type with colour, text and personalised statement). The results suggest that different areas of interest and age may affect the

**Table 3**
Eye tracking performance.

| Studies | Eye Tracking Performance | | Eye tracking metrics: Fixation: Number of fixations | (mean) fixation duration | Time to first fixation | Proportion of fixation | AOI | Heatmap/ gaze opacity | Gaze duration | Pupil size or blink rate | Saccade count |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Yu et al. (2024) | Viewing performance | Content searching | | X | | X | | | X | | X |
| Beattie and Morrison (2019) | | | X | | X | | X | | X | | |
| Bergstrom et al. (2016) | | | X | X | | | X | X | | | |
| Bergstrom et al. (2013) | | | | | X | X | X | | | | |
| Etcheverry et al. (2012) | | | | X | | | X | | | | |
| Liu et al. (2023) | | Content reading | X | | | | | | | X | |
| Liu et al. (2022) | | | X | X | X | | X | | | | |
| Hou et al. (2020) | | | | | | | | | | X | |
| Bol et al. (2016) | | | | X | | | | X | X | | |
| Zhou et al. (2023) | Interaction performance | Swiping direction | | X | | | | | | X | |
| Wu et al. (2022) | | Menu selection | | X | X | | X | | | | |
| Zhou et al. (2022) | | | | X | | | | X | | X | |
| Hou and Hu (2021) | | | | | X | X | X | | | | |
| Haesner et al. (2018) | | Form filling | X | X | | X | X | | X | | |

reading performance of the image.

Regarding reading texts, two studies mainly use pupil size. Hou et al. (2020) adopt pupil size and blink rate to measure the cognitive load and the symptoms of the eyes (stress, anxiety etc.) to explore the effect of text spacing and size of Chinese characters in older adults. The results imply that the combination of text spacing and size is contingent upon their motivation, needs and contexts in which they are reading. In terms of identifying icons, Liu et al. (2023) compare four types of icon styles (skeuomorphism concrete icons, flat concrete icons, flat abstract icons and skeuomorphism abstract icons) and investigate the cognitive performance between older users and young users.

### 3.4.2. Interaction performance

*3.4.2.1. Menu selection.* Menu selection focuses on the process of selecting options within the interface menu. Three studies investigate menu selection interaction in mobile settings. Two recent studies investigate the menu design of the icons within mobile phone settings. Regarding icon size, Hou and Hu (2021) use the time to first fixation, the proportion of fixation duration and AOI to investigate the optimal combinations of icons in different scenarios. The results suggested that large icons (pictogram and text size combination) could improve the readability and legibility of older adults. Regarding icon visual types, Wu et al. (2022) compare two types of icon styles and employ fixation duration, time to first fixation and AOI to investigate the four types of icon types (flat icons, flat icons plus text, skeuomorphism icons, and skeuomorphism icons plus text) between older adults and older adults with mild cognitive impairment (MCI). The results show that both groups of older adults search poorly with flat icons. One study explores how different login interfaces with menus impact older adults (Zhou et al., 2022). They investigate how the layout, colour and information of the mobile interface impact the performance of older adults. Mean fixation duration, heat map and mean pupil size were employed. The results imply that the palace layout, featuring a 3x3 grid menu distribution, performs more effectively for older adults.

*3.4.2.2. Form filling.* Form filling emphasises the user interaction and experience involved in completing forms within the interface. Haesner et al. (2018) compare the differences between older adults and older adults with MCI in completing menu selection and form filling in webpages. They mainly adopt the number of fixation, fixation duration, proportion of fixation, AOI and gaze duration to analyse the usability of the webpages. Not surprisingly, The results suggest that older adults with MCI performed less efficiently compared to those without MCI. Furthermore, there are no apparent distinctions in eye movement patterns between these two groups in most of the tasks. However, in terms of average fixation duration, the two groups show limited differences in all tasks.

*3.4.2.3. Swiping direction.* Swiping direction examines the interaction dynamics involved in swiping gestures. Zhou et al. (2023) investigate the interaction performance of swiping direction among older adults in a mobile setting. The eye tracking metrics they use include mean fixation duration and pupil size to investigate the emotional and cognitive state. The results indicate that older adults perform better with vertical swiping and show a clear preference for it over horizontal swiping.

### 3.5. UI design implications informed by eye tracking

The findings provide UI design implications, including icon design, image and text design, interaction design and layout design, that influence older adults' usability and cognitive load when interacting with digital interfaces. These results were derived from eye-tracking findings and provide evidence-based recommendations for enhancing the design of digital interfaces to better accommodate the needs of older users.

**Table 4**
Design implications informed from Eye Tracking Findings.

| Design Areas | Main Eye Tracking Findings | Main Design Implications Informed from Eye Tracking Findings |
|---|---|---|
| Icon design | Icon size (Hou and Hu, 2021):<br>• The best ratings for readability and legibility were achieved with a text size of 0.60°.<br>• When pictograms exceeded 72 × 72 px (1.38° × 1.38°), older adults focused on text before pictograms during visual search tasks. | • Increase pictogram and text sizes to enhance readability and legibility for older adults.<br>• Offer tailored recommendations for the size of pictograms and text based on specific scenarios as detailed in Table 4 of Hou and Hu (2021) |
| | Icon style:<br>• Older adults demonstrated optimal search accuracy, response time, and processing efficiency with skeuomorphic icons paired with text (Wu et al., 2022).<br>• Skeuomorphic concrete icons reduced cognitive load and enhanced cognitive performance (Liu et al., 2023). | • Include skeuomorphic icons accompanied by text to improve older adults' visual and cognitive performance (Wu et al., 2022).<br>• Focus on designing concrete and skeuomorphic icons to enhance familiarity and usability for older users (Liu et al., 2023). |
| Image and text design | Health information design:<br>• Task completion time and accuracy were consistent across four visualisations (Liu et al., 2022).<br>• Older adults tended to overlook peripheral or less prominent information (Liu et al., 2022).<br>• Cognitive illustrations were less engaging for older adults, leading to lower recall compared to younger adults (Bol et al., 2016).<br>Text spacing and size (Hou et al., 2020):<br>• Significant correlations were observed between user experience and metrics such as pupil size and blink rate. | • Combine text with personalised information and colours to provide effective visual cues (Liu et al., 2022).<br>• Use salient and visually engaging elements to capture and sustain the attention of older adults (Liu et al., 2022).<br>• No specific actionable implications were provided in Bol et al. (2016).<br>• Provide specific design recommendations for font size, word spacing, and line spacing tailored to particular contexts as detailed in Table 4 of Hou et al. (2020). |
| Interaction design | Form filling (Haesner et al., 2018):<br>• Multi-step tasks caused older adults with MCI to have more fixations compared to those without MCI.<br>Swiping direction (Zhou et al., 2023)<br>• Vertical swiping required longer fixation durations for older adults than horizontal swiping. | • Simplify multi-step tasks to make them more accessible for older adults with MCI Referring to the accessibility guidelines.<br>Swiping direction (Zhou et al., 2023)<br>•Tailor swipe gesture directions to specific functionalities: vertical for consistency and horizontal for navigation or segmentation. |
| Layout design | Web interface<br>• Older adults predominantly focused on the central areas of the screen compared to younger users (Bergstrom et al., 2013).<br>• Removing distractions resulted in similar performance between older and younger participants (Bergstrom et al., 2013).<br>• Older adults spent limited time fixating the information from the | • Position essential information in the central part of the layout (Beattie and Morrison, 2019; Bergstrom et al., 2013).<br>• Repeat important information in both central and peripheral parts of the interface (Bergstrom et al., 2013).<br>• Adopt a clean and minimalistic layout to minimise distractions. (Bergstrom et al., 2013).<br>• Placing the information in the central of the interface and repeat links in both centre and |

(continued on next page)

**Table 4** (*continued*)

| Design Areas | Main Eye Tracking Findings | Main Design Implications Informed from Eye Tracking Findings |
|---|---|---|
| | peripheral navigation (Bergstrom et al., 2016).<br>• Older adults spent less time fixating on low-level dual-navigation (left-side) (Yu et al., 2024).<br>• Navigation elements placed in the top AOI received higher fixation from older adults (Beattie and Morrison, 2019).<br>• Participants, including older adults, spent less time initially viewing the left AOI with left navigation (Beattie and Morrison, 2019).<br>• Older adults fixated navigation and search targets for longer time than young adults (Etcheverry et al., 2012).<br>Mobile interface (Login interface) (Zhou et al., 2022)<br>• The login interface of the Smart Aging app exhibited the shortest average fixation durations and smaller average pupil sizes.<br>• The heat map revealed that intuitive colour contrast and clear designs are effective in capturing their visual attention. | the main navigation (Bergstrom et al., 2016).<br>• Older adults preferred left-aligned, low-level dual navigation in smart home interfaces (Yu et al., 2024).<br>• Avoid positioning navigation elements in the top peripheral areas (Beattie and Morrison, 2019).<br>• Positioning navigation on the left side of the interface (Beattie and Morrison, 2019).<br>•No specific actionable implications were provided in this study (Etcheverry et al., 2012).<br>•Employ multi-column layouts with low information density and balanced login icon proportions.<br>• Making the login icon more visually prominent and using colours effectively can assist older adults in finding it more quickly. |

Table 4 summarises the key eye-tracking findings and their corresponding design implications. These insights are essential for developing age-friendly designs that reduce cognitive load and enhance task performance in older adults.

## 4. Discussion

### 4.1. Main findings

This research examined studies on eye tracking in the context of older adults' interactions with user interfaces and provided insights for designing interfaces based on their performance. This review encompassed a total of 14 studies, which were categorised into two distinct aspects of eye tracking performance: viewing performance and interaction performance. Design implications were categorised based on the icon design, image and text design, interaction design and layout design.

Regarding viewing performance, there are contradictory findings between older adults and young adults. Two studies suggest that older adults perform similarly to young adults in tasks when searching for content (Bergstrom et al., 2016; Etcheverry et al., 2012). However, two other studies indicate that older adults are less efficient than their younger counterparts in these tasks (Beattie and Morrison, 2019; Liu et al., 2022). Furthermore, two studies suggest that older adults may allocate less time to peripheral areas compared to younger adults (Bergstrom et al., 2013, 2016), while another study contradicts this by indicating that older adults actually spend more time in the top peripheral regions of interfaces (Beattie and Morrison, 2019). These disparities suggest that the viewing performance of older adults can be influenced by a range of factors, including differences in interface design, task setup and participant characteristics. The limitations listed in these studies (Beattie and Morrison, 2019; Haesner et al., 2018; Hou and Hu, 2021; Yu et al., 2024) confirmed the issue. For example, participant demographics, such as age distribution, cognitive abilities, or familiarity with technology, can further impact outcomes. In line with this perspective, Al-Maskari and Sanderson (2010) posit that participant characteristics and the effectiveness of the user interface are pivotal elements influencing information retrieval within the user interface. Therefore, to address these discrepancies, it is important to carefully account for and control such variables during research design. While it may not be feasible to consider every possible influencing factor, prioritising key variables and ensuring consistent experimental settings across studies can significantly enhance the scientific rigour of investigations involving older adults.

Concerning the interaction performance among older adults, the research within this field looks at three specific interaction modes: form completion, menu navigation and swiping patterns. Due to the heterogeneity of the types of interaction, a meaningful comparison between these studies is challenging. Nonetheless, it is found that the interaction styles discussed in this review can be located in Shneiderman et al. (2016)'s comprehensive summary of interaction styles. However, the additional interaction styles they include, such as direct manipulation, dialogue boxes, command-based interactions and natural language interactions, have not been extensively investigated within this topic. In terms of the characteristics of older adults, those experiencing MCI appear to exhibit less efficient performance in user interface tasks compared to their peers who are ageing normally (Haesner et al., 2018; Wu et al., 2022). These align with findings from previous interface research (Chen and Cai, 2023; Chen et al., 2022), which also suggest that older adults with MCI demonstrated limited efficiency in interacting with the interface.

In terms of design implications, several recommendations show similarities across studies. Both Beattie and Morrison (2019) and Yu et al. (2024) suggest placing navigation on the left side of the interface. Similarly, Beattie and Morrison (2019) and Bergstrom et al. (2013) recommend positioning essential information in the central part of the layout. Additionally, Bergstrom et al. (2013, 2016) advocate for repeating important information in both central and peripheral parts of the interface. Overall, these suggestions align with established interface design guidelines for the ageing population, such as avoiding small font sizes, ensuring adequate spacing for comfortable reading, and directing attention to critical information (Johnson and Finn, 2017). Among them, some of the design implications also align closely with those derived from Cognitive Load Theory (CLT), particularly the Split Attention Effect and the Redundancy Effect. For instance, simplifying task steps, as suggested by Haesner et al. (2018), aligns with addressing the Split Attention Effect by minimising cognitive demands on older adults with MCI. Similarly, reducing unnecessary distractions that may divert attention to irrelevant screen areas and adopting a clean, decluttered layout, as proposed by Bergstrom et al. (2013), align with the Redundancy Effect by eliminating superfluous information and promoting focus on essential content. However, it's worth noting that the design recommendations primarily focus on individual design elements, such as the layout and icons. Conversely, there is relatively less emphasis on implications for combinations of design elements or context-sensitive design, though a few research (Hou et al., 2020; Hou and Hu, 2021) proposed context-sensitive suggestions towards icon design and text design.

### 4.2. Future directions

As previously stated, varying factors may affect the performance of older adults in user interface tasks, resulting in heterogeneous results. Concerning the characteristics of users, the previous studies have mainly focused on the internet experience, age, and physical health of older adults, which provide useful references when investigating their task performance. Nevertheless, according to the Technology Acceptance Model (TAM), which underscores that the perceived usefulness and perceived ease of use are pivotal factors influencing the acceptance of technology, these factors might also need to be considered when developing eye tracking experiments. For example, in terms of perceived usefulness, the current emphasis has been looking at health information websites, tourist information websites, and government information websites. These are certainly useful online platforms for older adults. However, other online services like social media and banking can also be useful and beneficial for older adults (Nayak et al., 2010). For example, studies highlight the importance of older adults participating in social media platforms (Hogeboom et al., 2010; Sinclair and Grieve, 2017). Therefore, it is suggested that future research could also investigate the eye tracking performance of older adults in varying online activities that may be useful for older adults. There also might be potential performance differences between these platforms that can be studied in order to offer novel insights regarding different types of online platforms. With regard to perceived ease of use, the existing studies include interaction and viewing performance that are relatively easy to conduct, such as searching for specific content on the webpage or selecting the correct navigation links. The interaction styles such as financial transactions in banking apps, and purchase items in shopping websites or apps, have not been incorporated. These complex interaction styles might also need to be investigated and compared with other interaction styles further. In addition, as previously stated, interaction styles such as direct manipulation, dialogue boxes, command-based interactions, and natural language interactions have not been incorporated into this topic either. Another necessity is to rate the complexity level of these tasks so as to understand the current internet skill level of older adults. Therefore, future research is also recommended to conduct relevant research in this regard. Overall, it is recommended that future research should not only consider user characteristics but also take into account the perceived usefulness and ease of use of the interface when designing eye-tracking experiments.

Regarding the design implications, as previously noted, few research offer context-based design suggestions. When taking context into account, it may be beneficial to pay attention to five key dimensions: individuality, location, time, relations, and activity (Zimmermann et al., 2007). In the included studies, two studies (Hou et al., 2020; Hou and Hu, 2021) focus on activity-based context to offer customised design implications. Future research, therefore, is suggested to consider developing more dimensions of context such as individuality, location, time and relations. For example, when considering location, older adults in different locations, such as homes, shopping centres, parks or hospitals may perform differently towards the same interface task. This is particularly significant when they are using mobile phones, as these devices are portable and can serve various purposes in diverse contextual situations (Böhmer et al., 2010). In addition, included studies tend to provide design implications pertaining to individual design components, such as the icon design implications (Hou and Hu, 2021; Liu et al., 2023; Wu et al., 2022). The constraints associated with such recommendations are that they might fail to consider the interrelationships among various elements of interface design. Nevertheless, design elements are always interrelated (White, 2011). Therefore, future research on this topic could also focus on providing design implications regarding design element combinations.

### 4.3. Strengths and limitations

The highlights of this systematic review come from its novelty and practicality. Although a few systematic reviews focus on the website eye tracking behaviour (Kamangar, 2020; Strzelecki, 2020), to our knowledge, no previous reviews have paid attention specifically to older adults. Thus, this review's findings may provide applicable references regarding online performance and the design implications among older adults.

The limitation of this review is that we only include English journal articles, which would lead to a small sample size of the total eligible studies and may miss additional results. Researchers who wish to identify conference papers, book chapters or non-English journal articles may not be able to find relevant evidence in this review. Besides, this study did not include a comparison between subjective measures obtained from the questionnaires and objective measures collected via eye tracking, which could have provided deeper insights. Moreover, there is a potential risk of bias stemming from the researchers' backgrounds, including their prior experiences, assumptions or disciplinary perspectives, which could have influenced the interpretation of findings or the framing of research questions.

## 5. Conclusion

This systematic review first synthesised the online performance of older adults and the design implications for older adults and then identified the potential gaps and future directions in such a field. Overall, in terms of the online performance of older adults, the findings suggest that their performance may be affected by multiple factors. In terms of design implications, the findings reveal that most of the studies provide design implications that are specific to single design elements. It is recommended that future research could propose context-based or unified design implications. This review supports the use of eye tracking in the user interface area among older adults and it is expected to guide future researchers and designers who wish to further investigate such a field.

## CRediT authorship contribution statement

**Guanyu Li:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation. **Tang Tang:** Writing – review & editing, Supervision, Methodology, Conceptualization.

## Declaration of competing interest

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

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## Appendix A. Quality Assessment adopted from Dybå and Dingsøyr (2008)

Questions of quality assessment checklist from Dybå and Dingsøyr (2008).

*Answer Yes (1)/No (0)*

1. Is the paper based on research (or is it a discussion paper based on expert opinion)?
2. Is there a clear statement of the aims of the study?
3. Is there an adequate description of the context in which the research was carried out?

4. Was the research method appropriate to address the aims of the research?
5. Was the recruitment strategy appropriate to the aims of the research?
6. Was there a control group with which to compare treatments?
7. Was the data collected in a way that addressed the research issue?
8. Was the data analysis sufficiently rigorous?
9. Has the relationship between researcher and participants been considered adequately?
10. Is there a clear statement of findings?
11. Is the study of value for research or practice?

These 11 questions align with the quality assessment items in Table below.

| Study | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Total (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Research | Aim | Context | Research Design | Sampling | Control Group | Data Collection | Data Analysis | Reflection | Findings | Value | |
| Yu et al. (2024) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 10 |
| Zhou et al. (2023) | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 8 |
| Liu et al. (2023) | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 9 |
| Wu et al. (2022) | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 9 |
| Liu et al. (2022) | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 9 |
| Zhou et al. (2022) | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 8 |
| Hou and Hu. (2021) | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 9 |
| Hou et al. (2020) | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 9 |
| Beattie & Morrison. (2019) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 10 |
| Haesner et al. (2018) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 10 |
| Bergstrom et al. (2016) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 10 |
| Bol et al. (2016) | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 9 |
| Bergstrom et al. (2013) | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 8 |
| Etcheverry et al. (2012) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 10 |
| Total (14) | 14 | 8 | 14 | 13 | 14 | 10 | 14 | 13 | 0 | 14 | 14 | 128 |

## Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apergo.2025.104538.

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