AmslerTouch: Self-testing Amsler Grid Application for Supporting a Quantitative Report of AMD Symptoms

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Abstract

Age-related macular degeneration (AMD) is a progressive chronic disease that is led by damage in the macula. Due to its irreversible characteristics and disastrous effects on the patients, a precise diagnosis of the symptoms is extremely important. Yet, paper-based Amsler Grid, which is known as the most prevalent testing method, is highly limited in that it requires the indirect report of patients and quantitative reporting is difficult. To address this, I propose AmslerTouch, a touch-based Amsler-testing web app that supports patients to self-report AMD symptoms. Based on the heuristic evaluation for identifying enhancements, I also discuss possible enhancements of my proposed system.

Keyword

Age-related Macular Degeneration, Amsler grid

1. Introduction

Age-related macular degeneration (AMD) is a progressive chronic disease that is led by damage in the macula [7]. According to Jeon et al., AMD is a highly prevalent disease in society, where 6.62% of the South Korean population are suffering from the symptoms of AMD [12]. It is widely known that the symptom often accompanies disastrous symptoms, such as blurred vision or vision loss [7]. In addition to its detrimental effects on the vision itself, older adults with AMD are also prone to be affected psychologically, such as being depressed from being marginalized from the society [13].

To date, however, little or no effective treatment for treating AMD exists [17]. Although some promising approaches such as stem cell implant have been proposed [1], these methods are still yet to be widely applied. Thus, considering that it is almost impossible to revert once the degeneration is exacerbated, the most feasible and cost-effective management of AMD is to prevent further development of symptoms [18], implying the necessity of the early detection and precise diagnosis of AMD.

As such, the importance of precise diagnosis has been highly emphasized so far. Yet, most of the diagnoses of AMD are limited in precisely reporting the region of issue. Specifically, patients and practitioners who conduct Amsler grid testing, the most prevalent AMD testing since the 1940s, often suffer from communicative issues, thus limiting the validity of the test [15]. Heavily relying on the indirect, verbal report of patients, the regions of an issue are often inexactly reported, making such symptoms difficult to be accurately managed.

To address this, I propose a novel application of self-reporting symptoms of AMD with Amsler grid. Specifically, based on the literature review on frequently observed symptoms, I developed AmslerTouch, a touch-based Amsler-testing web app that supports patients to self-report AMD symptoms. AmslerTouch supports users to precisely annotate regions of symptoms. As such, I aimed to facilitate the decision-making of practitioners with the quantitative report of AMD symptoms.

To evaluate the usability of AmslerTouch, I ran a heuristic evaluation with the checklist for heuristics. Based on the result and reflection on AmslerTouch, I also discuss possible enhancements and future works.

2. Related Work

2.1 Computer-assisted Symptom Diagnosis and Management

With the advent and distribution of personal computing devices, it became possible to diagnose and manage the symptoms of various diseases and disabilities. Unlike previous methods of manual, text-based symptom recordings, computer-based recordings are more easily manageable. Plus, with various computer-based interaction methods such as touch, sensors, and head-mounted displays (HMDs), the recording became more precise.

As such, previous studies have explored and proposed techniques that support diagnosis and management across various domains, such as developmental disabilities [16], heart rate monitoring [6], and computer vision syndrome [4]. By actively making use of computing devices, networks, and input methods, these studies revealed the possibility of computer-based diagnosis and management of various symptoms. Moreover, by utilizing highly mobile devices such as tablets and mobile phones, these works have lowered the barriers to diagnosis.

Extending these works, in this study, I seek for designing a mobile, self-reportable AMD application targeted to touch-based devices. Specifically, I considered that the web-based implementation of my feasible application might lower barriers to using the app, letting patients and practitioners utilize it regardless of device specifications, operating systems, and various constraints. As such, I propose a touch-based AMD diagnosing web app.

2.2 Age-related Macular Degeneration (AMD) and Amsler Grid

Age-related macular degeneration is a symptom that is accompanied by damage to the macula. According to Lim et al., AMD is a highly prevalent disease, with more than 20% of aging populations affected by it [7]. Consisting of dry- and wet-AMD, AMD is often referred to as a disastrous disease due to its irreversible symptoms and leading patients to social isolation, it is important for patients to precisely understand the progress of the disease and manage it with an accurate diagnosis.

To diagnose AMD, Amsler grid (Figure 1(a)) has been widely used. Consisting of dozens of squares as a grid, Amsler grid aims to report distorted areas or blurred regions in sight verbally to the medical practitioners. Here, since AMD is heterogeneous in terms of symptoms, it is important to precisely understand each symptom to design the tool to support patients with reporting each issue easily. Thus, by following the questionnaires of Schuchard's study for diagnosis using Amsler grid [15], I summarized the common symptoms of AMD that are observable through Amsler grid as follows:

- **Distortion**: Patients with AMD are known to often suffer from the distortion of vision (Figure 1(b)). They see some lines as if these lines are not parallel, or are perceived as either concave- or convex-shaed.
- **Blurry sight**: Blurry sight is also a common symptom suffered by patients with AMD. This symptom is also described as dark spots or blur.

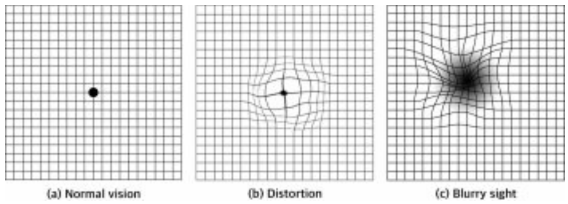

Figure 1 Frequently observed symptoms and their illustration on top of Amsler Grid

2.3 Diagnosis of AMD with Amsler grid

While describing symptoms, there are important points that patients should adhere to, in terms of precise testing. I summarized several important guidelines that my possible design may follow:

- **Keeping a designated distance from the grid**: If the location of sight changes, the scope of vision also changes. Thus, the distance between grid and vision should be fixed for the precise report (e.g., 28 - 30cm away for 10cm * 10cm grid) [2].
- **Center-align the vision focus to the central point**: It is important for the patients to center-align their sight to the central point of the grid. The affected regions of vision are relative in location. In other words, the report might be affected by the focus of sight, thus requiring a person to fix the sight to the center [2].

2.4 Computer-based AMD Diagnosis

Previous studies have explored several techniques that support medical practitioners and patients to diagnose symptoms of AMD in computers. Since paper-based AMD testing had been shown unsuccessful in terms of precise diagnosis [3, 14], these studies emphasized the feasibility of a computer-based approach for the precise and quantitative report of symptoms (e.g., computer [8], wearable system [9], 3D screens and glasses [5]).

Yet, these are limited in their efficiency and generalizability, since (i) they do not ensure high accuracy or (ii) the techniques required costly devices. With the recent distribution of touch-based tablets, I found that these devices might give people a great opportunity to precisely note regions of the symptom with their existing devices. Thus, in this study, I propose an AMD diagnosis app that lets users easily utilize it within their hand-held devices.

3. Design of AmslerTouch

In this section, I discuss the design implications and the implementation of the touch-based Amsler grid web app: AmslerTouch.

3.1 Design Implications

Based on the literature review, I summarized several design decisions for a touch-based, self-reportable Amsler grid application as follows:

- **The system should offer both (i) fixed-shape tool and (ii) free-shape tool**: In most cases, I identified that the region of symptoms is circular or ellipse, which implies the need for annotating with a circle-shaped tool. Yet, patients may still want to draw more freely and accurately, which requies to offer them a tool for drawing freely.
- **The system should offer a color picker for the drawing tool**: As previously noted, AMD is a heterogeneous disease in terms of symptoms, where more than one visual symptom often appears. Thus, it is reasonable to let users change the color of each markup to distinguish each symptom.
- **The system should let users download drawings as an image**: My system ultimately aims to facilitate communication between a patient and medical practitioner. On such an account, it is important for the system to offer a reportable format of drawings.
- **The system should make the user focus on the center of Amsler grid**: As noted in the literature review, it is extremely important to have patients center-align their vision while taking a test. Similarly, I considered it important to induce users to center-align as well in the interface.
- **The system should have users away from a designated distance from the screen**: Since the visual area is relative to the distance from the screen, it is important to keep them away from a fixed distance.

3.2 AmslerTouch: Web-based Self-reporting Amsler Grid App

Based on the design implications, I designed AmslerTouch, an interactive web-based Amsler grid app. I discuss some important design elements for inducing successful testing and reporting of symptoms. The overall interface is shown in Figure 2.

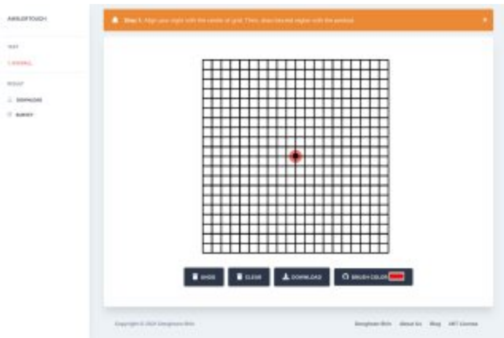

Figure 2 Interface of AmslerTouch

- **Circle tool and pen tool for drawing**: To ensure that users may draw both burden-free and precisely, I applied two types of markup tools for drawing: Circle tool and pen tool. Exemplar usage of each tool is illustrated in Figure 3.

  (i) Circle tool. Stemming from the idea that most of the reported regions are circle in shape, the circle tool focuses on intuitive use by letting users easily draw. Specifically, once a user keep pressing on a specific region, a circle is created and enlarged until the users stop holding.

  (ii) Pen tool. Like a real-world pencil, pen tool lets users freely draw without any constraint. This tool makes users draw every shape precisely.

To let users switch between Circle tool and Pen tool easily, I applied an algorithm to change a tool based on the user's initial point of the cursor and point of the cursor after 500ms. To be specific, I considered that if the user moves the position of cursor drastically in 500ms, the user would want to draw using a pen tool. Otherwise, the user is considered to start using a circle tool:


```
Procedure ISCIRCLE(initialPosition):
    timer ← fire
    while timer.isValid and elapsedTime < 500ms do
        if initialPosition.distanceTo(currentPosition) > 50px
then
            return false
        end if
    end while
    return true
endprocedure
```

Algorithm 1 Algorithm for detecting a drawing tool

- **Download function for saving drawings as an image file**: Along with the precision of digital formats, I considered that medical practitioners and users may easily compare the drawings over time if they are saved as a file. Thus, I added a download function.

  Once the user clicks the download button located at the bottom center, the drawings are downloaded as an image (PNG). As such, I considered that the medical practitioners may better understand the scope of the region in a more quantitative fashion.

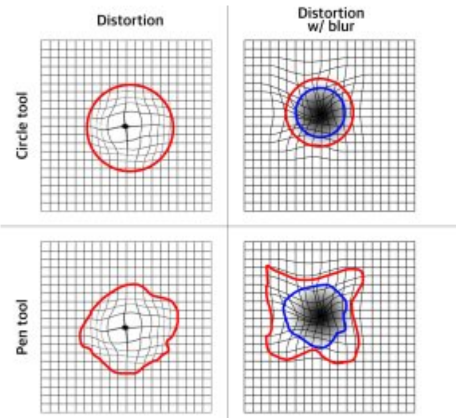

Figure 3 Exemplar usage of AmslerTouch

- **A circle-shaped, diffusing animation for inducing users' focus**: It is important to keep the user's vision at the center of Amsler grid while testing. Thus, I designed a spreading circular animation to keep users focused on the center. At the center of the grid, a circle keeps growing every 1 second (Figure 2 center), with the opacity going down, accordingly making as if it is diffusing.
- **A tooltip view for keeping them with a fixed distance**: To make users stay away from the screen, I added a tooltip view on top of Amsler grid. As such, I aimed to notice them with how much they should be away from the screen, prior to starting testing. Since I used Amsler grid of 550px * 550px in resolution and given that 10cm * 10cm Amsler grid testing requires participants to be away from 28 - 30cm, the system induces users to keep 55cm away.

The system was built with Svelte, a Javascript-based framework, and later deployed on Google Firebase hosting service.

4. Evaluation

To evaluate the usability of AmslerTouch, I conducted a heuristic evaluation based on the pre-defined questionnaires from the literature review.

4.1 Method

Heuristic evaluation is an evaluation method that enables informal, internal assessment on the usability of interfaces [11]. In this study, I chose original checklist suggested by Nielsen [10], in that (i) it has long been proved efficient across various domains of interaction design and (ii) little or no specialized checklist exists for our domain. Based on the checklist (Table 1), I conducted a heuristic evaluation, which lasted approximately 2 hours.

Table 1. Checklist of our heuristic evaluation

Number	*Heuristics*
#1	Visibility of system status
#2	Match between system and real world
#3	User control and freedom
#4	Consistency and standards
#5	Error prevention
#6	Recognition rather than recall
#7	Flexibility and efficiency of use
#8	Aesthetic and minimalist design
#9	Help users recognize, diagnose, recover from errors
#10	Help and documentation

4.2 Result

In this subsection, I describe the result of heuristic evaluation. Specifically, I sorted the identified issues by rank and discuss four top issues.

- **Insufficient description exists for how the user may initiate using the system**: Even though the interface of AmslerTouch is intuitive, it was hard to initiate using the system. Specifically, with only a grid and a set of buttons available on the screen, users may not be able to fully understand the way of manipulating the objects. Thus, I considered that it is necessary to add some design elements that help user onboard successfully (e.g., additional tooltips, popup).

Table 2. Result of the heuristic evaluation. Severity is based on 5-point (0 – 4), and Ease of Fixing is based on 4-point (0 – 3) Likert scale, as suggested by the guideline

Issue	*Severity*	*Ease of Fixing*	*Type*
Insufficient description exists for how the user may initiate using the system	3	1	#10
The text on tooltip view is too small to recognize	3	1	#1, #2
There is no perceivable distinction between Clear and Undo button	2	1	#1, #6, #10
No detailed guideline exists on how the drawing algorithm works	2	2	#9, #10
It is difficult to pick a color for markups; lack of scaffolded options	2	3	#3, #7
Tooltip does not induce user to stayaway for a designated amount of distance	3	3	#1, #9, #10
User cannot setup directory for downloading the markup	1	3	#7

- **The text on tooltip view is too small to recognize**: I realized that the text was too small to read successfully, requiring bigger text for users to fully perceive. In addition, considering the user group where users may face issues regarding the vision, other physical methods may also be beneficial to inducing such a behavior. For example, by implementing a vibrotactile feature from the wearable devices, users may get feedback to keep moving away from the screen until the user reaches a certain distance.
- **There is no perceivable distinction between *Clear* and *Undo* button**: In AmslerTouch, *Clear* button indicates the removal of all markups, whereas *Undo* button cancels only the previous action. Since *Clear* action is destructive, it is important for users to fully understand the difference between the two buttons. However, in my interface, it was quite difficult to perceive the difference between the two buttons at first glance. Thus, it is required to clarify the wordings of each button, while giving users additional information with tooltips or popups.
- **No detailed guideline exists on how the drawing algorithm works**: Although I designed an algorithm for determining user's drawing between circle and pen drawing, no sufficient clue or metaphor exists that makes users perceive or infer it. Thus, the system should offer users with enough explanations about it.

5. Discussion

The system initially assumed physical settings, such as hospitals, with a patient and a medical practitioner co-located. Yet, as the system fully runs online and may make use of the internet network, I believe that my system is extensible to clinic situations, where stakeholders collaborate remotely.

Plus, in such a way, I expect that the process may also be automated. For example, once the data is accumulated enough to generate a model, the change in the region in Amsler grid imagery may be calculated with such pre-trained models. In such a case, progress may easily be tracked and reported in a more manageable way, thus requiring less burden.

Still, my study has several limitations that are required to be addressed. First, I made design implications and implemented designs from the literature. An additional user study with real-world users might be needed to gain better insights. Plus, this study adopted a heuristic evaluation method without evaluating the system with real-world users, which may not fully reveal the usability issues of users. In order to fully understand how patients perceive the system and gain feedback from them, clinical testing and interviews are required.

6. Conclusion

In this paper, I proposed AmslerTouch, a web-based interactive Amsler grid testing app. Consisting of various interactive tools, AmslerTouch supports users with interactively annotate the regions of issues with touch interaction, and further let them precisely report them. Based on the result of heuristic evaluation, I address future research direction that might enhance the overall interface.

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