Programmable Peripheral Vision: augment/reshape human visual perception

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Figure 1: a) Dynamic Periperal Vision Blocking Glasses. b) Saliency Reducing Glasses. 3) Gaze Guiding and Saliency Adjustable Glasses.

ABSTRACT

Over time our daily visual tasks become more complex continuously, however, the natural adaptation of our visual system does not adapt as fast as the living environment changes. As the representations of this unbalanced trend, concentration difficulty and visual overload are experienced and studied intensively. As well as universal motion sickness occurs in both real-life and virtual environments. Besides, online learning and co-working experience are far from satisfactory, which is partly due to lacking engagement and instantaneous visual interaction that we used to have when conducting those activities offline. Thus, my goal is to propose methods helping us better adapt to rapidly changing visual contexts. In the formative research, I created dynamic peripheral vision blocking glasses, and its experimental result indicates that wearing such glasses helped its users suffer fewer motion sickness symptoms while accessing fast-moving surrounding scenery in a VR environment. For the following studies, I am creating dynamic saliency adjusting glasses and gaze guiding glasses to augment and reshape daily-life visual perception.

CCS CONCEPTS

• **Human-centered computing → Ubiquitous and mobile devices**; **Interactive systems and tools**.

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KEYWORDS

smart eyewear, gaze guiding, peripheral vision, visual saliency adjusting

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1 CONTEXT

Compared to the drastic changes in our living environment over the past centuries, our visual system is almost the same as our ancestors. This unbalanced development of the environment and human vision system resulted in a series of vision-related negative consequences. For instance, increased myopia rate worldwide. Unavoidable long screen use and other modern visual tasks partly reflect such unbalance. Besides, vision-related illnesses like computer vision syndrome are becoming a widespread phenomenon [4].

As adaptational methods, if we are nearsighted we use the concave lenses. If we are farsighted we use convex lenses. If we want to see something far away, we use the telescope. Some novel glasses make those lenses adjustable [12]. Hence I wonder if we can make other properties of our vision system programmable. For example, if we want to focus on something can we block distracting objects in our peripheral vision area, saving part of our cognitive resource. Meanwhile, although augmented reality and virtual reality have been created and developed for decades, severe and universal motion sickness symptoms impede their further popularization.

Moreover, unavoidable online/ online-offline-hybrid teaching, learning, and co-working circumstances will at least last for a while or even be entrenched. At the same time, complaints and impaired teaching and learning experience are being discussed intensively. For instance, lacking gaze contact or gaze interaction that we used to have while attending or teaching off-line classes is now unavailable. To deal with those physical limitations such as the disparity between the locations of the subject's gaze and the camera while making video calls have been well addressed and solved [14].

1.1 Research Situation

I am doing my Ph.D. studies in the Graduate school of Media Design at Keio University, Kanagawa, Japan. My advisor is professor Kai Kunze. I am in the second half of my candidature which I started in April 2020. I had my first paper published in ISWC 2021, the 25th annual International Symposium on Wearable Computers [28]. I received my B.A. and M.F.A. degrees from fine art universities, which have a relatively less apparent correlation between Human-Computer Interactions, however, with those previous experiences of creating and studying visual art content, I am conducting my human vision augmentation-related studies smoothly and enthusiastically. I believe that I am on track to complete my Ph.D. in April 2023.

1.2 Motivation

My motivation, first, we can expect a world where we have more control of our vision system, therefore we can adjust our vision to best match corresponding visual tasks. Currently, to be less affected by audio noise, we can use noise-canceling earphones or headphones. Yet, besides well-addressed audio noise, visual noise also brings negative influences on both our mental state and cognitive performance. Thus, I wonder if we can also leverage external devices that help us suffer less from visual noise or current work irrelevant visual information.

As well as for myself, I am one of those people who experience visual overload frequently in daily life. In the case of my personal experience, my past practice in art universities required me to be highly sensitive to subtle visual differences, which ultimately made my visual information processing threshold keep at a relatively low level. It also means I can access the visual details quickly and effectively. On the other hand, I am not able to adjust my visual processing threshold properly, such as when is the optimal timing to be sensitive or when is the best timing to be visually numb to avoid potential visual interruption and overload.

Hence, I am eager to contribute to those areas to propose potential methods and better vision-adaptive systems for the gradually universal vision-related syndrome.

2 RELATED WORKS

Regarding vision augmentation, [17] presented many ways to modulate our visual experience, for instance, by using their device people who suffering color blindness can now distinguish the hid patterns [11]. [8] addressed the light adaptation and dark adaptation which usually take a long time when people get older or undergo substantial luminance changing. They presented a novel method that assists their users to deal with significant illumination change as well as enhance underexposure visual objects. In terms of augmenting spatial awareness even beyond the invisible area of our eyes, [3] presented a device that aims to allow its users to perceive and respond simultaneously to multiple spatial information sources by leveraging haptic stimulus.

In terms of reshaping visual experience, [24] introduced a concept that programmable physical architectures, where we can decide what part of the external world we see based on our changing needs. It also mentioned another concept called programmable shadows, in which we can adjust the amount of sunlight without blocking outside views completely. Both of them demonstrate the possibilities that we can intentionally leverage agency devices to adjust visual information based on our instant needs.

Besides, peripheral vision is one of the visual features that we are taking advantage of in order to augment or reshape our visual perception. Specifically, [25] pointed out that peripheral-vision space around the user is a valuable resource for awareness and communication systems. [18] aims to offer intuitive off-screen information obtaining experience. As well as [21] used two LED matrix displays to show information to the peripheral vision area in order to influence its user's behavior. [10] introduced a method that not only displays information to its user but can also change the information type from simple to detailed accordingly based on whether the user's visual focus is on the display area or not. Sparse Peripheral Display demonstrates methods to augment the field-of-view of head-mounted displays as well as to reduce potential motion sickness symptoms [26]. To influence the perception of speed, [19] designed patterns and displayed them based on the concept of Sparse Peripheral Displays.

On the contrary, rather than adding information to the peripheral vision area, removing or blocking part of visual information is used to evaluate visual task performance [16]. [28] presented eyewear that can dynamically block part of its user's peripheral vision area in order to reduce motion sickness symptoms while accessing fast-moving scenery. [13] applied the concept of diminished reality to remove content-irrelevant visual objects while accessing augmented reality contents.

To augment human vision by computational eyewear, [15] presented a device that can compensate for color vision deficiency. [6] indicates that gaze information strongly reflects the human interest or their attention; if we can smoothly guide the user's visual attention towards a certain target without interrupting them from their current visual attention, we are able to enhance the gaze-based interface. [7] proposed a method to guide their users' attention to the intended location without being noticed by using a subtle blur effect. Besides, [1, 5] addressed the involuntary attention in visual processing performance.

However, gaps remain in those topics aforementioned. For instance, those studies are insufficient regarding how to deal with dramatically changing visual processing demands. Sensory conflict such as motion sickness occurs due to our current vision system did not well-adapted to fast-moving-surrounding scenery when our body is relatively static. Second, saliency adjusting methods above did not cover daily visual processing activities and even failed when dealing with some cases such as objects that have significantly superior saliencies, items having a face or faces, or face-like features versus no face or no face features-having objects.

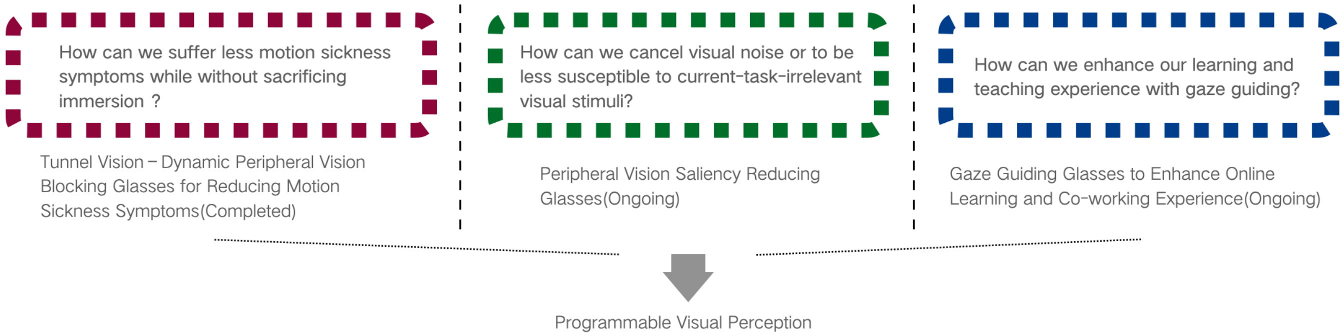

Figure 2: Current state of my PhD progress.

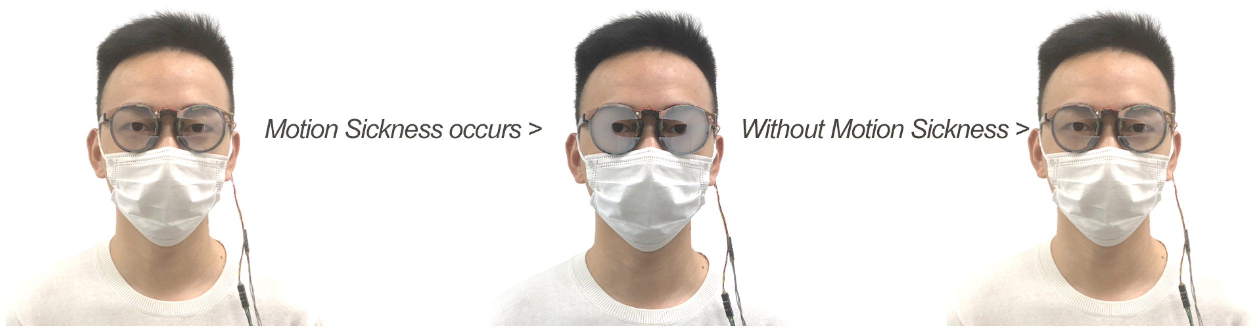

Figure 3: Tunnel Vision glasses help the user deal with motion sickness. Left, the user can see through the glasses as usual; middle, the glasses start to block visual stimuli in the peripheral vision; right, if the user starts to move their gaze away from the center, the glasses return to their transparent state.

2.1 Research Question

The main research question that ***how can we well adapt to dramatically changing daily visual activity*** is divided into three subsets:

- How can we suffer less motion sickness symptoms without sacrificing immersion?
- How can we cancel visual noise or be less susceptible to current-task-irrelevant visual stimuli?
- How can we enhance our learning and teaching experience with gaze guiding?

3 RESEARCH APPROACH AND PROGRESS TO DATE

3.1 Reduced motion sickness symptoms in both VR and real-life using scenario.

To examine the question that ***how can we suffer less motion sickness while accessing potential motion sickness triggers.*** I built a device that can adjust its user's field of view, especially to prevent its user from seeing visual information via peripheral vision, I used a transparent-opaque switchable film instead of an optical lens, known as polymer dispersed liquid crystal (PDLC) switchable smart film (see figure 1). I measured 16 college students (8 male and 8 female) in advance and found their average interpupillary distance was 63.3 mm (SD = 3.3, MAX = 70, MIN = 58). Based on this data and actual experience with the glasses, I cut out a horizontal elliptical area with a major axis of 8 cm. The participants seem to be comfortable in the setup if looking straight.

As the controlling system for changing between transparent and opaque mode, I used an Arduino compatible Pro Mini development board. Concerning its interactive design, we use two photoreflective sensors to detect users' eye movements. Regarding the interactive system of the glasses, I assume that if our participants feel sick, they can focus on any place without moving their eyes for 3.5 seconds, then the dynamic glasses' switchable PDLC film will become opaque to prevent its user from experiencing the fast-moving surrounding scenery via their peripheral vision. In comparison, if the users move their eyeballs, I assume that they feel well, then the film will be transparent to support them getting more visual information.

The result of dynamic peripheral vision adjusting glasses shows that using our method to reduce motion sickness symptoms simultaneously has less impact on immersion. In detail, there was a statistically significant difference in the symptoms, Nausea, Difficulty concentrating, and Fullness of the head, without impacting immersion.

3.2 Saliency Reducing Adjustable Glasses

How can we cancel visual noise or be less susceptible to current-task-irrelevant visual stimuli. I finished the prototypes of Saliency

Figure 4: Patterns designed for reducing saliency of the objects around the peripheral vision area.

Reducing Glasses, see figure 4, 5. It aims to address if we can dynamically adjust the saliency of current-work-irrelevant visual objects around our peripheral vision area. It was indicated by the previous peripheral vision blocking glasses that instead of blocking part of the visual information of the peripheral vision area, it is more intuitive and acceptable to alter those current-task-unrelated visual objects around the peripheral vision area less salient, or in other words, making them cognitively meaningless.

To examine what kind of patterns of design works well such as what can make current-task-irrelevant visual information less salient or less cognitively attractive as well as how much space can we adjust while without sacrificing the resolution of the central area of view. I designed and tested three types of patterns based on Wizard of Oz, see figure 4. As the result of a pilot test, the central radial pattern worked well as a semi-transparent filter to blur the peripheral vision without feeling significant difference while gradient dots pattern and fully-block pattern reached uneasy feelings.

3.3 Gaze Guiding Glasses

Besides, a gaze-guiding glasses that I am building recently is in its 70% completion and which is increasing gradually, see figure 1 (c). It aims to address ***how can we enhance our learning and teaching experience with gaze guiding?*** For instance, offer methods to guide its user's gaze to the speaker's intended place. As well as, to help its users to better catch up with instructors' or co-workers' points while lots of people are complaining about dissatisfied online education and online co-working experience nowadays. When the prototype building is finished, then a pilot experiment will start. As the gaze guiding material, I used two monochrome Liquid Crystal Displays. Those kinds of displays were used by [8] that generate a semi-transparent layer in between the real-world visual information and our eyes to suppress extreme bright illumination change. Now I am designing patterns that can work as blurry effects [7] to induce the user to move their gaze to the unobscured area or the relatively high-resolution area with the consideration of how to avoid significantly salient objects such as face-having objects affect the gaze guiding performance. Therefore, it is more adaptive and practical to blur the area beside the intended place based on context-aware design instead of making the blur effects uniformly.

3.4 Contributions

To the best of my knowledge, the peripheral vision blocking glasses within this research scope is the first study that presents a wearable device to reduce motion sickness symptoms in VR/AR and real-life situations without impacting immersive experience. This study suggests a practical method that will, directly and indirectly, propel the popularization of the VR/AR contents related industry. Since with our glasses' help, users will feel less sick while enjoying visual content without sacrificing immersion.

The study of saliency-reducing glasses will improve our visual task performance such as working in an environment where fulfilled with visual noise, or in other words, current-tasks-irrelevant visual information.

Third, my gaze guiding glasses are expected to help its users to better catch up with instructors' or co-workers' points while lots of people complain about dissatisfied online education and online co-working experiences. These studies may also contribute to increased concentration since [23] clarified that with or without gaze, we have different sound processing reaction times from short to long.

3.5 Challenges

According to [7] that how-to guide users attention without failing to deal with objects have significant and superior saliency compared to others, such as face-having objects versus no-face objects, as well as some certain designs have superior saliency than others among the same kind of group is still a tough problem. Besides, various visual preferences would also influence the robustness of the gaze guiding system.

Myopia rate increases worldwide [9, 27]. This trend also appears when I was recruiting participants to join my experiments, I found the majority of them are usually nearsighted or farsighted. As a result, how to implement my works to cover poor-eyesight users' diverse situations could be an inevitable issue.

4 EXPECTED NEXT STEPS AND LONG TERM GOALS

Thinking human-computer integration, for instance, [2] introduced a system that provides real-time computer assistance to its user based on EEG signals from the user's visual cortex. It reveals the potential that we can leverage pre-attentive signals to act beyond the biological limitations of our bodies. Therefore, I am planning to implement such a method into my future work to gain deeper insights into human vision augmentation scenarios.

I am also inspired by the studies regarding bodily ownership [2, 20, 22] which indicates that there are crucial timings exist when we reach the illusion that computational assistance is part of our own capability. Therefore, besides making computational intervention subtle, I am going to dig into more natural or more intuitive human-computer interactive scenarios especially in terms of auto-adaptive human-vision-enhancing systems. I envision a future when we can have more control of our cognitive resource distribution such as attention and concentration, which will not only increase productivity but also will contribute to our mental health.

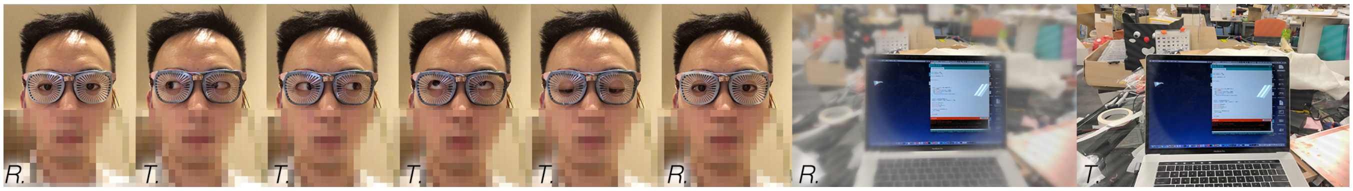

Figure 5: Saliency Reducing Glasses Woring Demonstration. R. indicates Saliency Reducing Mode. T. is Transparent Mode.

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