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ARTICLE

Sunny Pointer: Designing a mouse pointer for people with peripheral vision loss

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ABSTRACT
We introduce here a new mouse cursor designed to facilitate the use of the mouse by people with peripheral vision loss. The pointer consists of a collection of converging straight lines covering the whole screen and following the position of the mouse cursor. We measured its positive effects in a group of participants with peripheral vision loss of different kinds and found that it can reduce by a factor of seven the time required to complete a targeting task using the mouse. Using eye tracking, we show that this system makes it possible to initiate the movement toward the target without having to precisely locate the mouse pointer. Using Fitts' Law, we compare these performances with those of full visual field users in order to understand the relation between the accuracy of the estimated mouse cursor position and the index of performance obtained with our tool.

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KEYWORDS
human computer interaction; lost cursor; mouse cursor; mouse pointer; peripheral vision loss; visual impairment

Introduction

Peripheral vision loss (PVL), also known as “tunnel vision”, is a disability in which a person’s visual field (VF) is restricted to a small centered portion of its normal size (Rosenholtz, 2016). It may be caused by various diseases such as retinitis pigmentosa or glaucoma, which was identified in 2002 by the World Health Organization as the second cause of blindness worldwide (Resnikoff et al., 2004) with a projection of 100 million affected people by 2040 (Tham et al., 2014). People suffering from PVL encounter several major difficulties that can severely affect their personal and professional lives (Evans et al., 2009; Quaranta et al., 2016; Ramulu, 2009). Despite its low resolution (Westheimer, 1982), peripheral vision provides important information about the environment (Larson & Loschky, 2009; Thorpe et al., 2001) and can guide the gaze for high-resolution inspection with the fovea during visual search (Coeckelbergh et al., 2002; Geisler et al., 2006; Hooge & Erkelens, 1999). It can also provide online information in the control of movement direction (Khan et al., 2004). The use of a computer is problematic for people with PVL (J. A. Jacko et al., 2000b; Jacko & Sears, 1998).

One of the main difficulties for these people is the use of the mouse, which remains one of the most commonly used tools for the selection of interactive items spatially distributed on a computer screen. The problem is that the surface of a screen measuring 50.9 cm in width and 28.6 cm in height placed 70 cm away from the user is approximately 110 times bigger than what a person with a centered visual field (VF) reduced to 1.5° radius sees. This restricted VF slows the speed of the PVL computer user and necessitates important cognitive resources that can bring about mental fatigue which may become unbearable. A system specifically designed to improve the accessibility of the computer mouse for people with PVL is thus of great import in improving their quality of life.

In the context of their restricted field of view, the process users with a PVL impairment follow to click on a target can be separated into three successive steps. First, the user has to localize the spot he or she wants to click on. Localizing this spot depends on many parameters such as the color, the position, the size and the user’s prior knowledge of the graphical interface. Second, the user has to identify where the mouse pointer is located prior to moving it toward the target on the screen. And third, the PVL user has to guide the mouse pointer trajectory toward the target, a difficult task as it is impossible to simultaneously see the target and use peripheral vision to control the trajectory of the mouse pointer(Proteau et al., 2000). In this paper, we describe a new assistive solution to help people with PVL use a mouse during the two last steps (i.e. the initial localization of the mouse pointer and its trajectory control).

As described in (Fraser & Gutwin, 2000), such an assistive technology may take action on several levels. The first one is the perceptual channel used to assist the user. It may be visual, auditory or tactile. The second dimension describes whether knowledge of its context is required by the assistive system. In the case of a mouse cursor, this corresponds to whether or not the mouse cursor has preliminary knowledge of the targets that can be accessed on the screen. The third refers to the phase of operation that is facilitated by the system. In our case, this may be the localization of the pointer or the target, the move of the pointer toward the target or the click on the precise position of the target.

In terms of the above-mentioned dimensions, the pointer design that we present belongs to the category of visual and context-agnostic technologies developed to ease the localization of the pointer and its move toward the target.

Previously developed projects to ease the use of the mouse by the visually impaired are already included in the category of

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visual and context-agnostic assistive tools (Liu & Zhao, 2018). The most obvious members of this category are pointer magnification tools which are now integrated into every common operating system. They consist of tools which increase the size of the pointer, draw large circles around the pointer or draw a visual trail materializing the recent pointer moves (Baudisch et al. 2003; Fraser & Gutwin, 2000). Although use of these tools can undoubtedly help to localize the mouse pointer, people with severe PVL still have difficulty since these systems do not help to simultaneously see the pointer and the target and they thus provide no assistance during the move of the pointer toward the target. Moreover, the proper setting value for the size of these visual cues results from a trade-off between the visibility of the pointer and the visibility of the rest of the interface. Such tools are thus designed more for people with low visual acuity than for people with PVL (Chiang et al., 2005; J. Jacko et al., 2000a).

The tool most commonly used by PVL users currently seems to be *ZoomText* (Vispero) that draws a big crosshair composed of one vertical line and one horizontal line that intersect at the mouse position. Users with PVL will, however, typically be able to see either the horizontal or the vertical line, although not both, and will thus be missing clear context to determine the correct direction of the cursor position. The user has to move the pointer, potentially in the opposite direction of the target, to disambiguate the information.

Color Eyes is another system, one that presents a stylized pair of eyes on the screen which continually gaze toward the mouse pointer and encode its distance by means of a color code (Kline & Glinert, 1995). Using this tool, the user can have an approximate idea of the localization of the mouse pointer and thus search for it in a reduced portion of the screen. However, in order to localize the pointer, this assistive technology requires the user to first look at an additional visual component, a process which can perturb memorization of the localization of the target.

A new version of the tool called *RPMouse*? has recently been released. This tool draws a line from the top left corner of the screen to the mouse pointer position. Compared to the standard use of the mouse pointer, the user of the tool can more easily localize the mouse pointer without the need to visually scan the entire screen. To move the pointer toward the target, the user has first to look at the top left corner of the screen, to visually follow the line to its end in order to localize the cursor, then to move the cursor in the estimated direction of the target until both the cursor and the target enter the field of view.

Another solution currently used by people with PVL consists in placing the pointer at a predefined spot on the screen, for example, by pressing a combination of hotkeys such as provided by the software *AutoHotkey* (AutoHotkey Foundation LLC) or by pressing a specific button on the mouse (Hollinworth & Hwang, 2011). Other users manually place the pointer in the top left portion of the screen after each click. Using such techniques helps users avoid searching for the pointer, but they might place the pointer in a suboptimal initial position; in addition, such practices do not help in the case where the user becomes confused about the position of the pointer during its move toward a target.

Despite all these tools, the use of the mouse pointer remains very difficult for people with PVL. We have thus developed a mouse pointer called *Sunny Pointer* that enables these special-needs users to speed up their use of the mouse to click on a target without ever losing sight of this target (as people who are able to use their full visual field would do). It can be freely downloaded at the following website (Sunny Pointer). In this work, we first describe our pointer design and experimental methods. We then present a first experiment with six PVL users showing that our tool can decrease the time to complete the task by a factor up to 7. In a second experiment, we used eye tracking methods with a trained peripheral vision loss participant, revealing that the pointer can be moved within the peripheral visual field toward the target while keeping the gaze on the target. Finally, we set out to identify the characteristics of our pointer that could be fine-tuned so as to obtain performances in participants with PVL similar to those of users with normal vision using a standard pointer. To do so, we compared, in a third experiment, the performances obtained by people with normal vision but with simulated PVL, with and without the Sunny Pointer.

Materials and methods

General description of the experiments

In this work, we tested participants' capacity to control the trajectory of the mouse cursor under different conditions. The task was to click as quickly as possible on a visual target placed at the center of the computer screen with the mouse cursor initially placed at several random positions. In the following discussion, the distances, positions and sizes of the graphical components displayed on the screen are expressed in a spherical coordinate system whose origin is a point located between the eyes of the participant. The coordinates are angles with regard to the line extending from the origin and reaching the center of the screen.

The mouse pointer that we developed draws straight lines starting at a short distance from the cursor and covering the screen. The complete 2π angle around the cursor is divided into several equal portions, each delimited by two lines. In other words, these lines materialize the radiuses of a circle centered on the mouse cursor, thus producing a structure resembling light rays coming from the mouse cursor (and accounting for the name of the tool). This graphical structure follows each move of the pointer. In order to stand out clearly from various graphical backgrounds, each line is composed of two colors, one for the inside of the line and another for its borders. In order to limit the parameter space and the complexity of this study, the following setup was chosen for all participants and all experiments: 128 lines, each line composed of a black line with a superimposed thinner white line (respectively 4 and 2 pixels wide); the lines are constantly displayed when our system is turned on; the lines start at a distance from the pointer corresponding to two degrees of the visual field and the lines end at the edge of the screen as presented in Figure 1A.

The visual target to click on was indicated by a 1° wide (diameter) red disk at the center of the screen. The position of the mouse cursor was materialized by a black cross identical in

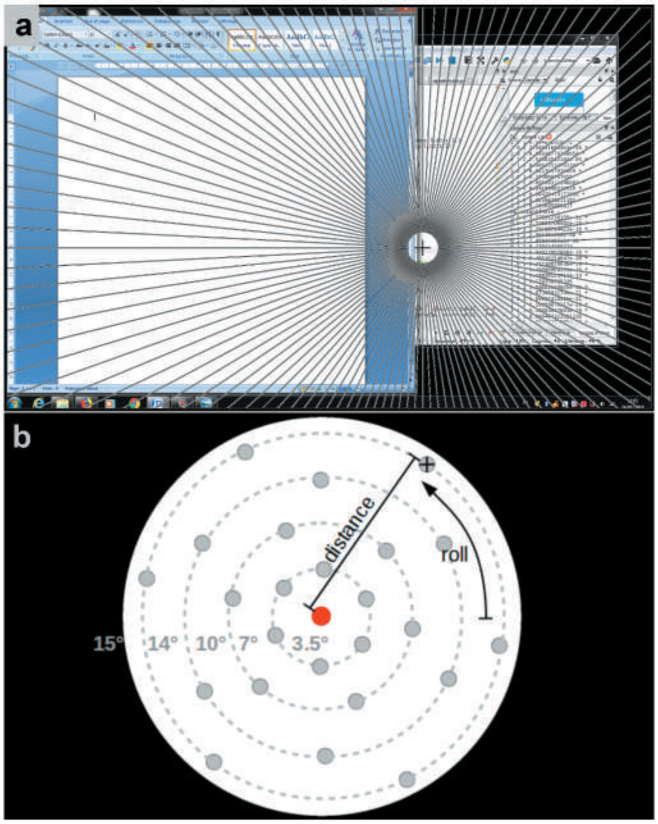

Figure 1. **A**: a screenshot of the Sunny Pointer during its activation over a standard desktop screen. The position of the mouse cursor is materialized by a black cross and the Sunny Pointer displays 128 equidistantly spaced "rays" that radiate from the mouse cursor toward the edges of the screen. **B**: an annotated scheme of a screen during experiments showing the area of response (white disk), the target (red disk), and the mouse cursor (black cross). Concentric circles and small gray disks are annotations showing the possible positions of the mouse cursor for each trial.

size to the target. The area in which the mouse cursor could appear and move was indicated by a gray disk with a diameter equal to the height of the screen and thus corresponding to a radius of 15° of the FOV centered on the screen. The mouse pointer was artificially maintained at the border of the gray area in cases where a move would have caused it to exit this area. The "rays" of the Sunny Pointer were completely hidden outside the gray area. In each exercise, four initial pointer-target distances were used: 3.5°, 7°, 10.5° and 14°. For each pointer-target distance, six pointer-target roll angles were used. For a given distance, the first of the six roll angles was uniformly chosen over a range of $[0 - 2\pi]$ and the five other angles were equidistantly spaced with $\pi/3$ starting from the first randomly chosen angle. An annotated scheme of the screen during experiments is shown in Figure 1B.

In each exercise, participants thus had to perform six trials for each of the four distances, making a total of 6 × 4 = 24 trials for each exercise. All the trials in each exercise were randomly permuted. Before each trial, the participant had to replace the mouse device at the center of the assigned moving area on the table. When the user was ready, he or she had to press the left mouse button. Immediately afterward, the mouse cursor was placed in a new position and the participant had to move it in order to click on the target with the left button as quickly as possible. When the target was clicked on, the pause to replace the mouse device at the center of the designated area was repeated before the next trial. Before the experiment, a questionnaire was completed recording the participant's age, gender, laterality, vision disorders and acuity, as well as a subjective evaluation of the participant's ability to use the mouse. A verbal explanation of the different tasks was briefly presented to all subjects before the start of the experiment.

The experimental apparatus consisted of a PC running Windows 7. The software was programmed using C#. A chinrest was placed in front of the computer screen so that the user's eyes were horizontally in line with the center of the screen. The screen was placed so that the angle between this horizontal axis and the top edge of the screen corresponded to 15° of the participant's visual field. For example, a screen 52 cm wide and 32 cm high was placed approximately 59.7 cm away from the chinrest. The mouse was placed on the table to the right of the chair (since only right handed subjects took part in the experiment) in the middle of an area large enough for the user to move the mouse freely. A logitech B110 optical mouse featuring a sensitivity of 800 dpi was used. To ensure that each participant had to perform the same physical arm movements across trials, sensitivity to the acceleration of the mouse was disabled in the operating system and the sensitivity of the operating system mouse was set in such a way that the height of the screen could be crossed with a move of the mouse device corresponding to 3.5 cm on the table. For example, the height of a screen with a resolution of 1680 × 1050 requires a mouse sensitivity of approximately 760dpi to be entirely vertically crossed with a 3.5 cm displacement. The program sampled and recorded the mouse position (X and Y) at a rate of 33 Hz. There was no perceptible lag between movement of the mouse device and the associated movement of the cursor.

General description of the analysis

In the following work, the time to complete the task (TCT) is considered the time lapse between the moment the target and the pointer are displayed on the screen and the moment the participant clicks on the target with the pointer. As proposed in (Card et al., 1980), we distinguish three periods in the TCT: the acquisition time (AT) is the time lapse between the moment the target and pointer have been displayed on the screen and the participant's first move. This first move is detected when the mouse cursor has been moved by more than 10 pixels from its initial position. This is the time used by the participant to collect information and to plan his/her move. The movement time (MT) is the period starting with the first detected move of the pointer and ending when the participant reaches the target for the last time (in case of multiple attempts due to overshoots). This is thus the theoretical moment at which the participant could have validated the trial if no time was required to click on the mouse button. The keystroke time (KT) is the period starting when the pointer reaches the target for the last time until the user clicks on it and thus completes the task.

In order to compare the results of one configuration to those of another, we use the Mann–Whitney U test to determine the probability that the two sets of results come from the same distribution. This test does not assume a normal distribution of the samples and can be applied to two non-paired and independent samples.

Experiment 1

In this experiment, we measured the improvement due to the Sunny Pointer compared to a regular use of the mouse in six participants with different types of Peripheral Vision Loss summarized in Table 1.

The experiment was composed of five successive exercises, each composed of 24 trials as explained in section 2.1. We used two types of exercises as illustrated in Figure 2A and 2B. In the first type of exercise, the Sunny Pointer is turned off and the pointer is only materialized by a small black crosshair as shown in the figure on the left. This type of exercise is referred to as the CP-PVL condition (Crosshair Pointer – Peripheral Vision Loss). The second type of exercise, shown in the figure on the right, is referred to as the SP-PVL condition (Sunny Pointer – Peripheral Vision Loss). The conditions of this exercise are the same as the previous one except that our pointer is now turned on, displaying lines radiating from the mouse cursor as depicted in section 2.1. Each participant completed a first exercise in the CP-PVL condition, then three exercises in the SP-PVL condition and then again one exercise in the CP-PVL condition. Due to the time required for some participants to complete the task in the CP-PVL condition, we decided to limit the number of exercises in this condition during the experiment to two. Their order of occurrence during the experiment (first exercise and last exercise) was chosen to prevent the improvement occurring during the experiment due to the user's habituation to the sensitivity of the mouse from contaminating the comparison of results between the CP-PVL and the SP-PVL conditions. The results presented in Figure 3 are aggregated results of the exercises of each type.

Table 1. Table summarizing the participant id (first col.), the corresponding radius of the binocular visual field express in degree (second col.), the corresponding binocular acuity given in 10^{e} in the test of Parinaud (third col.), and the type of visual disorder (RP: Retinitis Pigmentosa, GL: Glaucoma).

Participant	Bino. VF	Bino. Acc.	Vis. Dis.
	radius (deg.)	(10e Parinaud)	
A	1.25	7	RP
B	2	4.5	RP
C	2.5	7	GL
D	2.5	2	GL
E	2.5	2	RP
F	5	1.6	RP

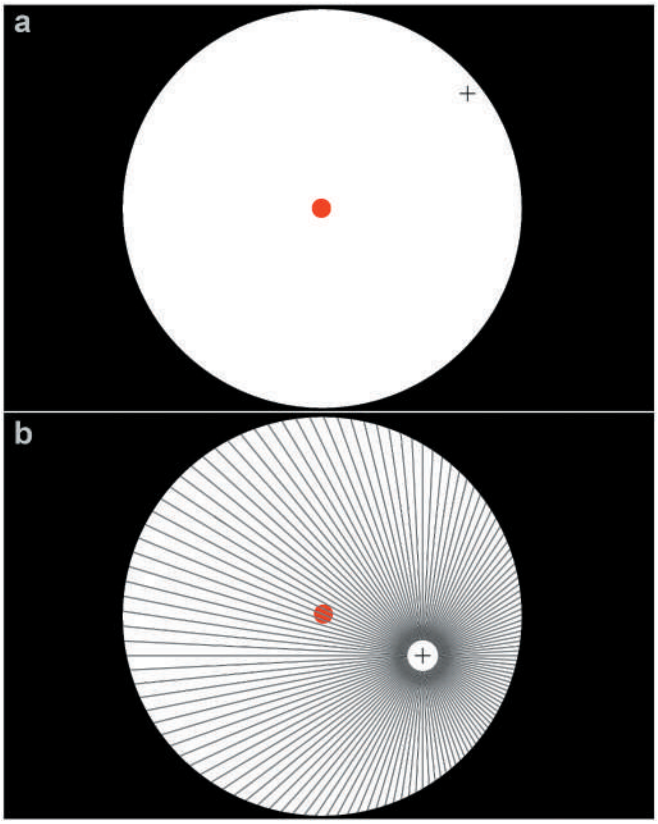

Figure 2. **A**: a screenshot when the Sunny Pointer is turned off, i.e. the CP-PVL condition (Crosshair Pointer – Peripheral Vision Loss). **B**: a screenshot when the Sunny Pointer is turned on, i.e. the SP-PVL condition (Sunny Pointer – Peripheral Vision Loss).

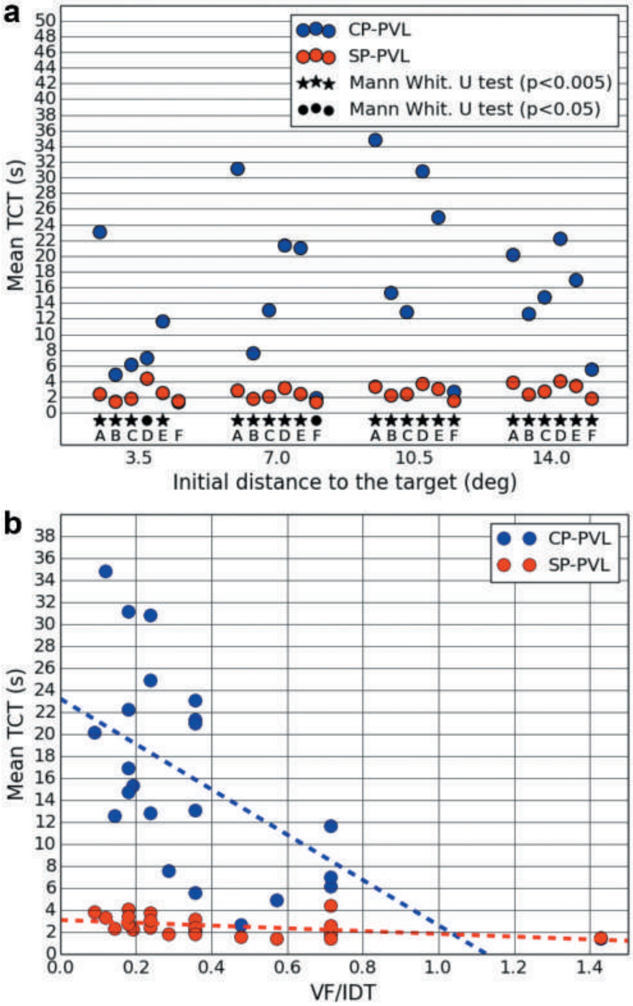

Figure 3. **A**: Mean Time to Complete the Task (TCT) without (CP-PVL) and with our pointer (SP-PVL) as a function of the initial distance from the pointer to the target for each of the six participants [A,B,C,D,E,F]. **B**: Mean Time to Complete the Task (TCT) without (CP-PVL) and with our pointer (SP-PVL) as a function of the ratio between the radius of the visual field of the user (VF) and the initial distance from the pointer to the target (IDT) for all the participants. Linear regressions are superimposed with dashed lines.

Results of experiment 1

The comparison between the mean Time to Complete the Task (TCT) without (CP-PVL) and with our pointer (SP-PVL) as a function of the initial distance to the target is shown for each of the six participants in Figure 3A. While using our pointer, the TCT ranges from 1 to 4 seconds (mean = 2.5s). The TCT in the CP-PVL condition is more variable, with a mean value of 17 seconds and results that depend highly on both the participant and the initial distance. All comparisons between CP-PVL and SP-PVL were significant except for that of participant F at an initial pointer distance of 3.5°.

The high variability in the CP-PVL condition is due to differences in the visual fields of the participants and in the strategies they used. As they told us after the exercises, some participants employed horizontal scanning from top to bottom in order to find the mouse pointer, others scanned in a spiral either from the outside toward the center or the inverse, while still others did not seem to use a specific strategy. Concerning participant F, this participant's visual field of 5° was large enough to simultaneously see the target and the pointer at an initial distance of 3.5°, but the TCT differences became more and more significant as the initial distance to the target exceeded the participant's visual field.

To better understand the relationship between the improvement due to the use of the Sunny Pointer and the conditions of its use, we plotted in Figure 3B the mean TCT as a function of the ratio between the radius of the Visual Field of the user (VF) and the initial distance from the pointer to the target (IDT). Results for all participants in the CP-PVL and the SP-PVL conditions are shown, superimposed by their respective linear regression in dashed lines. Not surprisingly, the advantage of our system strongly depends on the ratio between the visual field and the initial distance to the target. The improvement seems to appear at a ratio lower than 1 and reaches a value of 7 at a ratio close to 0.1. The coefficients of determination of the linear regressions in the CP-PVL condition and in the SP-PVL condition are respectively 0.41 and 0.15. We found no relation between the time to complete the task and visual acuity.

Conclusions from experiment 1

The Sunny Pointer can decrease by a large factor the time needed to click on a target compared to the standard use of the mouse. This conclusion seems to be valid in cases of peripheral vision loss due to both retinitis pigmentosa and glaucoma. However, it seems that people use the system in various ways. During the debriefing, some participants explained that they used the lines in order to find the pointer quickly, afterward moving the pointer as they would have done without the Sunny Pointer. Others directly began their move toward the target based only on the convergence of the lines covering it. We describe more precisely this latter strategy in the next experiment.

Experiment 2

John is 36 years old. Due to a retinitis pigmentosa condition diagnosed 15 years ago, his field of vision is restricted to approximately 3.5° around the direction of his gaze. His remaining central acuity is 3/10 and 4/10 but is corrected to 9/10 and 10/10 with the aid of the glasses worn during this experiment. He was a computer developer before his impairment and is thus used to handling the mouse. Before this experiment, his principal strategy was to place the mouse pointer in the top left corner of the screen after each click of the mouse and, after having found a new target, move it in the estimated direction of the new target while following the pointer with his eyes on the screen.

In order to understand how someone with PVL can use our tool after some training, the Sunny Pointer was installed on his computer two weeks before the experiment took place and we asked him to use it every day. He used the system on average one hour a day. After two weeks, we used an eye tracker (Tobii Pro TX300) during task performance to record this participant's gaze direction at a rate of 33 Hz. We did not experience any calibrating issues despite the fact that the participant wears glasses. The gaze was classified into three categories according to the following procedure: if the gaze was situated in a radius of less than 2° from the target, the gaze was categorized as being focused on the target; if not, and if the gaze was situated in a radius of less than 2° from the current mouse cursor position, the gaze was categorized as being focused on the mouse cursor; the gaze was categorized as being focused elsewhere if the two above conditions were not satisfied. For each trial, the gaze direction profile was renormalized on a time scale between 0 and 1, in which 0 is the time at which the cursor was displayed on the screen and 1 is the time at which the participant clicked on the target.

Results of experiment 2

As in the previous experiment, we formulated two types of exercises: one in the CP-PVL condition (Sunny Pointer turned off) and the other in the SP-PVL condition. The averaged gaze direction profiles in the CP-PVL condition for 3.5°, 7° and 14° initial pointer-target distances are shown in Figure 4A, 4B and 4C, respectively. Data for 10.5° in the CP-PVL condition are not shown as they conform to the general scheme presented in the previous three plots. The averaged gaze direction profiles in the SP-PVL condition (Sunny Pointer turned on) for an initial pointer-target distance of 14° are shown in Figure 4D. Data in the SP-PVL condition at 3.5°, 7° and 10° are not shown since they reproduce the data for 14°, i.e. a constant focus on the target.

As annotated in Figure 4C, the strategy used in the CP-PVL condition can be broken down into a sequence of four steps: (A) a proximity search in which the participant looks in the vicinity of the target to find the cursor; (B) a further search encompassing the complete screen if the cursor was not found during the proximity search; (C) the localization of the pointer and the estimation of the proper direction of movement; and (D) the moving of the pointer toward the target. The relative duration of the steps depends on the initial distance between the mouse cursor and the target. The longer the pointer-target distance, the longer the search on the screen. The participant explained this strategy as follows "I first seek the mouse cursor by following a spiral centered on the target. Sometimes, I also

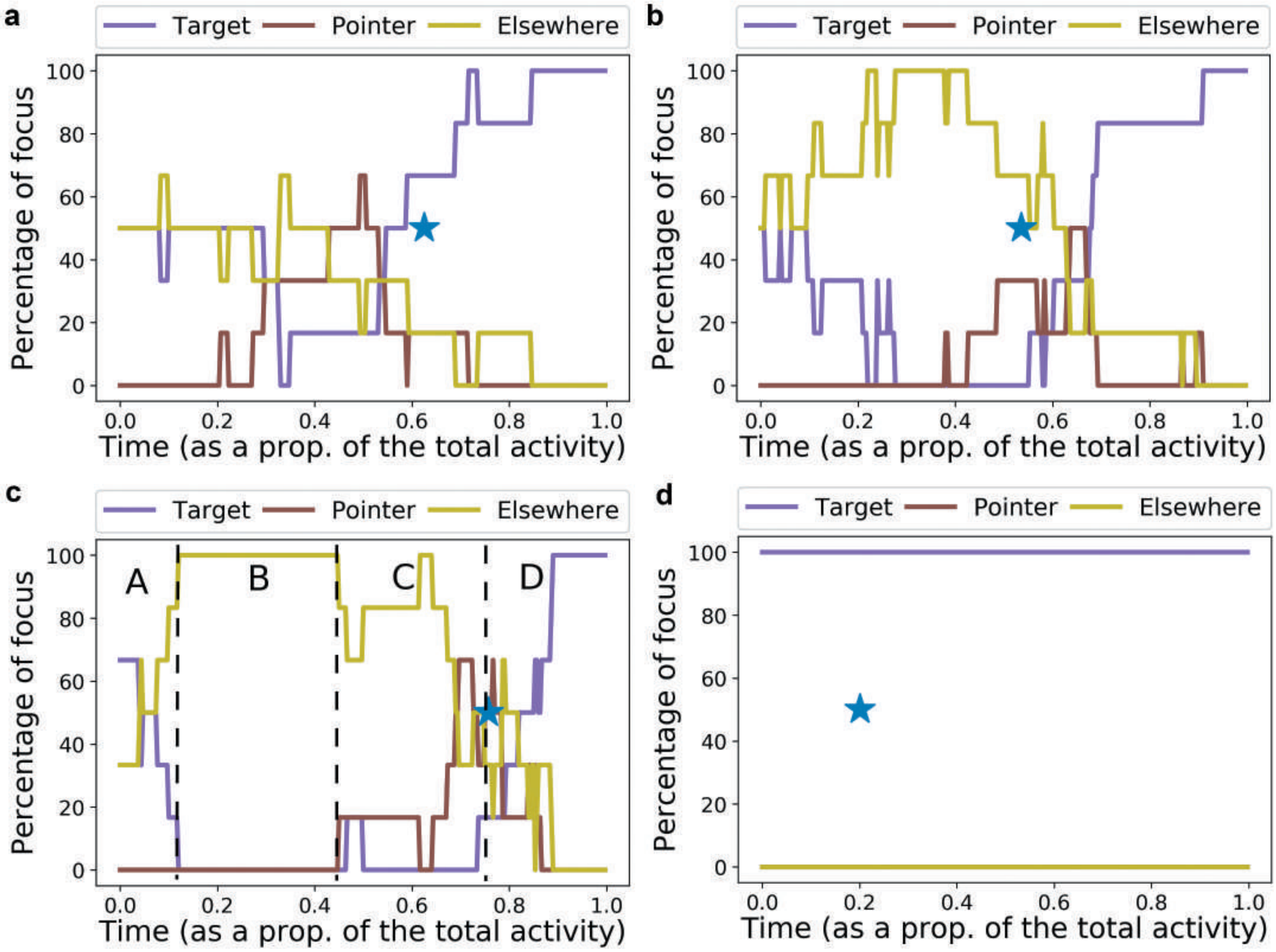

Figure 4. Figures showing the proportions of time the participant focused on the target, on the mouse cursor, or elsewhere on the screen. The blue star materializes the mean time of the first detected move. **A**: gaze recordings for an initial pointer-target distance of 3.5° in the CP-PVL condition (Crosshair Pointer – Peripheral Vision Loss). **B**: gaze recordings for an initial pointer-target distance of 7° in the CP-PVL condition. **C**: gaze recordings for an initial pointer-target distance of 14° in the CP-PVL condition. **D**: gaze recordings for an initial pointer-target distance of 14° in the SP-PVL condition.

try my luck by doing a random search. When I have found it, I move the cursor in the estimated direction of the target until both the cursor and the target enter my visual field."

In contrast, the profile of the user's gaze when the Sunny Pointer was turned on is completely different, as presented in Figure 4D. The participant focused exclusively on the target throughout the whole trial. This confirms the strategy that he explained in these terms after the experiment: "I constantly look at the target and I use the direction and the convergence of the lines to evaluate the direction in which I have to move the mouse." Our participant's strategy is similar to the first one depicted in (Smith et al., 2000) concerning full visual field users. This illustrates the first main advantage of our pointer: it not only facilitates the localization of the mouse pointer but also eliminates the need to precisely locate the pointer in the 2-dimensional space of the screen before starting the mouse move.

As shown in Figure 5A, this drastic change in strategy reduces the time required to complete the task (TCT) by a factor of up to 3, except in the case of the 3.5° distance. In this last configuration, John's VF of ± 3.5° was sufficient to quickly localize the target and the pointer and the assistance afforded by our pointer was thus not as significant as in the case of longer pointer-target distances. It should be noted that the standard deviations in the SP-PVL condition for 7°, 10.5° and 14° distances are 10 times lower than those observed in the CP-PVL condition, showing that the information provided by the Sunny Pointer is reliable enough to induce a reproducible TCT.

As shown in Figure 5B, most of the decrease observed in the TCT results from a major decrease in acquisition time in the SP-PVL compared to the CP-PVL condition (see section 2.2 for a definition of acquisition time). In the CP-PVL condition, the mean acquisition time ranges from 1.5 seconds for a pointer-target distance of 3.5° to up to 5 seconds for larger pointer-target distances. The use of the Sunny Pointer, i.e. the results obtained in the SP-PVL condition, reduces this time to approximately half a second, independent of the initial pointer-target distance. This decrease in acquisition time is the first advantage of the Sunny Pointer.

Figure 5C shows that in the SP-PVL condition, the movement time slowly increases from approximately half a second to a little more than one second. The situation in which our pointer is off (CP-PVL condition) is more complicated and the

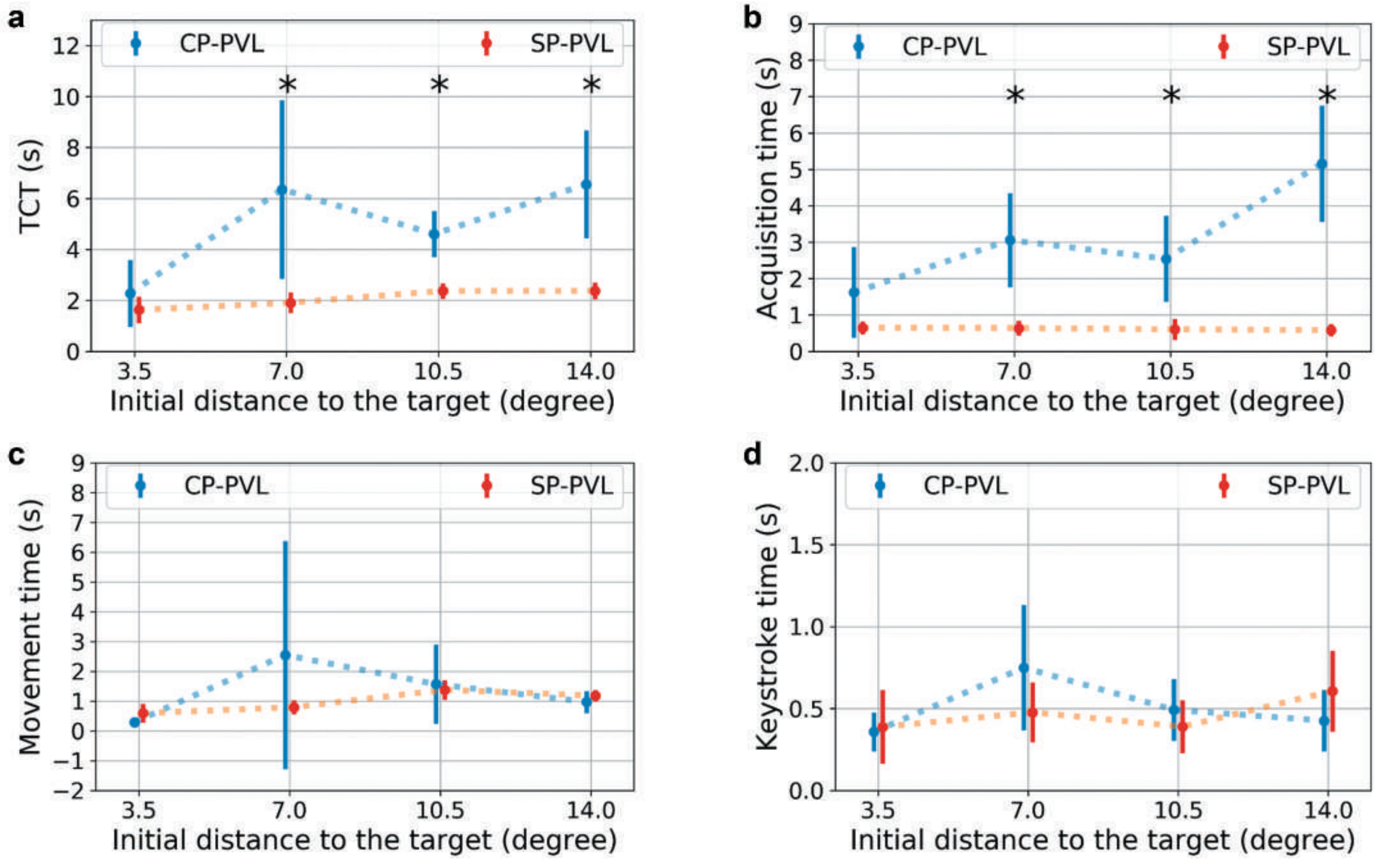

Figure 5. **A**: the time to complete the task (TCT) against the initial distance between the cursor and the target in the CP-PVL (Crosshair Pointer – Peripheral Vision Loss) condition (blue) and the SP-PVL (Sunny Pointer – Peripheral Vision Loss) condition (red). **B**: the acquisition time (AT). **C**: the movement time (MT). **D**: the time to click on the target (keystroke time: KT). Dotted lines are superimposed to show the variations in mean times. Stars materialize conditions in which the distributions in CP-PVL and SP-PVL conditions significantly differ using a Mann-Whitney U test ($p < 0.05$).

mean movement time does not significantly differ from the SP-PVL condition except in the 7° condition. During exchanges with the participant after the experiment, he mentioned trials in the CP-PVL condition in which he became confused about the position of the mouse cursor during its move toward the target. He thus stopped the move until he had once again localized the mouse pointer before completing the trial. The Sunny Pointer prevents such confusions from happening, which is the second advantage of its use.

Keystroke times shown in Figure 5D do not significantly differ from SP-PVL to CP-PVL conditions, showing an average value of approximately $0.5s$.

Conclusions from experiment 2

The Sunny Pointer can drastically change the way people with PVL use the computer mouse. Without the Sunny Pointer, the user searches the screen for the mouse cursor before starting to move it in the estimated direction of the target. With the help of the Sunny Pointer, the user can focus solely on the target and use the information provided by the "rays" of the pointer to determine how best to move the mouse cursor. The 2-dimensional localization of the pointer on the screen is no longer necessary and this brings with it a significant reduction in acquisition time, resulting in a decrease in the TCT by a factor of three. Moreover, the use of the Sunny Pointer seems to decrease the probability of confusion during the pointer move toward the target.

Experiment 3

In the third experiment, we sought to understand how to improve the performances obtained with the Sunny Pointer in order to bring them closer to those obtained by participants with full visual fields (FVF) using a standard mouse pointer. To this end, we studied the targeting performances of FVF participants with and without a simulated PVL. Twenty participants aged from 15 to 35 years old participated in this third experiment. All participants were right handed with a corrected visual acuity equal to or greater than 8/10 in the worst eye. They had no motor disabilities and subjectively evaluated their ability to move the mouse at 7/10 or higher.

This experiment was composed of four exercises and was organized as follows. The first two exercises were identical to the two described in the first experiment (section 3). The first exercise thus consisted in the normal use of a standard mouse pointer (a black cross) and a target materialized by a red disk (see Figure 6A for an illustration). This exercise is referred to as the CP-FVF condition (Crosshair Pointer – Full Visual Field). The second exercise was identical to the SP-PVL condition in the first experiment. But unlike the first experiment, results obtained during this exercise were not analyzed. It was

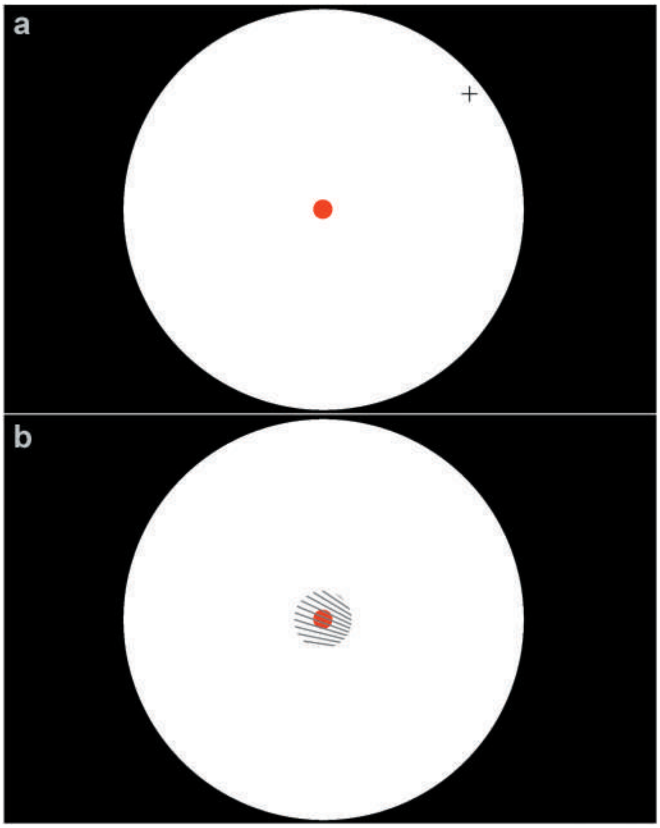

Figure 6. **A**: a screenshot in the CP-FVF condition (Crosshair Pointer – Full Visual Field). **B**: a screenshot of the SP-SIMPVL (Sunny Pointer – Simulated Peripheral Vision Loss) condition (radius 1.5°) and the Sunny Pointer turned on.

simply used as a preliminary exercise to accustom participants to the Sunny Pointer. In the third and fourth exercises, a mask completely hiding the screen except for a round aperture of 1.5° radius placed at the target position (the center of the screen) was superimposed in order to force the subjects to use only their central vision, as presented in Figure 6B. In other words, the mouse cursor and the "rays" of the pointer were hidden except for a small area around the target. This is thus similar to the "Window" paradigm used in (Larson & Loschky, 2009). This paradigm simulates a PVL impairment to the extent that participants can only use the lines of the Sunny Pointer that are visible in a restricted area to move the mouse cursor toward the target. The third exercise was designed to accustom participants to the simulated PVL. The fourth exercise is referred to as the SP-SIMPVL condition (Sunny Pointer – Simulated PVL) whose results are compared to those of the CP-FVF condition in the following figures.

Results of experiment 3

Mean TCTs plotted for the CP-FVF (Crosshair Pointer – Full Visual Field) and the SP-SIMPVL (Sunny Pointer – Simulated Peripheral Vision Loss) conditions against the initial pointer-target distance are shown in Figure 7A. In the SP-SIMPVL condition, the mean TCTs are significantly higher than those observed in the CP-FVF condition by a constant proportion of approximately 50% ($p < 0.001$).

As presented in Figure 7B, the acquisition times do not depend on the pointer-target distance in either condition. The difficulty inherent in estimating the correct direction of movement seems to be independent of the distance of the mouse cursor. In the CP-FVF condition, this suggests that the peripheral vision is good enough to quickly localize the position of the pointer relative to the target, even over a long distance (14°). In the SP-SIMPVL condition, this finding suggests that the difficulty in estimating the direction of convergence of the lines does not depend on the proximity of the center of convergence (i.e. the pointer position).

However, acquisition times are significantly longer in the SP-SIMPVL condition than in the CP-FVF condition by approximately 70 ms (390 ms VS 320 ms). During the acquisition time, the user visually collects information in order to determine the direction and velocity of the mouse cursor in order to move it in optimal fashion toward the target. In the CP-FVF condition, this decision can be made by localizing the mouse cursor in one's peripheral vision and planning its trajectory relative to the target. On the contrary, in the SP-SIMPVL condition, only the orientation of the lines of the Sunny Pointer and their degree of convergence can be used to estimate the position of the mouse cursor relative to the target. Given the parsimonious visual input available through the restricted aperture, this estimation is not straightforward. The additional 70 ms may thus reflect the additional cognitive processing time required by the participant to estimate the direction and the distance of the mouse cursor from the convergence of the "rays" of the pointer. However, although it is significant, this additional processing time remains remarkably short in view of the difficulty of the task to be performed, again illustrating the effectiveness of the visual system in quickly processing complex information (Thorpe et al., 1996).

As shown in Figure 7C, most of the difference in TCTs results from differences in movement time, with durations significantly longer in the SP-SIMPVL condition by a proportion of approximately 70% . This corresponds to additional times of approximately 400, 500, 600 and 700 ms for the initial distances of 3.5°, 7°, 10.5°, 14° respectively.

The keystroke times, presented in Figure 7D, do not depend on the initial distance to the target in either condition. However, a constant and significant additional latency of approximately $90ms$ was measured in the SP-SIMPVL condition. One explanation for this may be that the concentration of the "rays" close to the mouse cursor partly masks the target and thus perturbs the decision as to whether the validation click can be effected or not. This eventuality must be further studied to be confirmed.

To better understand the reasons for the longer movement time in the SP-SIMPVL condition, we analyzed the lengths of the paths and the movement velocities of the pointer trajectories. The length of a trajectory was computed by summing the lengths of all the detected moves of the mouse cursor. The trajectory excess is the length of the trajectory path minus the initial pointer-target distance at the beginning of the trial. It thus measures the length of the trajectory that could have been avoided if the control of the mouse cursor direction had been optimal, i.e. if the participant had moved the pointer in a straight trajectory from its initial position to the center of

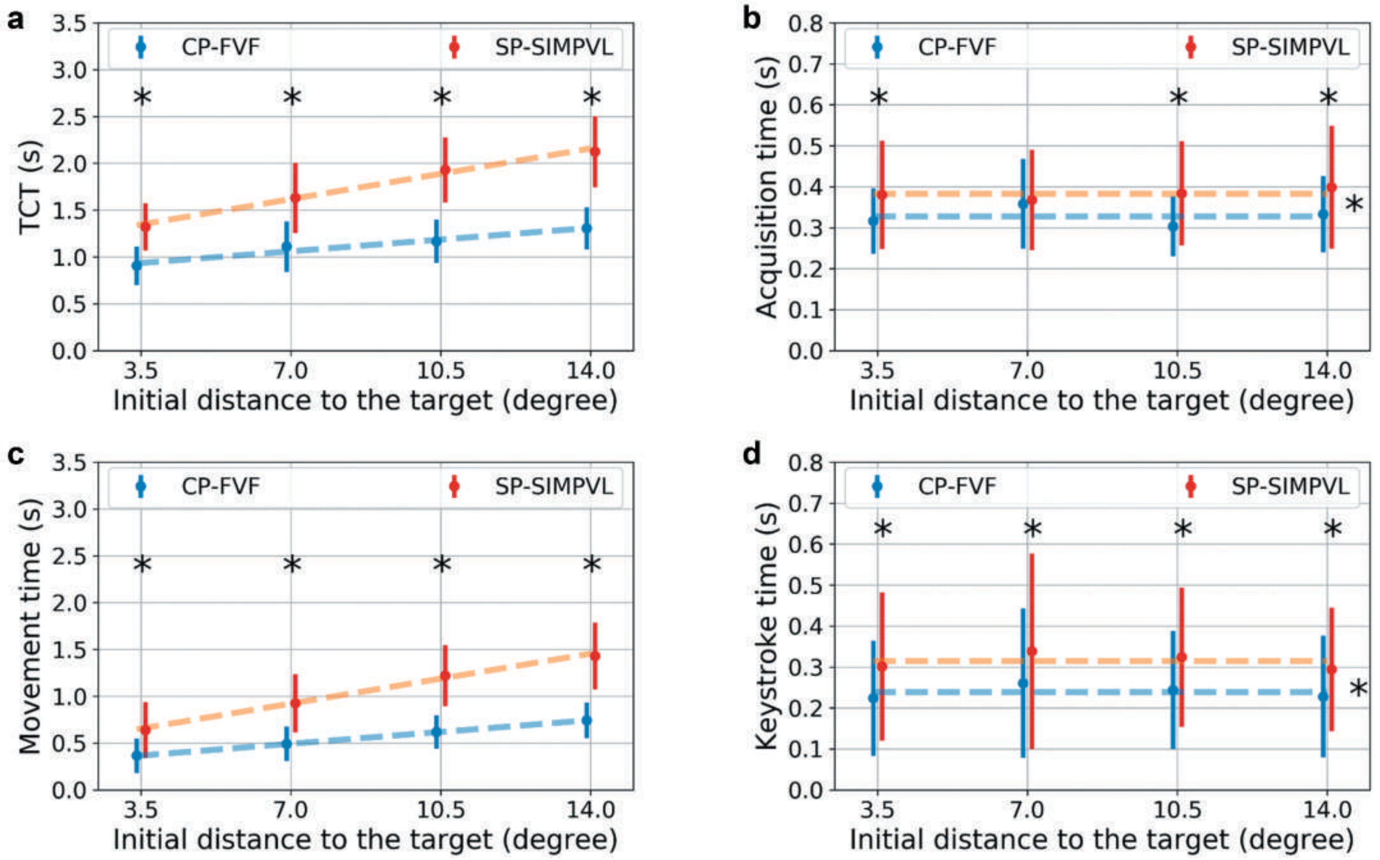

Figure 7. **A**: the time to complete the task (TCT) against the initial distance between the cursor and the target in the CP-FVF (Crosshair Pointer – Full Visual Field) condition (blue) and the SP-SIMPVL (Sunny Pointer – Simulated Peripheral Vision Loss) condition (red). **B**: the acquisition time (AT). **C**: the movement time (MT). **D**: the time to click on the target (the keystroke time KT). Dashed lines are superimposed to materialize the computed linear regressions of the results. Stars materialize conditions in which the distributions in the CP-FVF and SP-SIMPVL conditions significantly differed according to the Mann-Whitney U test ($p < 0.001$).

the target. A segment of the cursor trajectory is counted in the overshoot path if its ending point is localized in the half space behind a line passing through the target center point and perpendicular to the segment defined by the target center point and the initial cursor position.

As shown in 8A, in both the CP-FVF and the SP-SIMPVL conditions, with the exception of the SP-SIMPVL condition at an initial distance of 3.5°, the trajectory excess linearly increases with the initial distance from the target. The paths measured in the SP-SIMPVL condition are longer by a constant amount of approximately 0.7 degrees. Interpreting the orientation of the rays of the Sunny Pointer through the aperture by means of central vision in order to guide the pointer seems thus to be slightly less accurate than using peripheral vision. This confirms the important role of peripheral vision in trajectory planning, as mentioned in previous works (Khan et al., 2004).

As presented in Figure 8B, the particularly longer path for the initial distance of 3.5° in the SP-SIMPVL condition was mainly caused by more frequent occurrences of overshoots. For the other pointer-target distances, the amount of overshoot in CP-FVF and SP-SIMPVL conditions did not significantly differ and the two profiles show a small linear increase with regards to the pointer-target distance.

Movement velocity was computed for each trial by dividing the length of the mouse trajectory by the movement time. As shown in Figure 8C, the mean movement velocity in the CP-FVF condition can be accurately approximated by a linear relation with regards to the initial pointer-target distance. We found Velocity = 0.71 D + 13 where D is the initial distance from the target. In the SP-SIMPVL condition, we calculated a near constant velocity equal to $12^{\circ}/s$. This finding signifies that, with an increasing pointer-target distance, users in the SP-SIMPVL condition do not increase the mean velocity of the move, as would happen in normal pointer use (CP-FVF). The participant might be concerned about going too fast and overshooting the target and thus chooses to move the pointer at a velocity that allows him/her to quickly stop its movement as soon as it enters the visible area around the target.

Figure 8D shows the proportional impact of the difference in velocities and the difference in trajectory lengths that cause the differences in MT between the CP-FVF condition and the SP-SIMPVL condition, previously shown in Figure 7C. In order to compute these values, we first computed the time that the mean trajectory length measured in the SP-SIMPVL condition would have taken at the mean velocity observed in the CP-FVF condition. This calculation gives us the delay attributable to the differences in lengths. The delay caused by the differences in velocity is thus the movement time difference minus the previously computed delay caused by the length differences. Whereas the longer trajectories observed for the short initial distance (3.5°) have an important impact (65%), this impact rapidly decreases for longer distances, 21%, 14%

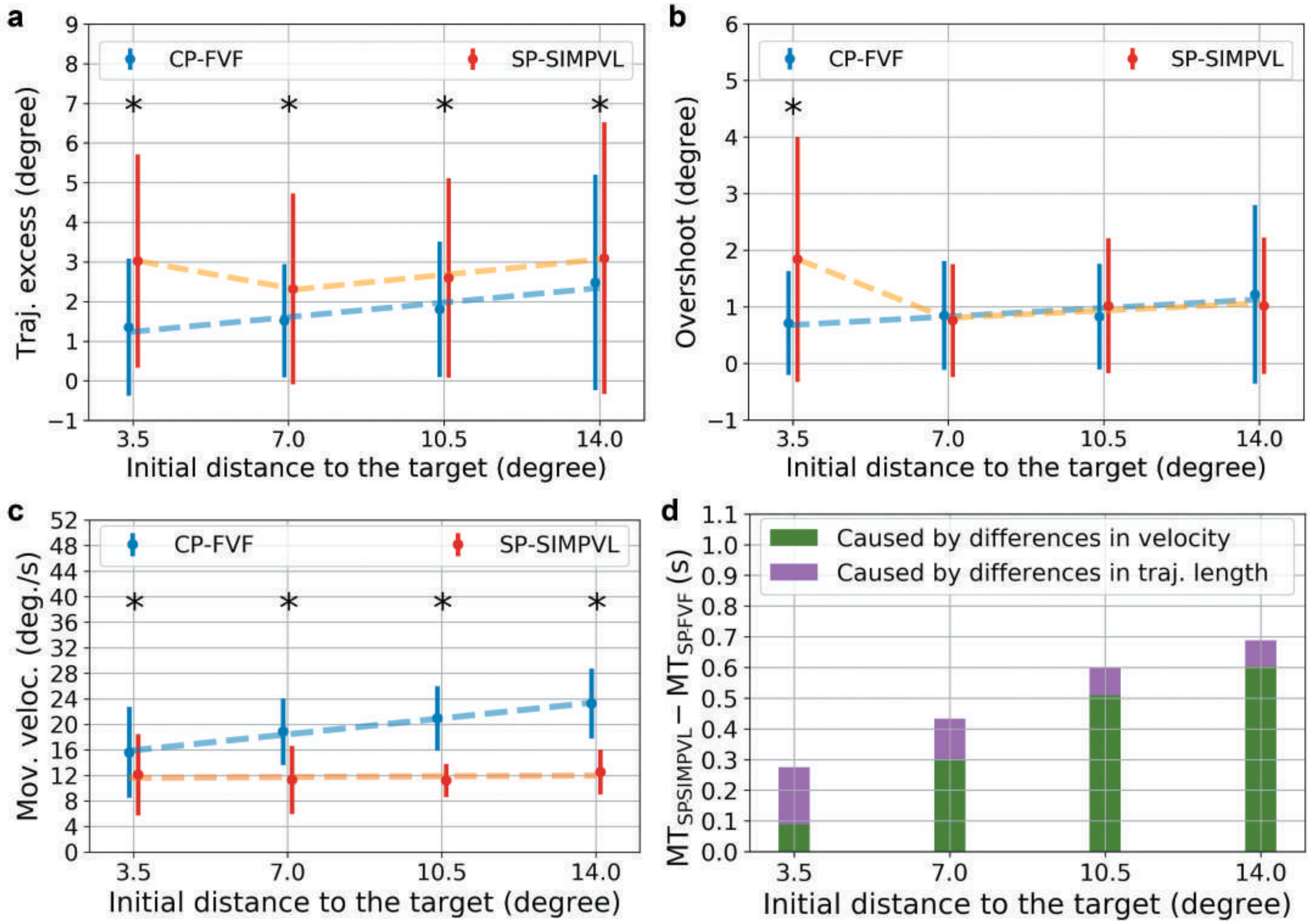

Figure 8. **A**: Trajectory excess computed as the mean length of the trajectories minus the initial distance between the target and the cursor. **B**: Trajectory excess due to trajectory overshoots. **C**: Mean velocity of the movements computed as the length of the trajectories divided by the time of movement. **D**: Differences in movement times between the SP-SIMPVL and the CP-FVF conditions. The differences are partitioned into delays caused by differences in movement velocities and delays caused by differences in trajectory lengths.

and 8% for 7°, 10.5° and 14° respectively. In these last three configurations, a very high proportion of the differences thus stems from the difference in movement velocity.

Before starting the experiment presented above, we asked each of the 20 participants to complete a preliminary exercise. In this exercise, the mouse cursor was randomly statically placed on the screen for one second with both the Sunny Pointer and the PVL simulation turned on. The user was thus placed in a situation similar to that in the above SP-SIMPVL condition, except that the Sunny Pointer was maintained static and therefore no movement toward the target was required. Instead, after one second, both the Sunny Pointer and the PVL simulation vanished and the participant had to click on the screen using a standard mouse cursor at the position where he/she thought the rays of our pointer, as displayed on the visible aperture of the screen, were converging. In each trial, the convergence point of the Sunny Pointer was randomly placed at various distances and roll angles relative to the center of the screen as in the previously described experiments.

We compared the distances of the estimated positions to the correct ones. As presented in 9A, the distributions of the estimated distances present an interesting profile. In the case of short distances (3.5°), participants overestimated the pointer distance by a mean value of approximately one degree. This overestimation could be the cause of the high number of overshoots seen in Figure 8B for 3.5° in the SP-SIMPVL condition. This overestimation decreases linearly before becoming an underestimation for a convergence point situated at 5.5° from the target. It continues to decrease linearly until finally reaching an underestimation of 4° for a distance of 14° ($\approx 29\%$). This mis-estimation can be modeled by means of the following formula: $D^{*} = -0.47D + 2.95$ where D^{*} is the estimated distance and D is the correct distance.

The standard deviations for 3.5°, 7°, 10.5° and 14° are 2°, 2.4°, 2.6° and 3.1° respectively, which represent 47%, 39%, 33% and 32% respectively of the mean estimated distances. The standard deviation in the estimated distance can be interpreted as an uncertainty that may explain the flat movement velocity profile shown in Figure 8C in the SP-SIMPVL condition, in which the user moves the mouse slowly due to uncertainty in the estimation of the proximity of the cursor in regards to the target.

The error in the estimated direction of the convergence is shown in Figure 9B. The mean error angle is zero centered, which means that no particular shift is present in the direction estimation. The standard deviation of the error is approximately $\pi/32$ except for 14° with a standard deviation of $\pi/16$. This perhaps reflects an uncertainty in the estimation of the direction that could be the reason for the constant trajectory excess of 0.7

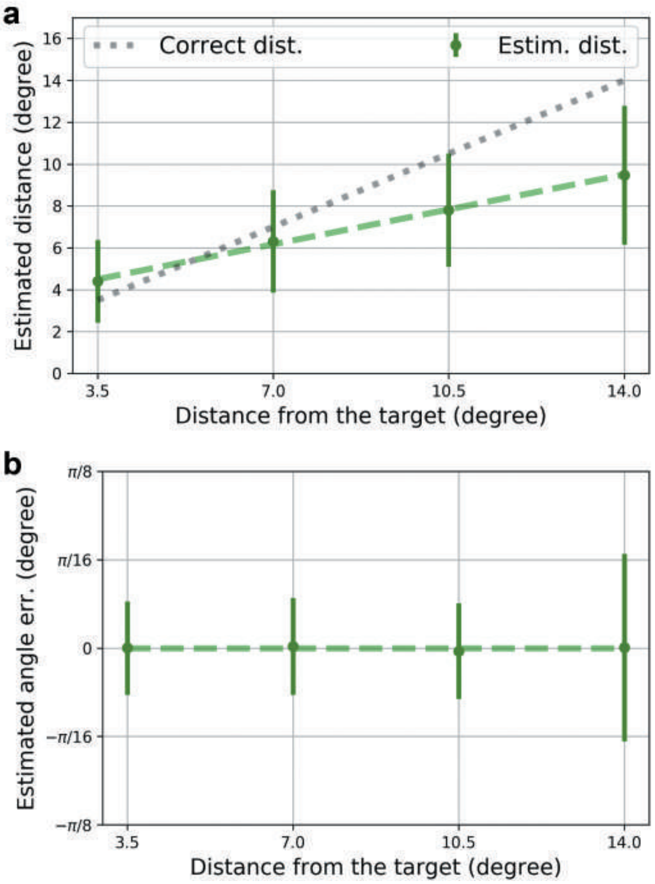

Figure 9. A: Estimation of the distance of the convergence point. **B**: Error in the estimation of the direction of the convergence point.

degrees seen in Figure 8A. Nevertheless, the increase in the uncertainty at 14° ($\pi/16$) is not reflected in a particularly larger trajectory excess.

Conclusions from experiment 3

The use of the Sunny Pointer only partly compensates the absence of peripheral vision in controlling the mouse during a targeting task. This is mainly due to inaccuracy in the estimation of the distance of the pointer from the target based on the convergence of the "rays," resulting in a flat pointer velocity profile. In addition to this velocity effect, the trajectory is a bit longer due to suboptimal orientation of the movements or due to overshoots. Finally, using the Sunny Pointer requires more time and probably involves more cognitive load to estimate the correct direction of movement and to click on the target.

Discussion

Altogether, these results draw a picture that can be interpreted as follows. A person with PVL using a standard mouse takes a long time to retrieve the position of the mouse cursor prior to initiating its movement toward the target on the screen. Moreover, the movement of the pointer toward the target is subject to transitory moments of confusion that may force the user to double check the relative positions of the visual components on the screen during the move, further decreasing efficiency. In contrast, thanks to the Sunny Pointer, visual localization of the mouse pointer on the screen is no longer necessary. Only the focus on the target and an interpretation of the convergence of the "rays" of the pointer above the target are required. This can be effected in less than 400 ms and the user can start to move the pointer toward the target a mere fraction of a second after the display. Moreover, the update of the "rays" according to the position of the pointer allows the user to reliably move the pointer in the right direction without transitional confusion. Together, these two contributions of the Sunny Pointer result in a much faster target selection.

However, although the Sunny Pointer can decrease by a factor of seven the time required by a person with PVL using a mouse to complete a task, this time remains 50% longer than what a person with functional peripheral vision using a standard mouse pointer can achieve. First, the interpretation of the information contained in the visual convergence of the lines of the pointer in a restricted area seems to imply an additional cognitive load that translates into approximately an additional 70 ms. Secondly, uncertainty surrounding the estimation of the direction of the point of convergence increases the length of the trajectory that the user follows in order to reach the target. This is especially true for short pointer-target distances, for which the user over-estimates the distance of the pointer, resulting in frequent overshoots. And thirdly, most of the additional delay comes from a mis-estimation of the distance of the convergence point. As a result, it seems that users choose to ignore their estimations of the distance and prefer to adopt a constant movement velocity, regardless of the distance from the pointer to the target. The adopted velocity thus seems to be a compromise between additional delay caused by movement that is too slow and that caused by overshoots from moving too quickly.

In order to compare the performance of a trained user with peripheral vision loss to that of full visual field users, we plotted in Figure 10 movement times measured in experiment 2 and experiment 3 as a function of the index of difficulty. Despite justified criticism (Guiard & Olafsdottir, 2011; Murata, 1996), in order to provide a basis of comparison with other studies, we chose Shannon's formulation of the index of difficulty first given in the context of Human-Computer Interaction (HCI) in (MacKenzie, 1992, 1995) expressed by the formula: $ID = log2(D/W + 1)$ where ID is the index of difficulty; D is the distance from the starting point to the center of the target (3.5°, 7°, 10.5°, 14°); and W is the width of the target measured along the axis of motion (1°). The results were linearly fitted by means of Fitts' law (Fitts, 1954) in which movement time linearly depends on the ID using the equation MT = bID+a where b is a parameter determined by regression analysis that is used to compute the index of performance (IP = 1/b). Parameter a (the y-intercept), often considered to be the time to click on the target in paradigms similar to the one we have used (MacKenzie, 1992), was fixed at 0 since the keystroke time was excluded from the movement time as explained in 2.2. In this plot, we thus compare the data presented above in Figure 7C and the data presented in Figure 5C on a new x-scale. For purposes of clarity, only the mean values and their associated linear fits are plotted.

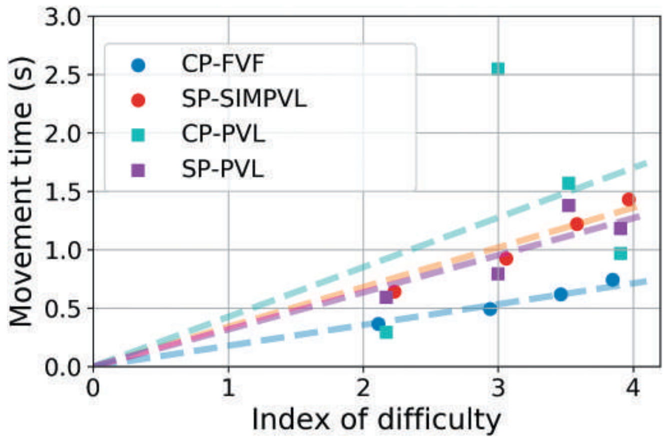

Figure 10. Movement times in the CP-PVL (Crosshair Pointer – Peripheral Vision Loss) and SP-PVL (Sunny Pointer – Peripheral Vision Loss) conditions of experiment 2 and the CP-FVF (Crosshair Pointer – Full Visual Field) and the SP-SIMPVL (Sunny Pointer – Simulated Peripheral Vision Loss) conditions of experiment 3 as a function of the index of difficulty. Linear fits are shown with dashed lines. The summary of the linear fits is presented in the table below.

The descriptive data of the fits are summarized in the table under Figure 10. As previously mentioned, due to confusions during the move of the pointer, the data in the CP-PVL condition shows major variations that disqualify the linear fit as a good predictive model. In the other conditions, Fitts' law can be used as an approximation for the results with a coefficient of determination of approximately 0.4. As expected, the best index of performance is obtained by people with an intact peripheral visual field using a normal mouse pointer (CP-FVF). Next in terms of performance is John and his 3.5% of VF (SP-PVL). Arriving in third place is the simulated PVL with the 1.5% of VF (SP-SIMPVL). Thus, the index of performance seems to depend on the size of the VF.

To confirm this hypothesis, we plotted in Figure 11 the index of performance measured in experiments 1 and 2 as a function of the visual field of the participants. These results can be approximated by a linear fit following the equation $IP = aVF$ with $a = 0.86$ and a coefficient of determination equal to 0.51. A narrower VF might thus cause greater inaccuracy in the estimation of the position of the pointer relative to the target and therefore lead to a slower and more cautious pointer move. This inaccuracy is composed, first, of a shift between the true distance and the mean estimated distance and, second, of an uncertainty in the estimated distance. This possible relationship between uncertainty in the distance estimation and the index of performance requires more experimentation to be confirmed. Obviously, acuity and motor control might also play important roles.

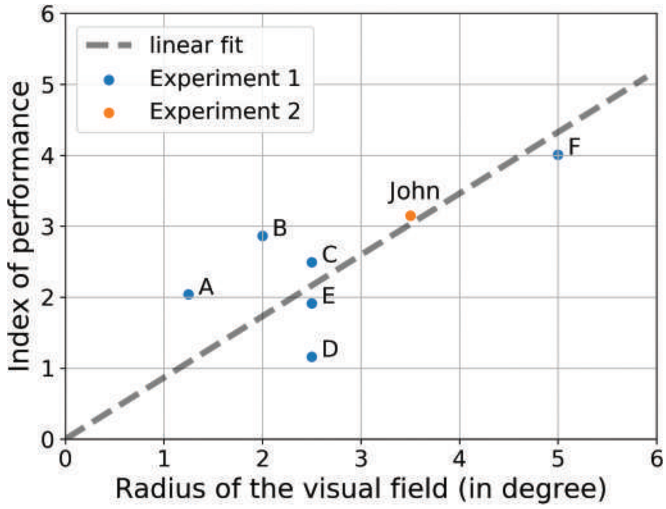

Figure 11. Index of performance in the CP-PVL (Crosshair Pointer – Peripheral Vision Loss) conditions measured during experiments 1 and 2 as a function of the radius of the visual field of the participant. The Linear fit is shown with a dashed line.

Fitts' law has been used as a predictive model for targeting tasks in the context of HCI for more than 40 years (Card et al., 1978). The values we found are in the range of those previously reported: from 2.55 bit/s (Epps, 1986), 3.2 (Boritz et al., 1991), 4.5 bit/s in (MacKenzie et al., 1991), 5.7 in (Han et al., 1990), up to a value of 10.42 bit/s (Card et al., 1978), which is close to the optimal value of 10.56 bit/s found in natural hand movements (Fitts, 1954). However, we found that the variation in movement time is accounted for by regression equations (R^2) to an extent representing approximately 40% whereas the proportion is 70% in (Epps, 1986), 83% in (Card et al., 1978) and approximately 90% in (Murata, 1996). This discrepancy might be due to inter-participant variations.

How this tool will be used in realistic pointing scenarios will depend crucially on each user's visual profile, on individual computer setups, and on the specific task each user is trying to perform. To respond to such diversity, the tool we provide includes many settings that have not been investigated in this work and that enable users to customize the graphical display and its ergonomic features. For example, the system offers two activation modes. In automatic activation mode, the lines appear as soon as a mouse move is detected and follow the subsequent moves of the mouse cursor until the cursor remains static for a period of 0.05s. At this time, the lines vanish until a new mouse move is detected. In manual mode, the user must press and maintain a certain key combination in order to make the lines visible. The Sunny Pointer can be activated, deactivated and closed by means of specific key shortcuts. The number of "rays" radiating from the pointer, their color, thickness and transparency, as well as the starting distance of the lines from the mouse pointer and their length are all parameters that can be adjusted.

Other visual cues could also be integrated to simplify the decoding of distance information. The first aim of further developments will be to facilitate the estimation of the pointer distance based on the visual information provided by the Sunny Pointer. Since the Sunny Pointer displays information related to the position of the pointer over the entire area of the screen, any visible area of the screen can contribute to its localization. It would thus be interesting to test whether or not the pointer we have developed might be of help to people with other types of impairments.

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References

AutoHotkey Foundation LLC. *AutoHotKey*. https://www.autohotkey.com.

Baudisch, P., Cutrell, E., & Robertson, G. (2003, September). High-density cursor: A visualization technique that helps users keep track of fast-moving mouse cursors. *Interact'03*, ACM, ed., 236–243, Zurich, Switzerland.

Boritz, J., Booth, K. S., & Cowan, W. B. (1991). Fitt's law studies of directional mouse movement. *Proceedings of Graphics Interface '91, GI '91*, 216–223, Calgary, Canada.

Card, S. K., English, W. K., & Burr, B. J. (1978). Evaluation of mouse, rate-controlled isometric joystick, step keys, and text keys for text selection on a crt. *Ergonomics*, *21*(8), 601–613. https://doi.org/10.1080/00140137808931762

Card, S. K., Moran, T. P., & Newell, A. (1980). The keystroke-level model for user performance time with interactive systems. *Communications of the ACM*, *23*(7), 396–410. https://doi.org/10.1145/358886.358895

Chiang, M. F., Cole, R. G., Gupta, S., Kaiser, G. E., & Starren, J. B. (2005). Computer and world wide web accessibility by visually disabled patients: Problems and solutions. *Survey of Ophthalmology*, *50*(4), 394–405. https://doi.org/10.1016/j.survophthal.2005.04.004

Coeckelbergh, T. R., Cornelissen, F. W., Brouwer, W. H., & Kooijman, A. C. (2002). The effect of visual field defects on eye movements and practical fitness to drive. *Vision Research*, *42*(5), 669–677. https://doi.org/10.1016/S0042-6989(01)00297-8

Epps, B. (1986). Comparison of six cursor control devices based on fitts' law models. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *30*(4), 327–331. https://doi.org/10.1177/154193128603000403

Evans, K., Law, S. K. A., Walt, J. G., Buchholz, P., & Hansen, J. (2009). The quality of life impact of peripheral versus central vision loss with a focus on glaucoma versus age-related macular degeneration. *Clinical Ophthalmology*, *3*, 433–445. https://doi.org/10.2147/OPTH.S6024

Fitts, P. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, *47*(6), 381. https://doi.org/10.1037/h0055392

Fraser, J., & Gutwin, C. (2000). A framework of assistive pointers for low vision users. *Proceedings of ASSETS 2000*, ACM Press, 9–16, Arlington, VA.

Geisler, W. S., Perry, J. S., & Najemnik, J. (2006). Visual search: The role of peripheral information measured using gaze-contingent displays. *Journal of Vision*, *6*(9), 1. https://doi.org/10.1167/6.9.1

Guiard, Y., & Olafsdottir, H. B. (2011). On the measurement of movement difficulty in the standard approach to fitts' law. *PLoS One*, *6*(10), 1–15. https://doi.org/10.1371/journal.pone.0024389

Han, S. H., Jorna, G. C., Miller, R. H., & Tan, K. C. (1990). A comparison of four input devices for the macintosh interface. *Proceedings of the Human Factors Society Annual Meeting*, *34*(4), 267–271. https://doi.org/10.1177/154193129003400406

Hollinworth, N., & Hwang, F. (2011, May). Cursor relocation techniques to help older adults find 'lost' cursors. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, ed., 863–866, Vancouver, BC, Canada.

Hooge, I. T., & Erkelens, C. J. (1999). Peripheral vision and oculomotor control during visual search. *Vision Research*, *39*(8), 1567–1575. https://doi.org/10.1016/S0042-6989(98)00213-2

Jacko, J., Barreto, A., Marmet, G. J., Chu, J. Y. M., Bautsch, H. S., Scott, I. U., & Rosa, R. (2000a, 1). Low vision: The role of visual acuity in the efficiency of cursor movement. *Proceedings of ASSETS 2000*, 1–8. Arlington, VA.

Jacko, J., & Sears, A. (1998). Designing interfaces for an overlooked user group: Considering the visual profiles of partially sighted users. In *Proceedings of ASSETS 1998* (pp. 75–77). (01). Marina del Rey, CA.

Jacko, J. A., Jr., Rosa, R. H., Scott, I. U., Pappas, C. J., & Dixon, M. A. (2000b). Visual impairment: The use of visual profiles in evaluations of icon use in computer-based tasks. *International Journal of Human–Computer Interaction*, *12*(1), 151–164. https://doi.org/10.1207/S15327590IJHC1201_7

Khan, M. A., Lawrence, G. P., Franks, I. M., & Buckolz, E. (2004). The utilization of visual feedback from peripheral and central vision in the control of direction. *Experimental Brain Research*, *158*(2), 241–251. https://doi.org/10.1007/s00221-004-1897-y

Kline, R. L., & Glinert, E. P. (1995). Improving gui accessibility for people with low vision. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '95*, New York, NY, USA, ACM Press/Addison-Wesley Publishing Co., 114–121, https://doi.org/10.1145/223904.223919.

Larson, A. M., & Loschky, L. C. (2009). The contributions of central versus peripheral vision to scene gist recognition. *Journal of Vision*, *9*(10), 6. https://doi.org/10.1167/9.10.6

Liu, C., & Zhao, R. (2018, August). Find the 'lost'cursor: A comparative experiment of visually enhanced cursor techniques. In D.-S. Huang, K.-H. Jo, X-L. Zhang (Eds.), *Intelligent computing theories and application* (pp. 85–92). Cham: Springer International Publishing. ISBN: 978-3-319-95933-7

MacKenzie, I. S. (1992). Fitts' law as a research and design tool in human-computer interaction. *Human-Computer Interaction*, *7*(1), 91–139. https://doi.org/10.1207/s15327051hci0701_3

MacKenzie, I. S., Sellen, A., & Buxton, W. A. S. (1991). A comparison of input devices in element pointing and dragging tasks. *CHI '91: Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 161–166). New Orleans, LA.

Maxime Ambard. Sunny Pointer. LEAD CNRS UMR 5022, Université de Bourgogne-Franche Comté.

Murata, A. (1996). Empirical evaluation of performance models of pointing accuracy and speed with a pc mouse. *International Journal of Human–Computer Interaction*, *8*(4), 457–469. https://doi.org/10.1080/10447319609526164

Proteau, L., Boivin, K., Linossier, S., & Abahnini, K. (2000). Exploring the limits of peripheral vision for the control of movement. *Journal of Motor Behavior*, *32*(3), 277–286. https://doi.org/10.1080/00222890009601378

Quaranta, L., Riva, I., Gerardi, C., Oddone, F., Floriano, I., & Konstas, A. G. P. (2016). Quality of life in glaucoma: A review of the literature. *Advances in Therapy*, *33*(6), 959–981. https://doi.org/10.1007/s12325-016-0333-6

Ramulu, P. (2009). Glaucoma and disability: Which tasks are affected, and at what stage of disease? *Current Opinion in Ophthalmology*, *20*(2), 92. https://doi.org/10.1097/ICU.0b013e32832401a9

Resnikoff, S., Pascolini, D., Kocur, I., Pararajasegaram, R., Pokharel, G. P., & Mariotti, S. P. (2004). Global data on visual impairment in the year 2002. *Bulletin of the World Health Organization*, *82*(11), 844–851. https://doi.org//S0042-96862004001100009

Rosenholtz, R. (2016). Capabilities and limitations of peripheral vision. *Annual Review of Vision Science*, *2*(1), 437–457. https://doi.org/10.1146/annurev-vision-082114-035733

RPMouse. *RPMouse*, http://www.rptools.org.

Scott Mackenzie, I. S. (1995). Movement time prediction in human-computer interfaces. In Ronald M. Baecker, J. Grudin, William A. S. Buxton, S. Greenberg (Eds.), *Readings in Human-Computer interaction* (2nd ed., pp. 483–493). Morgan Kaufmann Publishers Inc.

Smith, B. A., Ho, J., Ark, W., & Zhai, S. (2000). Hand eye coordination patterns in target selection. *Proceedings of the 2000 Symposium on Eye*

Tracking Research & Applications, ETRA '00, New York, NY, USA, ACM, 117–122, https://doi.org/10.1145/355017.355041.

Tham, Y.-C., Li, X., Wong, T. Y., Quigley, H. A., Aung, T., & Cheng, C.-Y. (2014). Global prevalence of glaucoma and projections of glaucoma burden through 2040: A systematic review and meta-analysis. *Ophthalmology*, *121*(11), 2081–2090. https://doi.org/10.1016/j.ophtha.2014.05.013

Thorpe, S., Fize, D., Marlot, C.(1996). Speed of processing in the human visual system. *Nature*, *381*(6582), 520–522. https://doi.org/10.1038/381520a0

Thorpe, S., Gegenfurtner, K. R., Fabre-Thorpe, M., & Bülthoff, H. (2001). Detection of animals in natural images using far peripheral vision. *The European Journal of Neuroscience*, *14*(5), 869–876. https://doi.org/10.1046/j.0953-816x.2001.01717.x

Vispero. ZoomText.

Westheimer, G. (1982). The spatial grain of the perifoveal visual field. *Vision Research*, *22*(1), 157–162. https://doi.org/10.1016/0042-6989(82)90177-8