Boundary Conditions for Information Visualization with respect to the User's Gaze

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ABSTRACT

Gaze tracking in Augmented Reality is mainly used to trigger buttons and access information. Such selectable objects are usually placed in the world or in screen coordinates of a head- or hand-mounted display. Yet, no work has investigated options to place information with respect to the line of sight.

This work presents our first steps towards gaze-mounted information visualization and interaction, determining boundary conditions for such an approach. We propose a general concept for information presentation at an angular offset to the line of sight. A user can look around freely, yet having information attached nearby the line of sight. Whenever the user wants to look at the information and does so, the information is placed directly at the axis of sight for a short time.

Based on this concept we investigate how users understand frames of reference, specifically, if users relate directions and alignments in head or world coordinates. We further investigate if information may have a preferred motion behavior. Prototypical implementations of three variants are presented to users in guided interviews. The three variants resemble a rigid offset and two different floating motion behaviors of the information. Floating algorithms implement an inertia based model and either allow the user's gaze to surpass the information or to push information with the gaze. Testing our prototypes yielded findings that users strongly prefer information maintaining world-relation and that less extra motion is preferred.

Author Keywords

Augmented Reality; Virtual Reality; Information Presentation; Gaze Tracking; Gaze Mounting;

ACM Classification Keywords

H.5.1. Information Interfaces and Presentation: Multimedia Information Systems: Artificial, augmented, and virtual realities; H.5.2. Information Interfaces and Presentation: User Interfaces: User-centered design

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INTRODUCTION

Augmented Reality (AR) adds virtual information, mainly on a visual basis, such as 3D objects or textual labels, to the view of the user. The superimposed information is placed – or mounted [24] – in the environment. The augmented content is usually placed w.r.t. the world or an entity in the world, or it is mounted to a human, either another person or the user themself. Concerning information mounted to a user, mostly the head or the hands define the respective coordinate system. However, no system has yet addressed information placement w.r.t. the gaze of a user.

With this work, we aim on placing information w.r.t. the user's gaze. This enables new paradigms for information access. Information capture no longer requires the user to determine the location of the information in its respect of placement (i.e. a location in the world or on a head-mounted screen). Especially in cluttered and visually complex environments, a gaze related information is thus constantly accessible in the same way by a somehow dedicated glance. This option bears the potential to allow for faster information access and also a faster return to the original gazing direction. While mounting information directly to the gaze would conceal the physical world, displacing the information by an angular offset would make information capture impossible as the information would constantly maintain this offset. This work therefore investigates boundary conditions for dynamic information placement and access.

The next section gives an overview about related work. An illustration of issues for such an approach and how we address these follows in the section covering the general concept. We discuss frames of reference for information alignment and develop three variants for information capture. The first variant maintains a rigid offset of the information and analyses gaze motion behavior. The other two variants let information float as having inertia, one allows the gaze to overexceed the information, the other does not. We then conduct a guided interview and a performance assessment study to investigate the different variants and determine boundary conditions.

RELATED WORK

Related work can be categorized in two classes, first AR systems that, at least somehow, employ gaze tracking and second, AR systems that „augment" the user or establish augmented information carriers to the user.

Gaze Tracking

The touring machine of Feiner et al. [8] does not implement gaze tracking but facilitates the center of a head-worn display as an approximation for gaze-directed selection. Kooper and MacIntyre [14] extend the concept of the touring machine by differentiating between glance selection and gaze selection in the reality web browser. The object nearest to the center of the screen is augmented with an anchor. Having an object glance selected starts a 2 second timer. The object is considered gaze-selected after the time-out. Reitmayr and Schmalstieg [22] also use selection through the center of the display.

The Kibitzer system [3] of Baldauf et al. implements gaze tracking, but, in contrast, requires the user to look at the desired object of interest and then close the eyes for 2 seconds to trigger the selection. Park et al. [19] use a dwell time approach combined with an aging technique. Asai et al. [1] used eye tracking for object selection and a trigger button for confirmation.

Nilsson et al. [17] investigated gaze interaction dialogues with dwell time selection in an HMD. They used three different regions for the gaze dialogues, static in the top region of the HMD view, static in the bottom region and dynamically placed w.r.t. a marker. A similar setup was also used in earlier work [16, 15] where trocars were to be assembled. The interaction regions (top or bottom) are empty when the user looks through the center region of the HMD. The interaction elements appear only when looking at the defined peripheral region of the display [10]. The respective interaction area begins approximately at a vertical angle of 7 degrees off the center of the HMD view.

Ashmore et al. [2] enhanced object selection by providing a fish-eye lens for magnifying the looked-at region of the screen by a factor of 3. The foveal area of the magnification lens covered approximately 6.3 angular degrees in the test setup. The angular width overall, including the lens shoulders, had approximately 19 angular degrees.

Drewes and Schmidt [5] investigated the use of gaze gestures. To control the system, users has to preform stroke gestures on a rectangular grid of up to 10 degree size. User feedback noted that the tasks were easy to perform and that cluttered background did not complicate gesture execution.

Novak et al. [18] investigated attentive automotive user interfaces with a gaze tracking system. Related to our concept is, that with their system, an information pops up at some location in the environment. If the user notices the information and looks at it, the attentive user interface conveys the attention and adapts its behavior accordingly, e.g. by presenting additional information.

Ishiguro and Rekimoto [12] developed a system to annotate a users peripheral vision. While their concept does foresee using any location in the peripheral field of view, do their implementation shows a simplified icon at a fix display position in the peripheral region. The information is expanded when the user looks at it.

All above systems have in common that they relate to an object or location that is in no respect to the user's gaze. No related work is known, to our best knowledge, that considers the gaze itself for information placement.

Augmented User-Centered Information Carriers

In the case that augmented content is mounted to the user, the placement can be at a static position, i.e., the users palm, or it can be floating nearby the user, we then call this a user-centered augmentation [24]. The picture sphere by Georgel et al. [9], a virtual, augmented sphere surrounding the user with the head as center shows automatically layouted pictures floating on the sphere. Feiner et al. [7] proposed screen-fixed information placement in a head-mounted display which is yet another line of argumentation for a sphere surrounding the user having the radius of the focal distance of the image plane. Yet, user-centered information not necessarily has to fit a sphere. Rather does every user and every entity have its personal perceptive aura. Using this paradigm, Benford [4] established a communication model that requires two auras to overlap to enable communication in any sense. For the visual channel, a user's aura is given through the visually achievable regions of the field of regard.

CAPTURING CONCEPT AND DEPENDENT ISSUES

The general approach for our user-centered information carrier places information with an angular offset to the line of sight. The information more or less stays at this offset wherever the user is looking, except when the user directly looks onto the information. The information then is *captured* and stays at the line of sight until it is released.

Offset Direction, Alignment and Angular Distance

The direction of the offset might be dependent on the application. Applications, whose main task orients along the vertical axis, such as finding entries in top-down lists, might strive for a horizontal displacement while others might prefer an offset of the information up- or downwards or in any arbitrary direction.

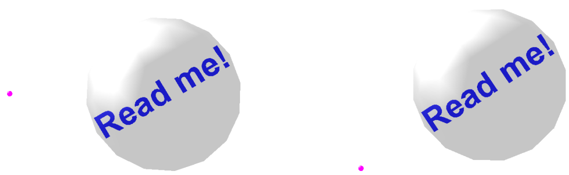
We nonetheless investigated the general frame of reference to which users relate gaze-mounted information. Essentially, two spatial frames of reference appear applicable. First, and specifically following the concept of gaze-mounted information, directions may be interpreted in head-mounted coordinates as the eyes are a body part of the human head. The directions left and right then would refer to the axis through the two eyes of the user no matter how users tilt their head sidewards. Second, directions may be interpreted in world-coordinates. The terms left and right then would relate to the horizon. These two possible frames of reference can be applied to two phenomena, first the direction of the offset (see Fig. 1) and second the alignment of the displayed information (see Fig. 2).

To get a first insight into the understanding of potential users, we issued a questionnaire to 18 volunteers (mean age 27.3, 94% male). Two initial questions were phrased on a general level to avoid possible bias w.r.t. the two latter questions. The questions were phrased as simple binary answer questions, thus no analysis of variance was calculated.

(a) World related directional offset

(b) Head related directional offset

Figure 1. Frames of reference for directional offset. Purple dot shows gaze direction. Head tilted to the left



(a) World related directional offset and head related information alignment

(b) Head related directional offset and information alignment

Figure 2. Frames of reference for information alignment. Purple dot shows gaze direction. Head tilted to the left

1. When setting up a video projector for yourself and adjusting the keystone manually: do you adjust the keystone so that
☐ the picture is rectangular on the wall?
☐ the picture has a correct perspective from your point of view?

2. Many monitors can be rotated left and right today. Imagine you were watching a movie with such a monitor while lying on a sofa. Would you
☐ let the monitor remain (or even adjust it to being) perfectly adjusted to the room?
☐ turn it so that the screens horizontal axis is collinear to an axis through both of your eyes?

3. Imagine information could be shown with respect to your line of sight. To not occlude your principal sight, the information would have to be a little bit off your line of sight.
   (a) With respect to left and right positioning, would you expect the information to be left or right with respect to a) the world or b) your head?
   (b) With respect to up and down positioning, would you expect the information to be up and down with respect to a) the world or b) your head?

Question 1 investigates the directional component of the information offset. Question 2 investigates the alignment of the information. Question 3 investigates the approach of the concept.

The results are as follows:

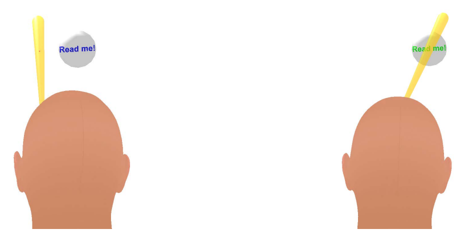
1. 89% voted for world-relation
2. 72% voted for head-relation
3. (a) 61% voted for head-relation
   (b) 56% voted for world-relation

The majority of users appear to tend towards a directional offset in world coordinates but with information alignment in head-coordinates. Surprising was the finding of question 3 were users seem to tend towards a non-perpendicular offsetting strategy.

Eventually, a value for the angular offset of the information is required. A minimum angle is given by the fact that the information should not lie in the foveal field of view, nor should it allow for peripheral fixation. The information should thus be at least 5 degree off the line of sight. The maximum angle is constrained in different ways. The information should be noticeable at all. As the information is not necessarily moving w.r.t. the line of sight, no changes in brightness might be perceived. The peripheral field of view (> 10 degree) should thus not be used. The information should, on the other hand, be comfortably reachable by a glance without enforcing too much strain on the eye muscles. The average visual field of eye motion usage covers around 20 degree where already supporting head movements are used [13]. After an expert study with values around 10 degrees we eventually decided for an 8 degree offset.

Information Capturing and Release

Suitable algorithms for information capture let the user's gaze roam freely without capturing the information unintendedly but let the gaze capture the information when the user intends to access the information.



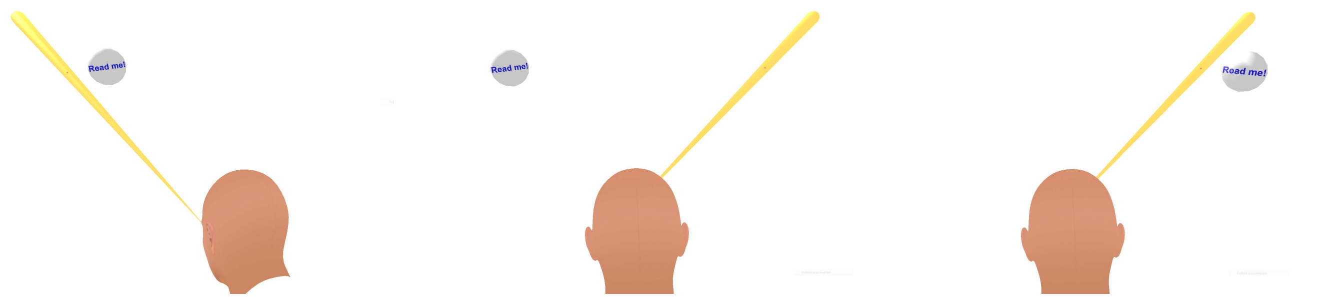
(a) Information mounted at angular offset to the line of sight

(b) Information mounted at the line of sight

Figure 3. Two states of information placement

The general capture and release concept uses a state machine differentiating three states. In an *uncaptured* information (see Fig. 3(a)) is *captured*, it is placed directly on the line of sight (see Fig. 3(b)). There it remains for a certain time that is based on the duration required to read the content. After this time the state changes to the information *floating back*. The information floats back to its original offset within 500 ms. If not stated through references, all herein given values were assured through repeated expert studies.

The requirement to let the user glance freely raises the question whether the information shall be floating w.r.t. the line of sight, say, if the information shall come nearer to the line of sight when the user is looking towards the information.



(a) Information is initially at fix offset

(b) User quickly gazes far right and surpasses information

(c) Information moves back to designated offset position without being captures

Figure 4. Illustration of information overexceeding

We developed two fundamentally similar algorithms with the difference that one maintains a rigid angular offset of the information while the other lets the information visually float nearer to the eye-line when looking towards and floating back to the specified offset when looking in the opposite direction. As the opportunity to let information float may enable the line of sight to surpass the information, we developed a third derivative, differing to the second by providing the option to overexceed the information.

Analysis of Eye Motion History

The visually rigid variant maintains the offset of the information. The algorithm constantly evaluates the motion history of the pupil. Three conditions must be met to enable information capture. First, the gaze must not have moved for at least 50 ms. This way, we ensure that the pupil has not already been in motion. Second, a saccade or a smooth pursuit movement must have been performed afterwards, not consuming more than another 50 ms (the general maximum time for a saccade in the average visual field [6]). Third, a target location must have been fixated for 200 ms. The target fixation time aggregates the averaged 100 ms any person requires to focus on a target location and an additional 100 ms to ensure that this is the aimed-at spot.

The information is captured and placed at the line of sight if the target direction of the gaze lies within 2.8 angular degrees around the offset of the information. This measure is depicted by the angular diameter of the human's eye foveal field of view.

Velocity-Based Floating

The second information capturing algorithm calculates pupil motion velocities and uses this data to let the information float along the offset direction as it had mass and thus inertia. The average angular speed towards and away from the information offset direction is calculated over the last 80 ms. The resulting speed value is used to calculate a delta angle (based on the rendering cycle time) relative to the original offset. Looking towards the information thus lets the information get nearer to the line of sight, looking away lets it move away until the original angular offset is reached.

This behavior is combined with a general push-back mechanism. If the angular speed of the pupil gets below 50 degree per seconds, the information is pushed back towards its original offset with a speed of 5 degree per second. If the line of sight collides with a bounding sphere centered around the information with a diameter 10% larger than the text width for 100 ms (general fixation time as in eye motion history algorithm), the information is captured.

A special behavior is defined for the case that the user is looking beyond the information. Having reached the information with the line of sight but still in angular motion, the information is technically hooked and carried along but it is not captured. It moves away as soon as the user does stop eye motion, eventually reaching its defined offset again. The information does never get to the opposite side of the gaze.

Velocity-Based Floating with Overexceeding

The third algorithm only differs w.r.t. the hooking option of the second algorithm. As Fig. 4 illustrates, the information can be surpassed when a user looks beyond the information, say, further than the angular offset of the information. This variant lets the line of sight get across the information. The information then reacts to the general push-back strategy but capturing is disabled while the information passes through the line of sight when getting back to its defined offset.

USER STUDY

We conducted a user study to gain general insight into the concept of information visualization w.r.t. the line of sight and our concept in particular. Of main interest for investigation were the frames of reference of information direction and alignment and the questions whether the information shall float visibly and if it shall be possible to overexceed the information.

Apparatus

We used the Dikablis [1] eye tracking system solely for pupil tracking. As Fig. 5 shows, three transformations are required to obtain the eye position. The head-mounted frame was equipped with three markers which were tracked by a webcam and the multi-marker tracking facilities of Ubitrack [20, 11]. The rigid transformation from the marker to the eye-facing camera was calibrated with a dual marker tracking system, using pose data of an extra marker tracked from

[1] Version 2, Ergoneers GmbH

both, the webcam and the eye-cam. The third transformation from the eye-cam to the eyeball is obtained as follows. We employed a gaze direction detection algorithm similar to the work of Reale et al. [21], determining the X-Y position of the eyeball in eye-cam coordinates from a straight look into the eye-facing camera. The eye distance was estimated from looking at another calibration marker and the need for equality of the calculated and measured gaze angles.

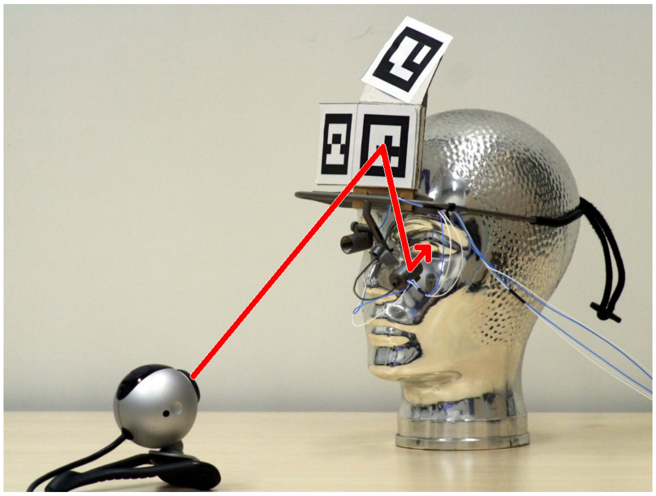


Figure 5. Tracking Setup of Head Unit

The gaze direction then is calculated by a back-projection of the X-Y position of the pupil in the image of the eye-facing camera and a line-sphere intersection with a sphere representing the eye-ball with the previously estimated radius.

We used a 24 inch monitor as a room-mounted display which was appropriately registered to the webcam, generating a fully registered virtual view embedded into the physical world. The average distance of the monitor to the user was 60 cm, yielding a field of view of approximately 50 angular degrees.

We added a saccade counter based on the work of Stampe [23] which considers every eye movement faster than 30 degree per second as a saccade and a 200 ms fixation time-out between saccades.

Procedure

The test participants were clustered into groups of similar eye-nose relationships just to reduce the required efforts for readjusting the eye-facing camera. The system then was appropriately calibrated for each user separately.

The users were given some time to familiarize with the system and were explained what they were seeing. They essentially saw a purple dot indicating their gaze direction and a half-transparent sphere containing the phrase „Read me!“ as a general representation of an information with. The offset direction was set to the right.

We then started a guided interview, asking the following questions.

1. How shall the direction of the information offset be aligned? W.r.t. a) the head or b) the world.
2. How shall the information be aligned? W.r.t. a) the head or b) the world.
3. Shall information float visibly? Yes / No.
4. When looking further than the information, shall it be possible to over-exceed the information? Yes / No
5. If the previous answer was yes: The information then would/could float back through the gaze. Shall it a) float back through the gaze without being captured, b) temporarily disappear or c) other (please indicate).

The first two questions assessed the different frames of reference which were visualized accordingly. The third question was accompanied by repeatedly switching the first and second capturing algorithm. Similarly switched were the second and third capturing algorithm for question four. The last question only had the third variant of the capturing algorithm as illustration as we assumed that a disappearing information is easily understood.

The interview was followed by a study to assess the performance of our preliminary algorithms to compare objective measurements to users' subjective preference.

For each of the three capturing variants, two tasks were to be absolved. In the first task, users had to look at a starting point at a fixed position at the left side of the monitor and then at a quasi random target point. This was repeated 2+20 times for each variant. The first two trials were used for familiarization. This test assessed how often the information was captured accidentally. In the second part, the users had to look at a starting point and then had to capture the information. This also was repeated 2+20 times for each variant with the first two trials for familiarization. This test assessed the quality of the different capturing algorithms.

The whole procedure took about 40 minutes.

Experimental Design

We used a single session within subjects design. All participants were exhibited to all three capturing algorithms. The order of the variants was permuted among all test participants, counter-balancing learning effects.

We defined two hypotheses. First, that *visible floating impairs capturing*. Second, *the option to overexceed the information impairs capturing*.

We defined two independent variables:
1. *Visible floating*: {not floating, floating}.
2. *Overexceeding*: {not overexceeding, overexceeding}.

We defined the following measures as dependent variables:

- Start-Target sphere task
  - Number of accidental information captures when looking at target sphere.

– Number of accidental information captures when looking at target sphere and target sphere nearer than 5 degree to the position of the information at the beginning.

- Information capture task.

  – Number of saccades to yield information capture.

  – Time required for information capture.

We interviewed and tested 12 male volunteers (mean age 29.8, SD 4.5). All having normal or corrected to normal vision.

RESULTS

This section presents the results investigating the frames of reference and other boundary conditions. Since the interviews questioned binary answer questions, no analysis of variance is calculated.

Frames of Reference

The results of the first two questions were quite distinct. 91.7 % of the test participants voted for a world related directional offset which is in accordance to the previous results (89 %). 75 % voted for information alignment w.r.t. the world which is in contradiction to the previous questionnaire (28 %). The questioned persons either might have had a diverging understanding of the two questions or treated the relationships differently.

Prior to any study we assumed that both frames of reference would be indicated in the same manner, either both in head or world relationship. Eventually, this assumption proved true. Applications using gaze-mounted information displays thus should provide an option to use world-related frames of reference. That might be of special interest for users who have to maintain poses with a tilted head, e.g., when working around a corner or in neat spaces.

Visible Floating

The second boundary condition under investigation belongs to the visual stability of the information w.r.t. the line of sight it the angular offset.

91.7 % of our test partitioners decided that they did not want to have the information floating as having an inertia. Feedback covered distraction and clutter due to the additional perceivable motion. Also an impaired feeling, where to actually look was reported.

Overexceeding the Information

75 % also stated that, if information were floating, they would not want to have the information being able to be overexceeded by the line of sight. The users then would prefer the variant were the line of sight pushes the information. Feedback also mentioned additional visual clutter and that the actual view would be concealed.

Objective Measurements

We consequently compared all three variants.

Number of Accidental Information Captures

We calculated the percentage values for the number of accidental information captures (false positives). Such captures occurred when the users were instructed to look at the start sphere and then at the target sphere and accidentally captured the information while performing the task.

The results of the 36 sums for each user and the motion algorithm were $mean - percentage = 28.8\%$, $median = 5$, $SD = 3.320$, for the velocity variant $mean - percentage = 27.9\%$, $median = 5$, $SD = 2.431$ and for velocity with overexceeding: $mean - percentage = 28.8\%$, $median = 5.5$, $SD = 2.126$.

A Kruskal-Wallis-Test over the 36 sums for each user in the three variant groups shows no significant difference with $H(2) = 0.212$, $p = 0.899$ among the full sample. We also checked the special cases where the information was nearer than 5 angular degree to the target location while the user is still looking at the start sphere. A similar Kruskal-Wallis-Test among the sample shows no significant difference with $H(2) = 0.491$, $p = 0.782$.

Number of Saccades

Solely counting the number of saccades until the information is captured is an inexact measure. Many users tried to gaze at the information, did not capture the information and then looked leftwards again to perform another attempt. Others immediately tried to execute another rightwards glance immediately after the first failed and only reversed the gazing direction when they reached the right border of the monitor.

The counted numbers still can be used to compare the variants, especially due to the within subjects design. Fig. 6 shows the average number of saccades required to capture the information.

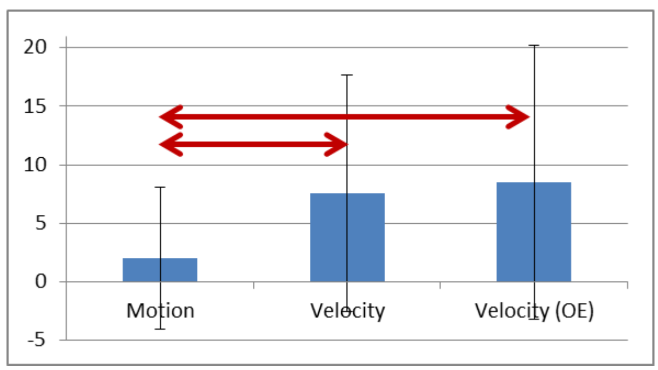


Figure 6. Mean number of saccades. Error bars show standard deviation. Double arrows show significant differences

A Kruskal-Wallis-Test on the 720 samples in 3 groups shows a highly significant difference with $H(2) = 146.253$, $p = 0.000$. Pair-wise post-hoc Mann-Whitney U tests showed highly significant differences ($p = 0.000$) for the pair motion ($mean = 2.883$, $median = 1$, $SD = 6.076$) and velocity ($mean = 8.508$, $median = 5$, $SD = 10.094$). The Mann-Whitney U test also showed highly significant differences ($p = 0.000$) for the pair motion and velocity with overexceeding ($mean = 8.775$, $median = 5$, $SD = 11.713$).

Fig. 7 shows the numbers of trials where a single saccade sufficed for information capture. A Kruskal-Wallis-Test over the 36 sums for each user in the three variant groups shows a significant difference with $H(2) = 9,063$, $p = 0.0108$. Pair-wise post-hoc Mann-Whitney U tests showed highly significant differences ($p = 0.004$) for the pair motion ($mean-per-user = 10.833$, $median = 9.5$, $SD = 6.517$) and velocity ($mean - per - user = 3.417$, $median = 2.5$, $SD = 3.040$). The Mann-Whitney U test also showed highly significant differences ($p = 0.007$) for the pair motion and velocity with overexceeding ($mean - per - user = 3.333$, $median = 1.5$, $SD = 4.007$).

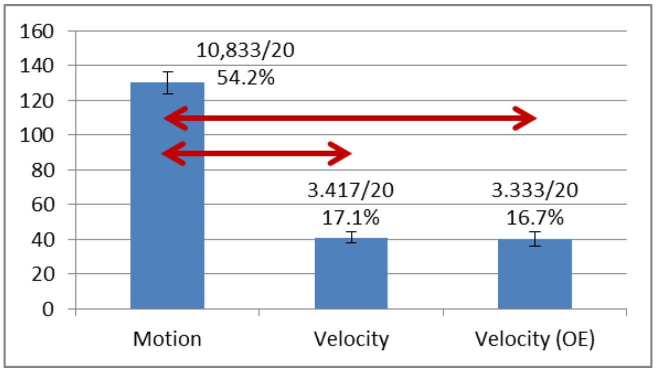


Figure 7. Number of captures with a single saccade. Error bars show standard deviation. Double arrows show significant differences

Time to Information Capture

The average time between looking at the start sphere and the subsequently requested information capture is depicted in Fig. 8.

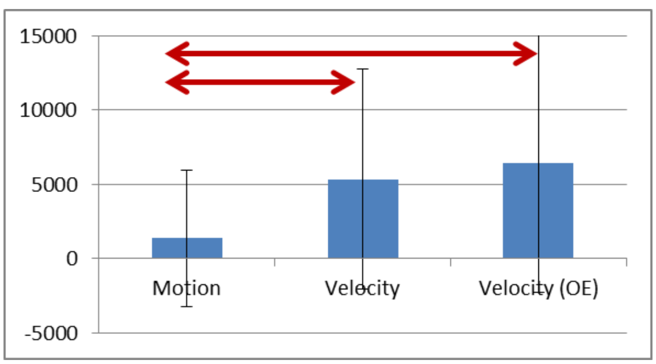


Figure 8. Average time to information capture in milliseconds. Error bars show standard deviation. Double arrows show significant differences

A Kruskal-Wallis-Test on the 720 samples in 3 groups shows a highly significant difference with $H(2) = 156.453$, $p = 0.000$. Pair-wise post-hoc Mann-Whitney U tests showed highly significant differences ($p = 0.000$) for the pair motion ($mean = 2105.913$, $median = 968.000$, $SD = 4586.550$) and velocity ($mean = 6273.379$, $median = 4111.500$, $SD = 7376.361$). The Mann-Whitney U test also showed highly significant differences ($p = 0.000$) for the pair motion and velocity with overexceeding ($mean = 6763.554$, $median = 4128.500$, $SD = 8647.884$).

The average time to information capture for tasks completed with a single saccade is shown in Fig. 9.

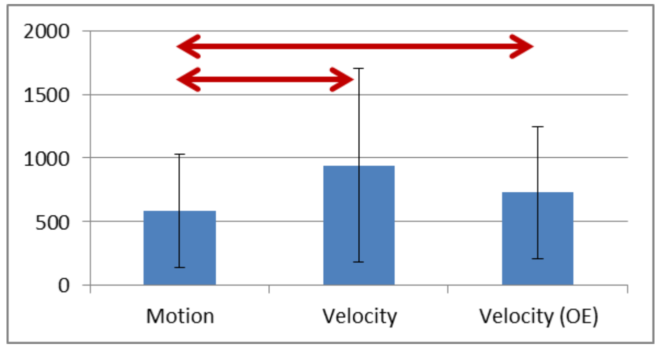


Figure 9. Average time to information capture with a single saccade in milliseconds. Error bars show standard deviation. Double arrows show significant differences

A Kruskal-Wallis-Test on the 720 samples in 3 groups shows a highly significant difference with $H(2) = 9.730$, $p = 0.008$. Pair-wise post-hoc Mann-Whitney U tests showed highly significant differences ($p = 0.002$) for the pair motion ($mean = 583.346$, $median = 567.000$, $SD = 445.205$) and velocity ($mean = 942.341$, $median = 701.000$, $SD = 760.888$). The Mann-Whitney U test showed barely significant differences ($p = 0.0497$) for the pair motion and velocity with overexceeding ($mean = 728.175$, $median = 558.500$, $SD = 521.204$).

DISCUSSION

The results show a vast majority of differences in favor for the motion history algorithm. We thus can acknowledge the first hypothesis („Visible floating impairs capturing.“) as valid. For the second hypothesis („The option to overexceed the information impairs capturing.“) we can not derive any results. The answers of the questionnaires in both cases however disliked floating in general and overexceeding in detail.

Yet, the motion history algorithm does still not provide error (capture) free gazing, nor does it yet provide accurate information capture. Two findings make the demonstration prototype a valid candidate for future investigation. The motion history algorithm already yielded a 54.8% capture rate with a single glance onto the information and the average capture time took 583ms.

We made a further observation during the course of the user study. A large number of our test participants let their gaze turn comparably slow when requested to „quickly“ look at the information. The speed in which the saccade was executed did not reach the speed required for either algorithm. This shows that transporting the concept in spoken words is not an easy task. At the time after the study had been completed, we yet can state that the short time of approximately 15 minutes for the objective measurements let enough time to get used to the concept in general and that the users thus were able to adopt to what we call a „quick glance onto the information“. Future implementations in any case need to adopt to the user and not vice versa.

CONCLUSIONS

Placing information with respect to the line of sight offers new means for information visualization and interaction, especially does it bear the potential to keep resuming times for the main task short. As a new field of investigation in human computer interaction and augmented realities, we first need to dig down into the heap of opportunities. With this work we investigated boundary conditions for such information presentation.

We investigated the frames of reference for which we could identify partially constant results over the course of two independent studies. We also investigated options for floating behaviors of information, whether it shall float at all and to what extend, respectively.

Our results indicate that, under the condition of future focus on the algorithms and their parameterization, there is a valuable field for future investigation. We will continue developing more robust algorithms and will test them with specific application tasks and against conventional strategies such as screen- and world-fixed information placement.

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