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HealthXR 2024 - Tutorial

IEEE | IEEE COMPUTER SOCIETY | IEEE vgtc

XR for Healthcare: Immersive and Interactive Technologies for Serious Games Tutorial

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Outline – part 2

HealthXR 2024 - Tutorial

Perception aspects in XR applications

- Perception-interaction loop
- Health context
- Computational neural models of visual perception for action tasks

Computational neural models of the front end of the visual perception channel

- Depth of field; Vergence-accommodation conflict; Log-polar mapping (foveation); Computational neural model accounts for human behavioral data

Computational neural models to improve XR applications

- Mitigating cybersickness through foveated rendering and depth of field
- Mitigating misperception of depth through addressing vergence-accommodation conflict

Case studies: XR applications in the context of clinical psychological field

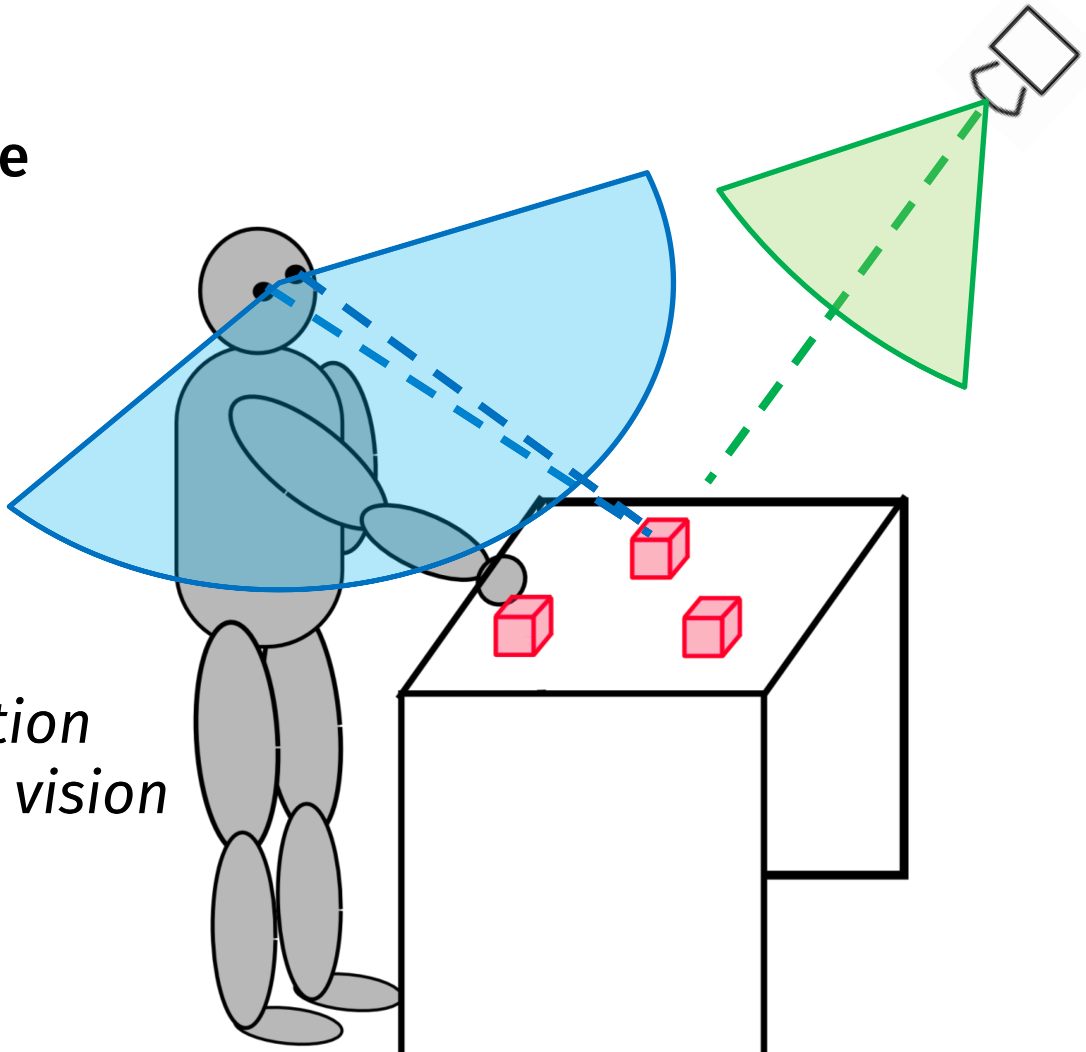
- Teleconsultations
- An exergame to assess the digital autonomy for web-based applications (WebGL)
- A serious game for the detection of disorders in social interactions

Perception aspects in XR applications

- Perception-interaction loop
- Health context
- Computational neural models of visual perception for action

Perception-interaction loop

Humans:
looking at the scene
acting in the scene
- *perception*
- *interaction*



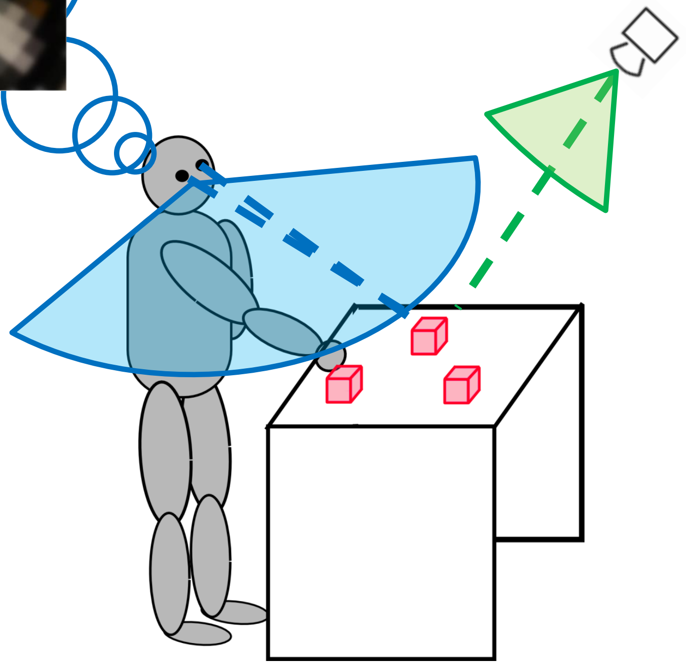
Standard devices:
looking at the scene
- *processing*

Standard devices:
- *Narrow field of view*
- *Uniform resolution*
- *Stereoscopic systems*
- *One focus plane*

Humans:
- *Large field of view*
- *Space variant resolution*
- *Stereoscopic vergent vision*
- *Accommodation*

Perception-interaction loop

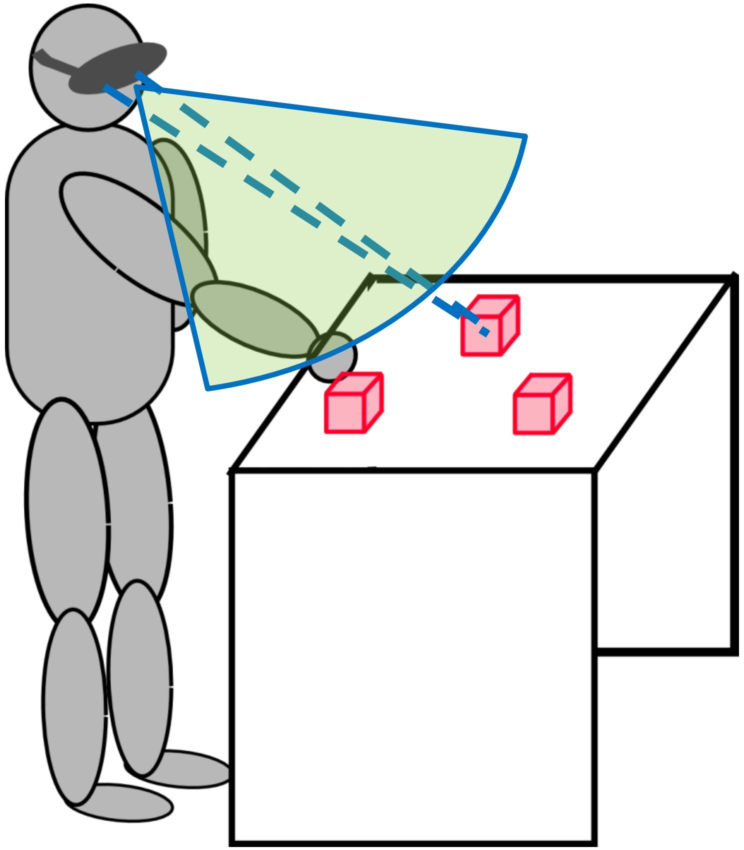
The perceived egocentric view of the surrounding environment affects
- *perceived distance*
- *perceived motion*
- *perceived objects*
- *natural interaction*



The standard device view of the surrounding environment
- *computed visual features*

Perception-interaction loop in VR/XR

Humans wearing standard devices:
Looking at the VR scene
acting in the VR scene
- *natural perception*
- *natural interaction*

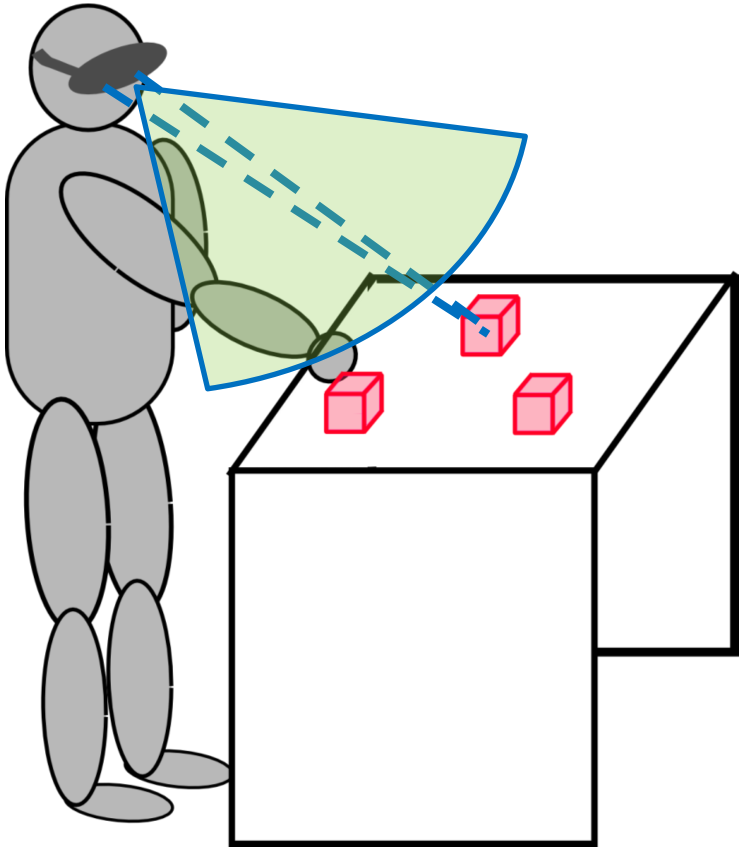


Computational models can help to understand human perception and interaction, thus allowing us to improve the VR/AR design
- *entertainment*
- *social environment*
- *training (Industry 4.0)*
- *H-R collaboration*
- *health, well-being*

but
- *Large field of view -> Narrow field of view*
- *Space variant resolution -> Uniform resolution*
- *Stereoscopic vergent vision -> Stereoscopic system par.optc.ax.*
- *Accommodation -> One focus plane*

Perception-interaction loop in VR/XR

Humans wearing standard devices:
Looking at the VR scene
acting in the VR scene
- *natural perception*
- *natural interaction*



Health
- Specific attention to mitigate side effects of XR
- XR in the daily clinical activity
- GDPR (in Europe)
- XR HW/SW issues related to HW/SW infrastructure of hospitals

but
- *Large field of view -> Narrow field of view*
- *Space variant resolution -> Uniform resolution*
- *Stereoscopic vergent vision -> Stereoscopic system par.optc.ax.*
- *Accommodation -> One focus plane*

Health context: Relaxation

XR healthcare field is wide, thus we focus on some aspects related to perception.

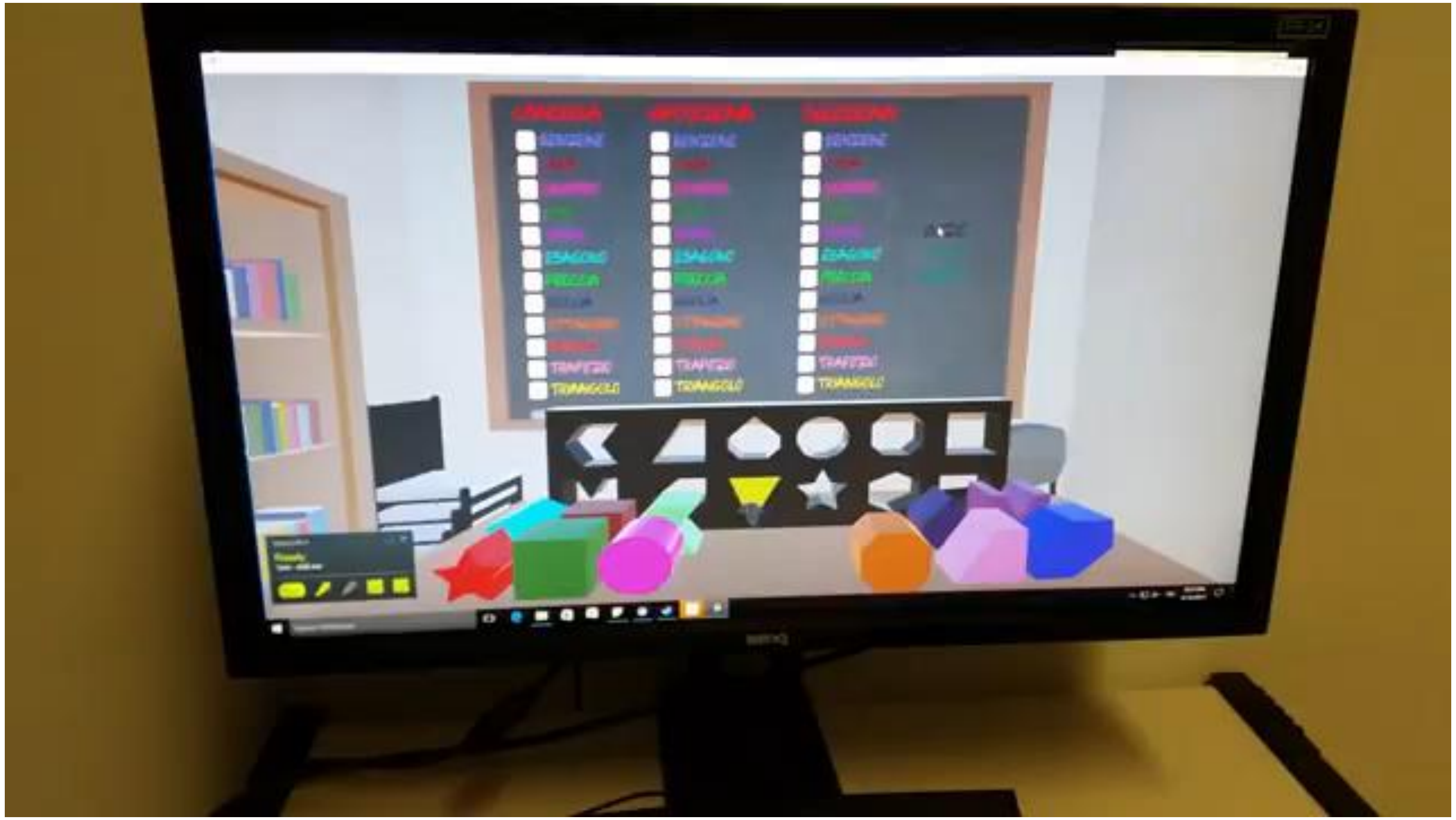
Innovative approaches are needed to supplement existing stress management techniques, particularly for people with mental health conditions.

Virtual reality relaxation is one such innovation that is attempting to meet this need.

Here, and in general, we need to pay attention to the side effect of the cybersickness.

Riches, S., Jeyarajaguru, P., Taylor, L., Fialho, C., Little, J., Ahmed, L., ... & Valmaggia, L. *Virtual reality relaxation for people with mental health conditions: a systematic review*. Social Psychiatry and Psychiatric Epidemiology, 58(7), 989-1007, 2023.

Health context: exergames and serious games



Here, we need to pay attention to the misperception of the depth.

E Gusai, C Bassano, F Solari, M Chessa. *Interaction in an Immersive Collaborative Virtual Reality Environment: A Comparison Between Leap Motion and HTC Controllers*. 19th Int. Conf. ICIAP September 10-12, 2017.

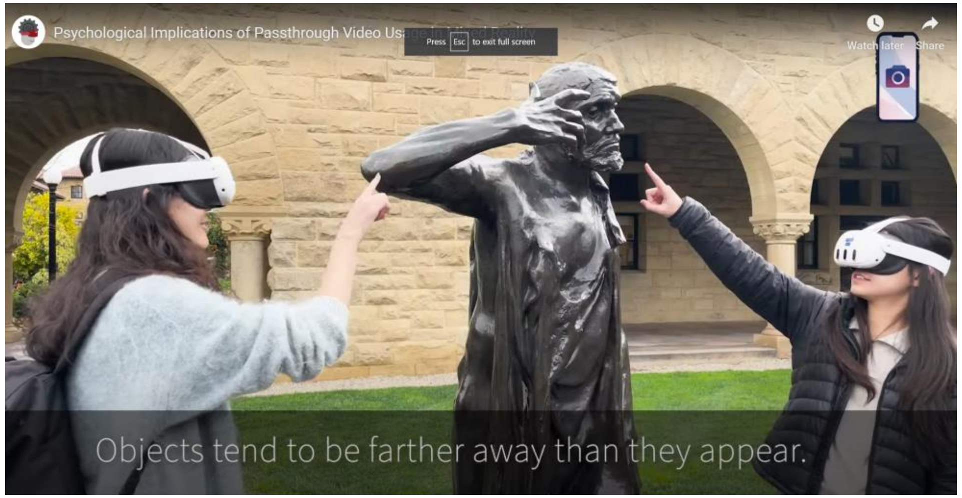
Current technologies: still, we must improve them

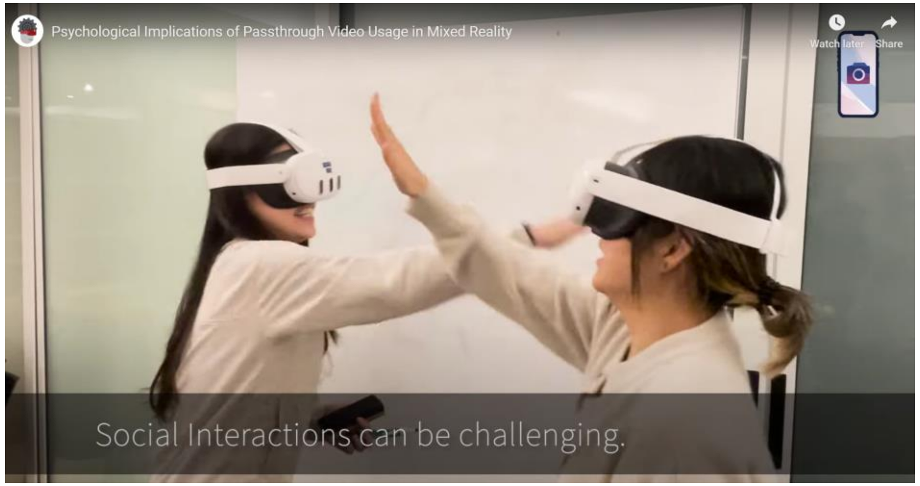
Technological specifications which make new passthrough headsets stand out from previous ones, but are still lower fidelity compared to human vision on parameters such as field of view, distortion, latency, and resolution.

The passthrough experience (*Meta Quest 3*) can inspire awe and lends itself to many applications, but will also likely cause *visual aftereffects, lapses in judgments of distance, induce simulator sickness, and interfere with social connection.*

Bailenson, J., Beams, B., Brown, J., DeVeaux, C., Han, E., Queiroz, A., Ratan, R., Santoso, M., Srirangarajan, T., Tao, Y. ., & Wang, P. *Seeing the World through Digital Prisms: Psychological Implications of Passthrough Video Usage in Mixed Reality*. Technology, Mind, and Behavior, 2024 (TA)

Current technologies: still, we must improve them





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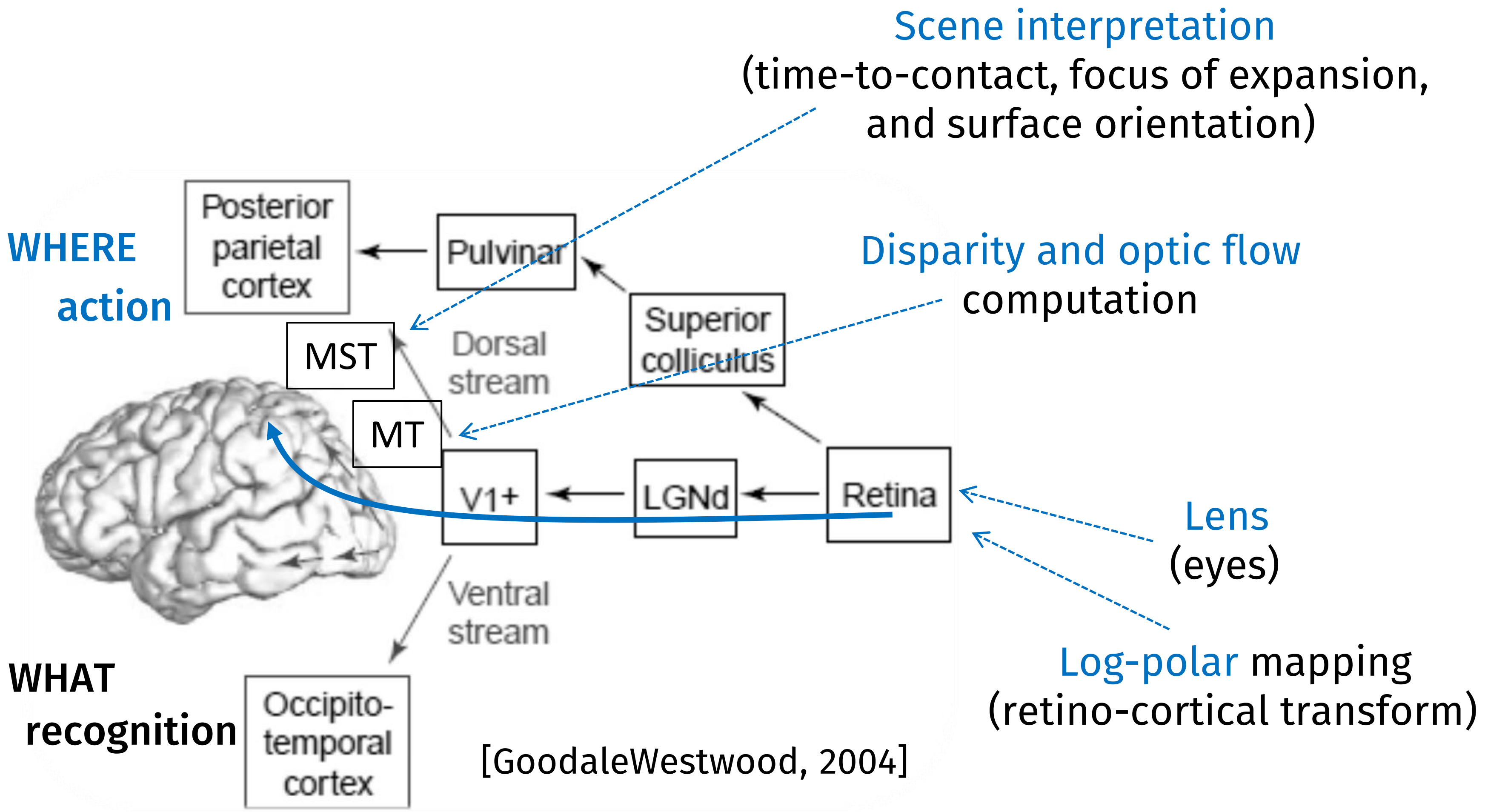
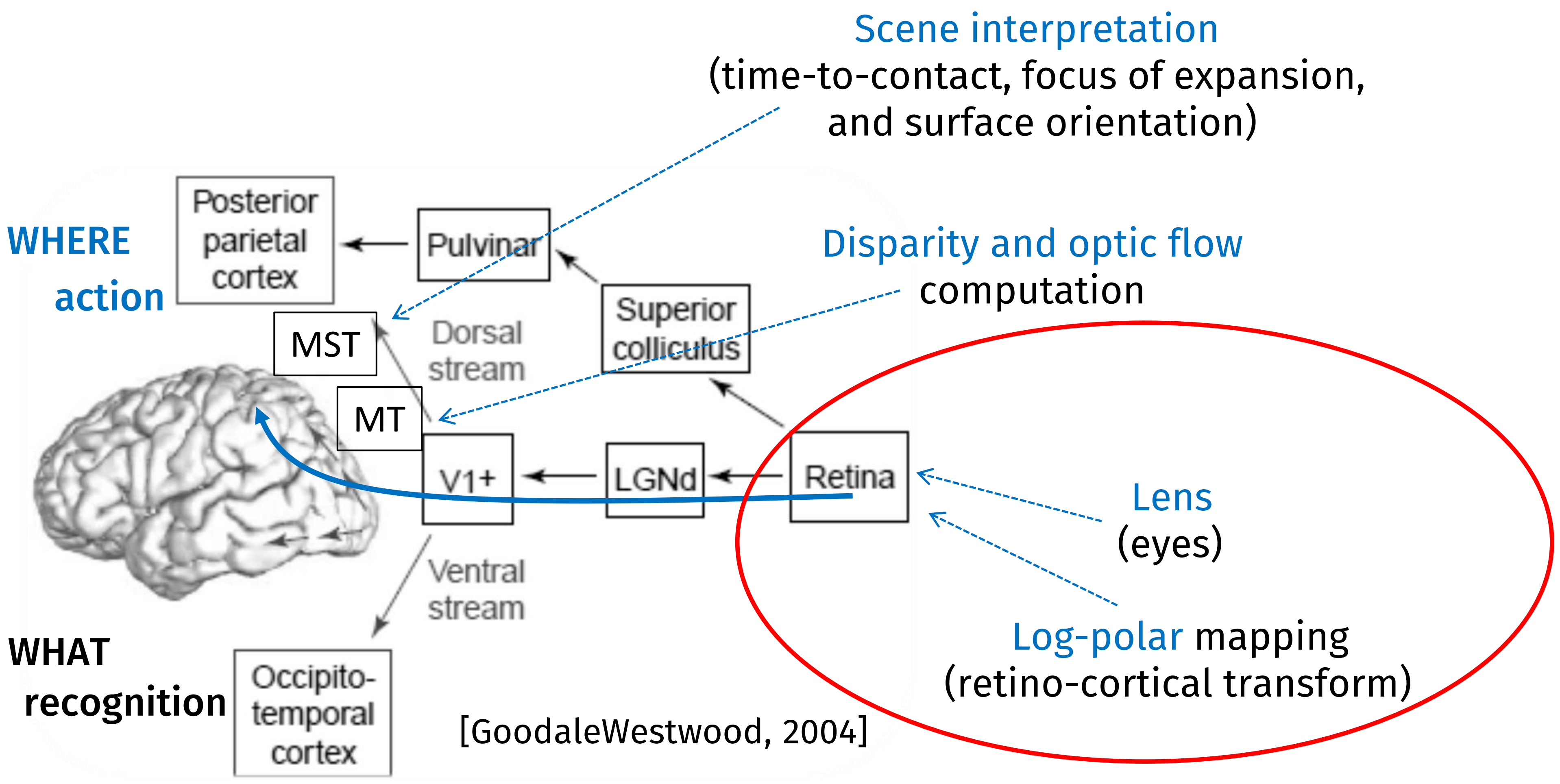
Computational neural models of visual perception for action tasks



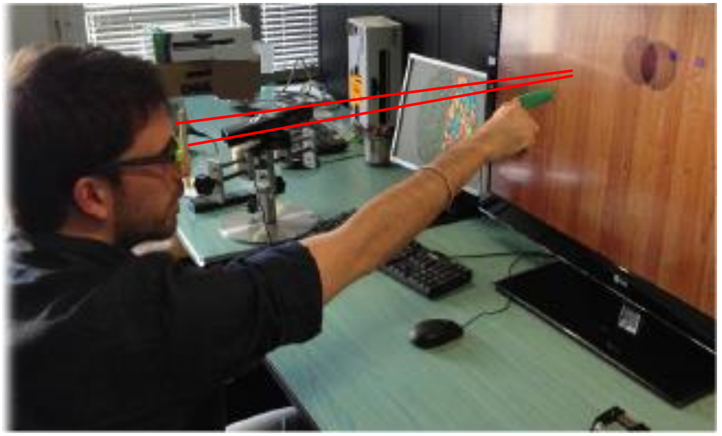
Computational neural models of visual perception for action tasks



[GoodaleWestwood, 2004]

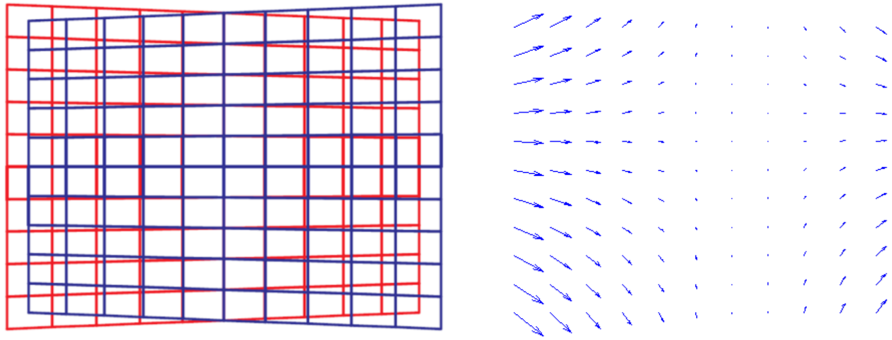
Active Vision for interaction: vector disparity

Natural vision system:
vergence movements (*active vision*)



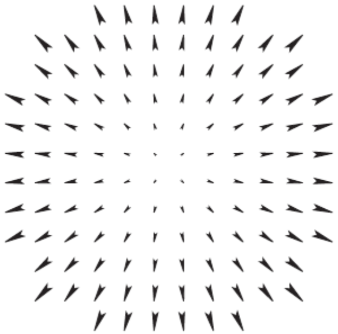
Disparity pattern: left and right projection of a fronto-parallel plane

convergent optical axes *disparity field*



Optic flow pattern: e.g., an expansion pattern

optic flow field



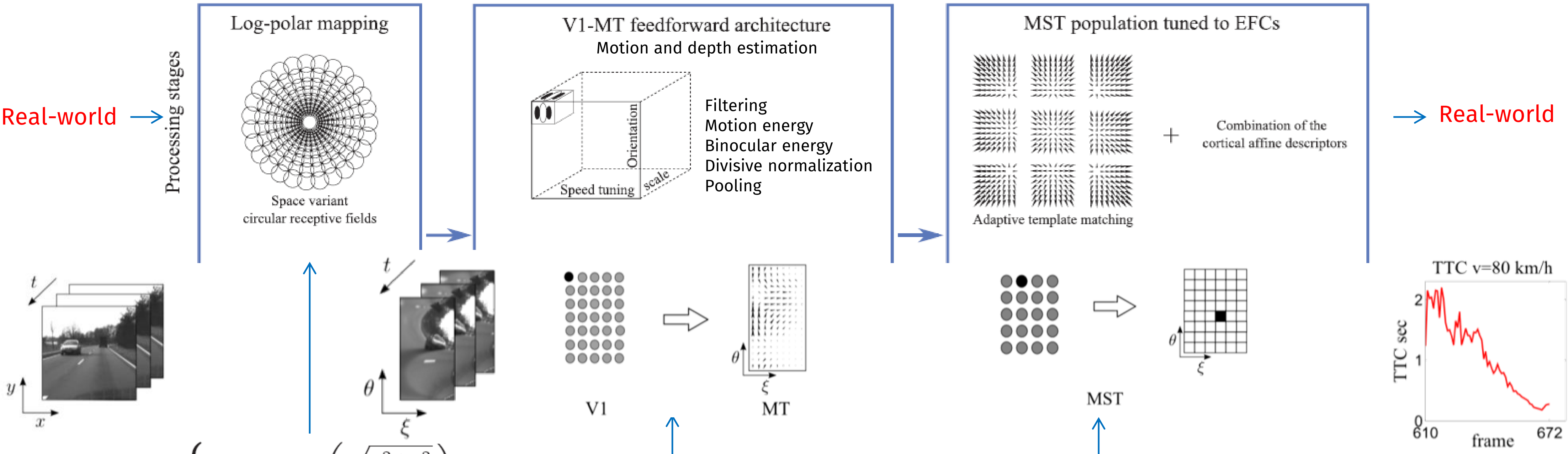
A computational neural model for action tasks

The proposed neuromimetic architecture, which captures in the simplest possible way the essential aspects of the neural computations that occur in the cortical motion and depth pathway (namely V1-MT-MST), exploits:

- *log-polar mapping* for data reduction
- a population of *energy neurons* to compute optic flow and disparity
- a population of *adaptive templates* in the cortical domain to gain the flow's affine description
- The *first-order representation* (i.e. affine) of optic flow for the visual understanding of the 3D scene

To compute higher visual features (e.g., time-to-contact, surface orientation, focus of expansion) that are related to action tasks.

A computational neural model for action tasks



$$\begin{cases} \xi = \log_a \left(\frac{\sqrt{x^2+y^2}}{\rho_0} \right) \\ \theta = \arctan\left(y/x\right) \end{cases}$$

$$\boldsymbol{v} = \boldsymbol{\alpha}^{\xi}\,\bar{v}_{\xi} + \boldsymbol{\alpha}^{\theta}\,\bar{v}_{\theta} + \mathbf{d}^{\xi}_{\xi}\frac{\partial v_{\xi}}{\partial \xi}\Big|_{(\xi_0,\theta_0)} + \mathbf{d}^{\xi}_{\theta}\frac{\partial v_{\xi}}{\partial \theta}\Big|_{(\xi_0,\theta_0)} + \mathbf{d}^{\theta}_{\xi}\frac{\partial v_{\theta}}{\partial \xi}\Big|_{(\xi_0,\theta_0)}$$

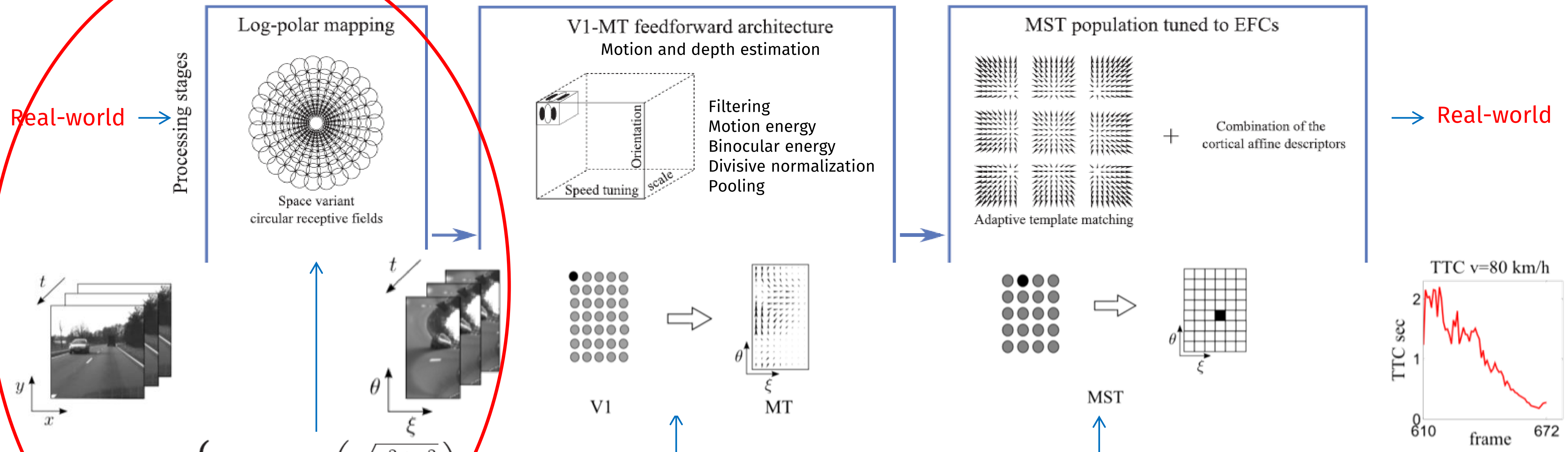
$$Q(\xi,\theta,t;\phi,\omega,v^{\phi}) = \iiint g(\xi-\xi',\theta-\theta',t-t';\phi,\omega,\omega_t)\widetilde{I}(\xi',\theta',t')d\xi' d\theta' dt'$$

M. Chessa, F. Solari. *A Computational Model for the Neural Representation and Estimation of the Binocular Vector Disparity from Convergent Stereo Image Pairs*. International Journal of Neural Systems, 29(5), 2019

F. Solari, M. Chessa, N. V. K. Medathati, P. Kornprobst *What can we expect from a V1-MT feedforward architecture for optical flow estimation?* Signal Processing: Image Communication, 39, 342-354, 2015.

F. Solari, M. Chessa, S.P. Sabatini. *An integrated neuromimetic architecture for direct motion interpretation in the log-polar domain*. Computer Vision and Image Understanding, 125, pp. 37-54, 2014

A computational neural model for action tasks



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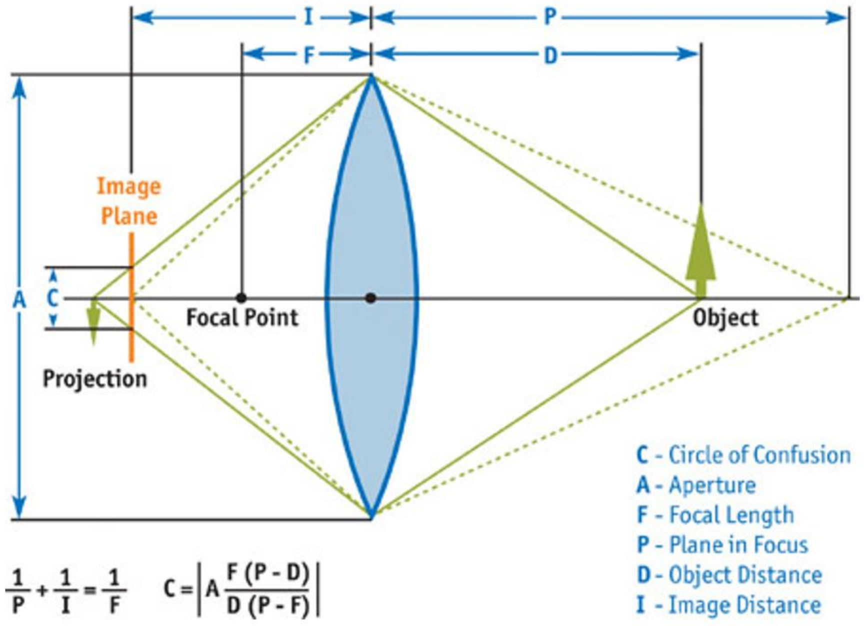
Computational neural models of the front end of the visual perception channel

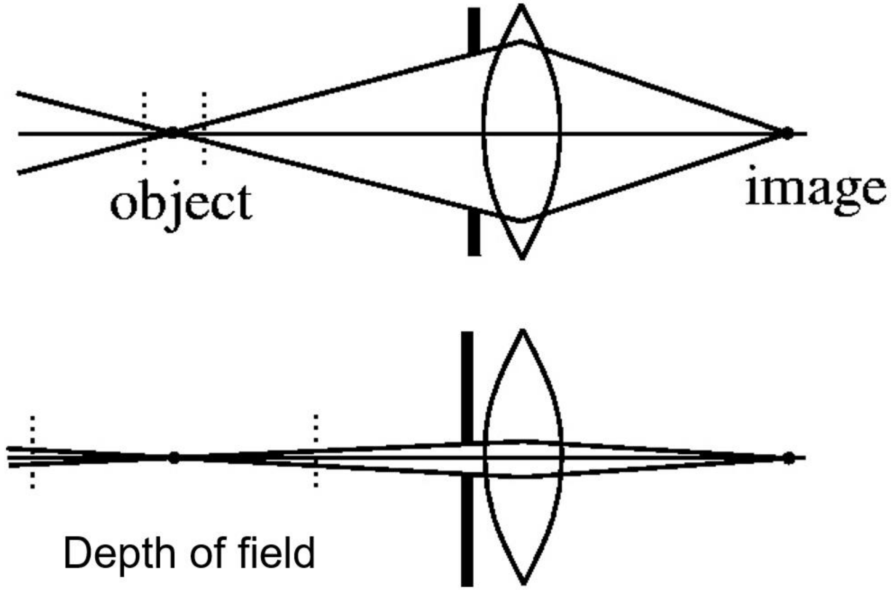
- Depth of field
- Vergence-accommodation conflict
- Log-polar mapping (*foveation*)
- Computational neural model accounts for human behavioral data

Depth of field

Rendering of virtual objects with the pinhole camera model commonly used in computer graphics will result in perfectly sharp images of all objects, irrespective of the focal depth.

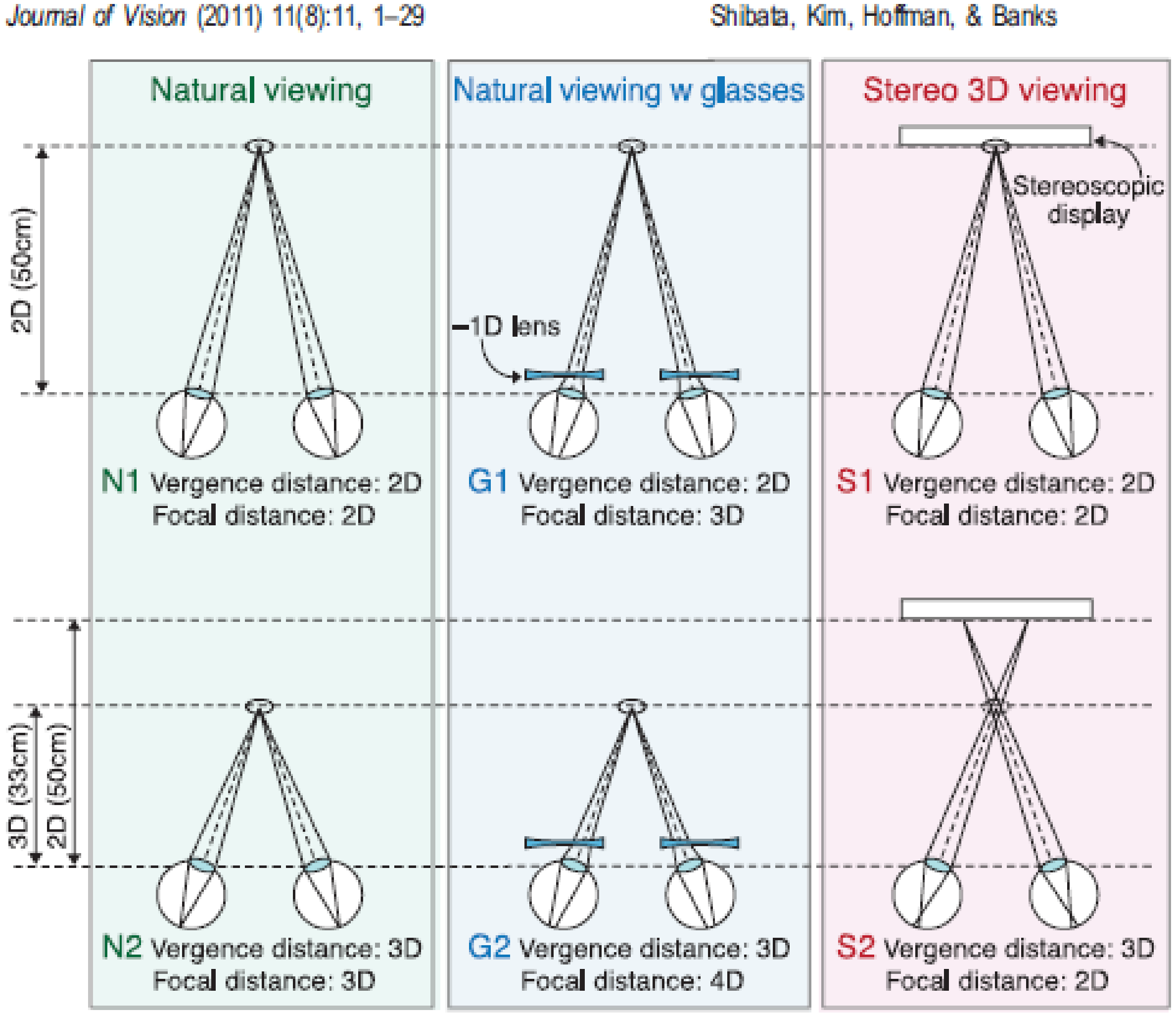
Our eyes and actual cameras have a certain aperture size and, therefore, have to cope with the problem of limited depth of field.

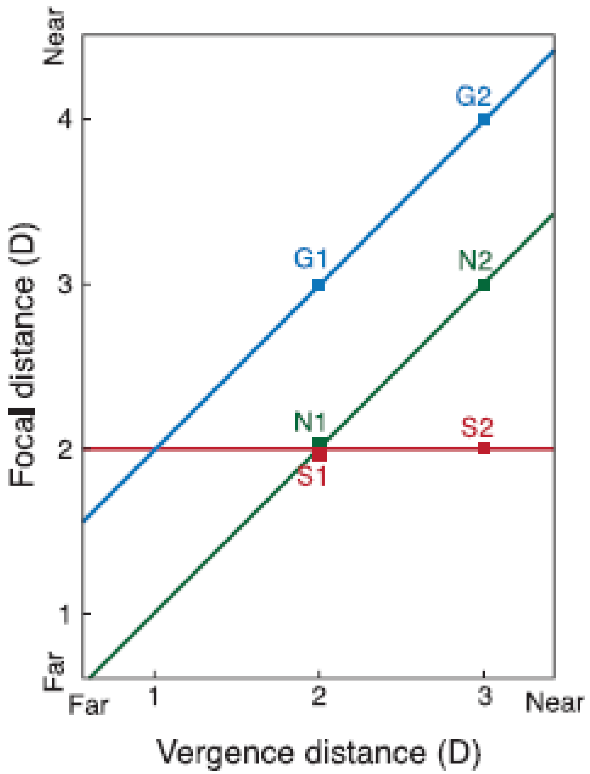




Vergence-accommodation conflict

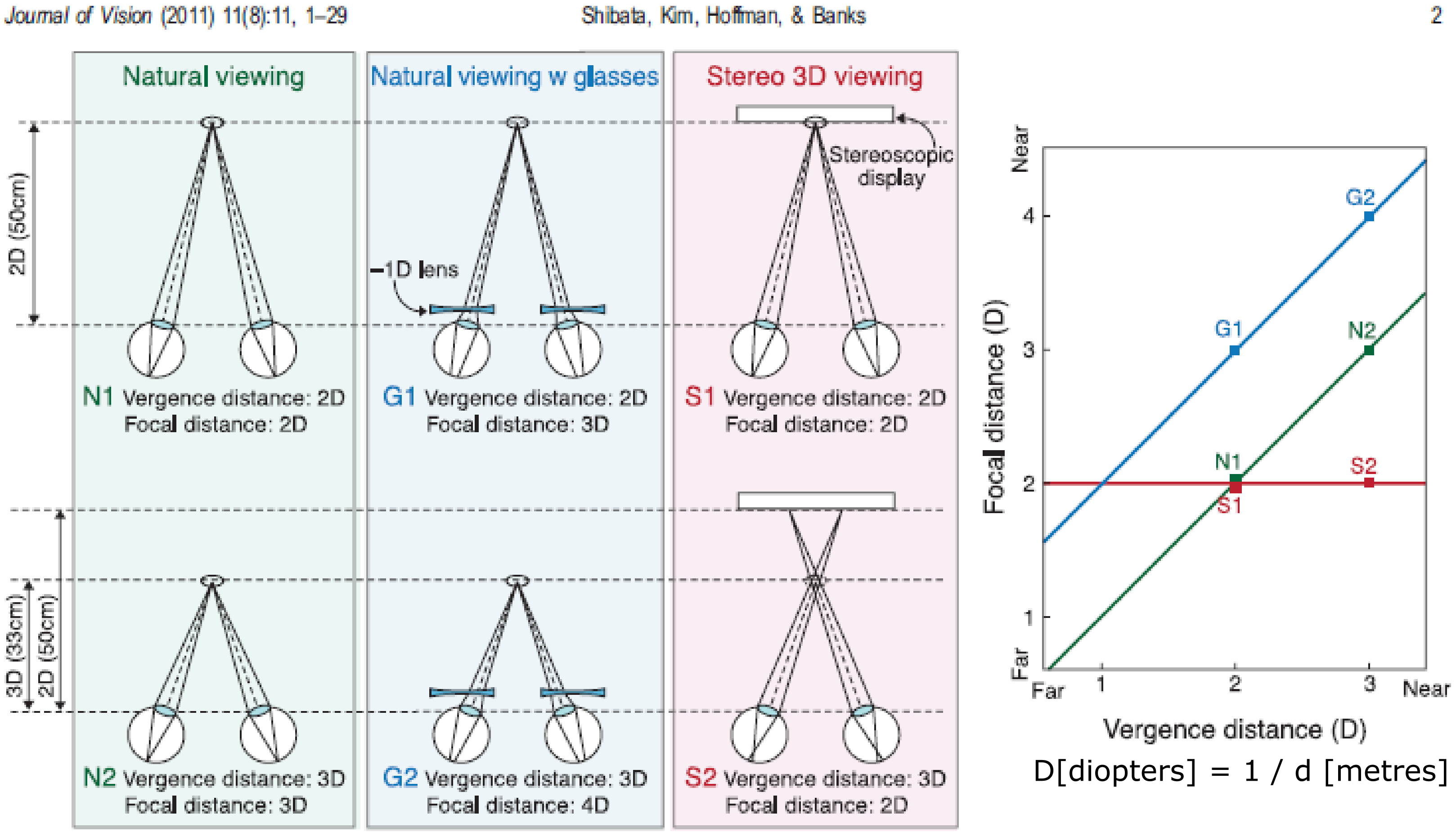
- Our eyes can *accommodate* (focus) at varying distances.
- Accommodation can occur as a reflex to *vergence*, independent rotation of eyeballs to fixate a point in space: vergence-accommodation reflex.





D[diopters] = 1 / d [metres]

Vergence-accommodation conflict



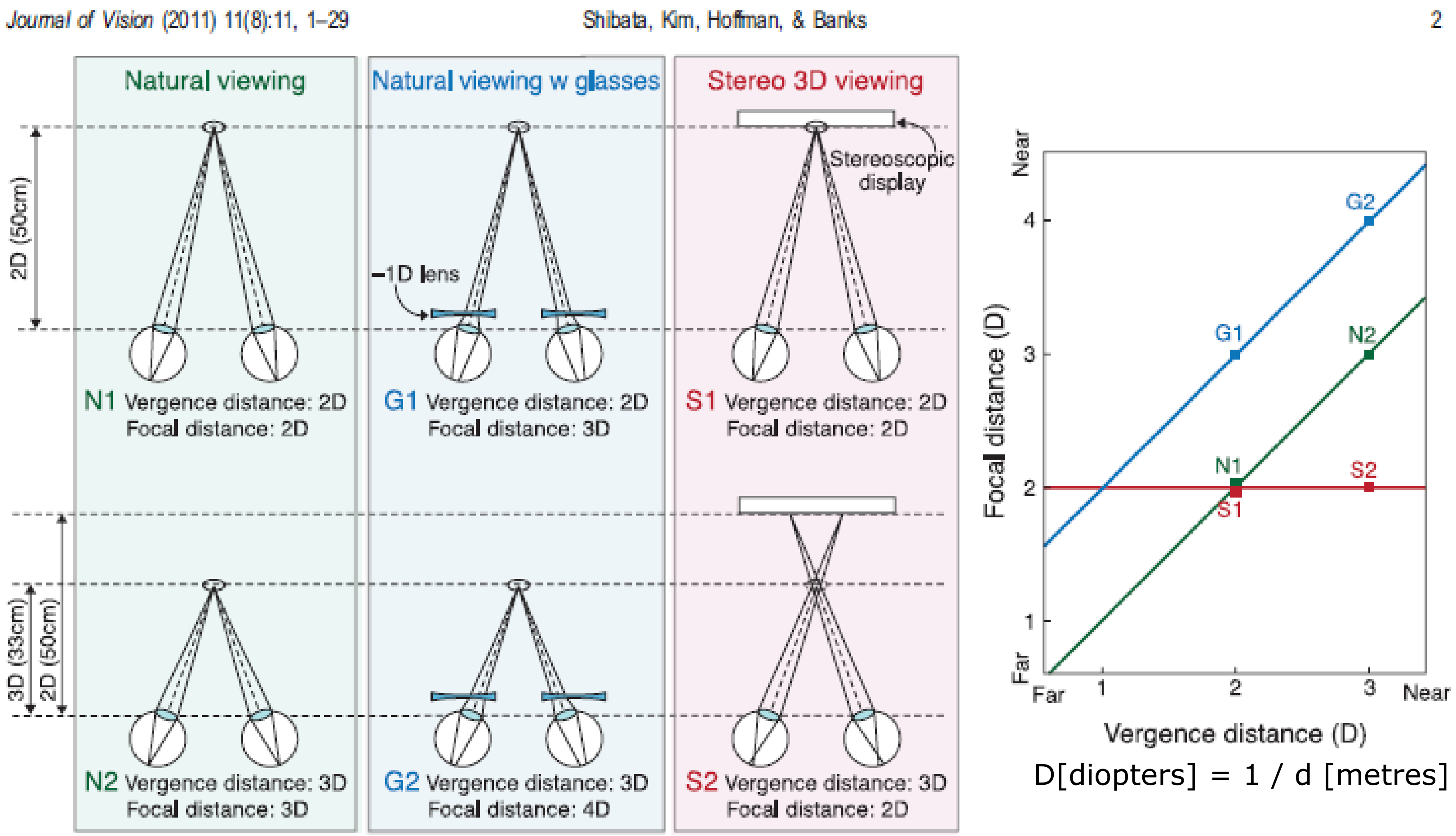
D[diopters] = 1 / d [metres]

NATURAL VIEWING:

vergence and focal distance are equal to one another, so they lie on the green line of slope 1 in the plot on the right (in the optometric/ophthalmic literature, this line is called the demand line or Donders' line (Donders, 1864).

Because vergence and focal distance are the same in natural viewing, it is not surprising that the responses are neurally coupled.

Vergence-accommodation conflict



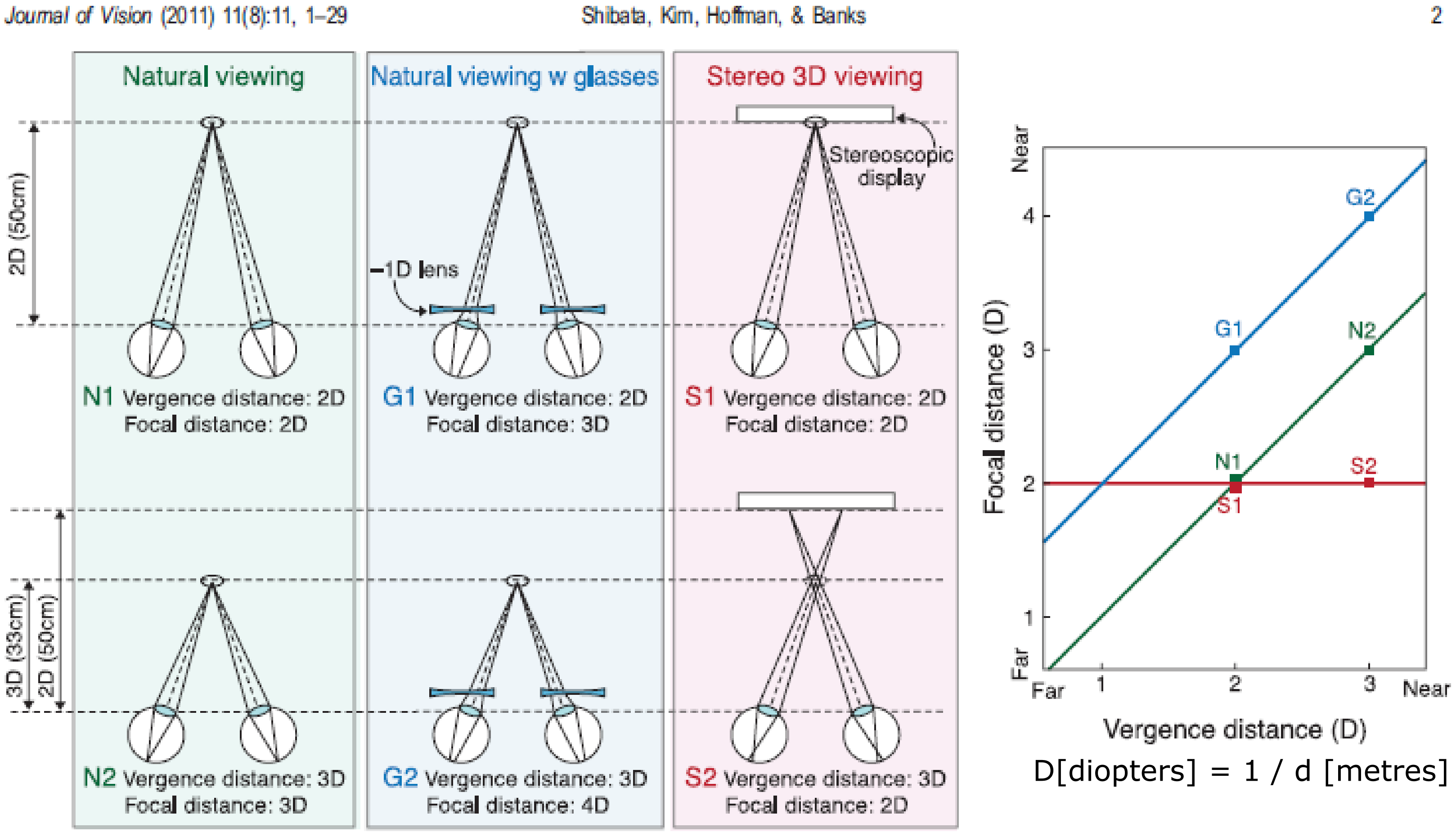
D[diopters] = 1 / d [metres]

OPTICAL CORRECTION:

the introduction of the correction (-1D) increases the focal demand on the crystalline lens within the eye without changing the vergence distance.

This creates a constant difference in magnitude between the vergence and focal stimuli. Thus, stimuli like G1 and G2 are shifted vertically from the natural viewing line by the dioptric power of the correction.

Vergence-accommodation conflict



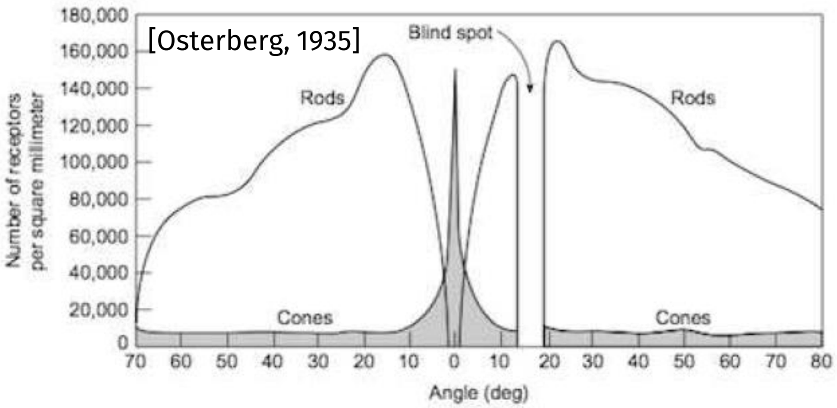
D[diopters] = 1 / d [metres]

VIEWING ON STEREO DISPLAYS:

focal distance is fixed at the distance from the eyes to the display screen. Vergence distance varies depending on the distance being simulated by the contents of the display.

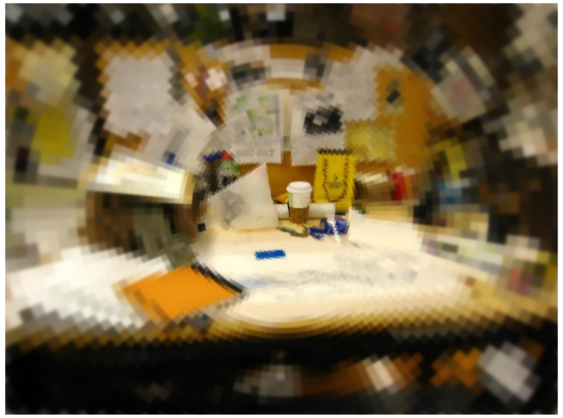
Thus, vergence–accommodation conflict is created by viewing stereo displays, but the magnitude of the conflict depends on the image contents relative to the viewer's distance from the display.

Log-polar mapping (*foveation*)



The log-polar mapping (retino-cortical transformation) simultaneously provides:

- a wide field-of-view
- a high spatial resolution on the region of interest
- a significant data reduction
- besides rotation and scaling invariance properties



The log-polar mapping provides a *decrease of spatial resolutions* as a function of distance from the fovea (focus of attention) and introduces a *distortion of local operators* from an image processing point of view.

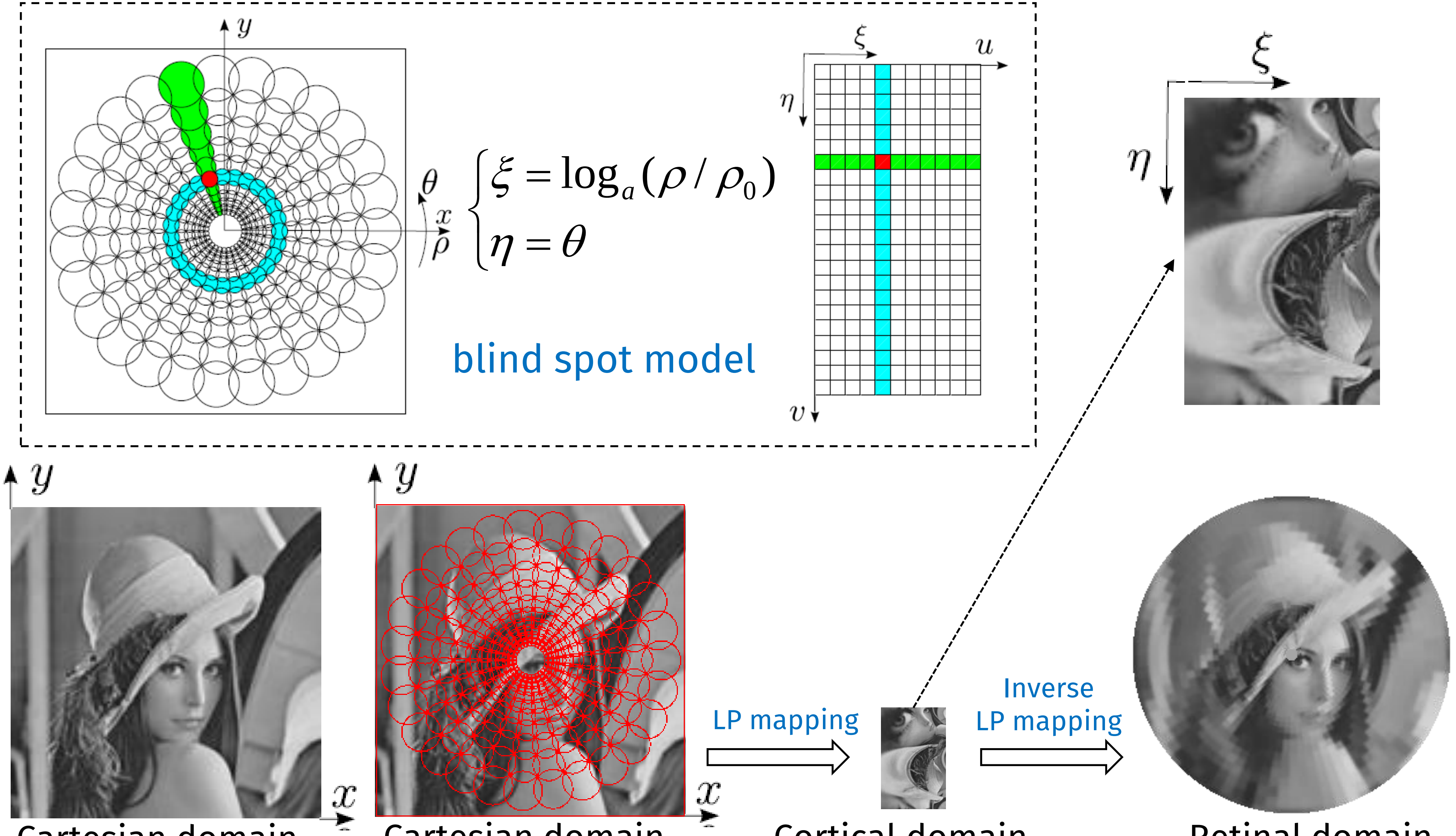
Log-polar mapping: models

To analyze the different models and techniques of the literature for implementing an effective log-polar mapping.

To perform quantitative comparisons of such techniques (at the pixel level):

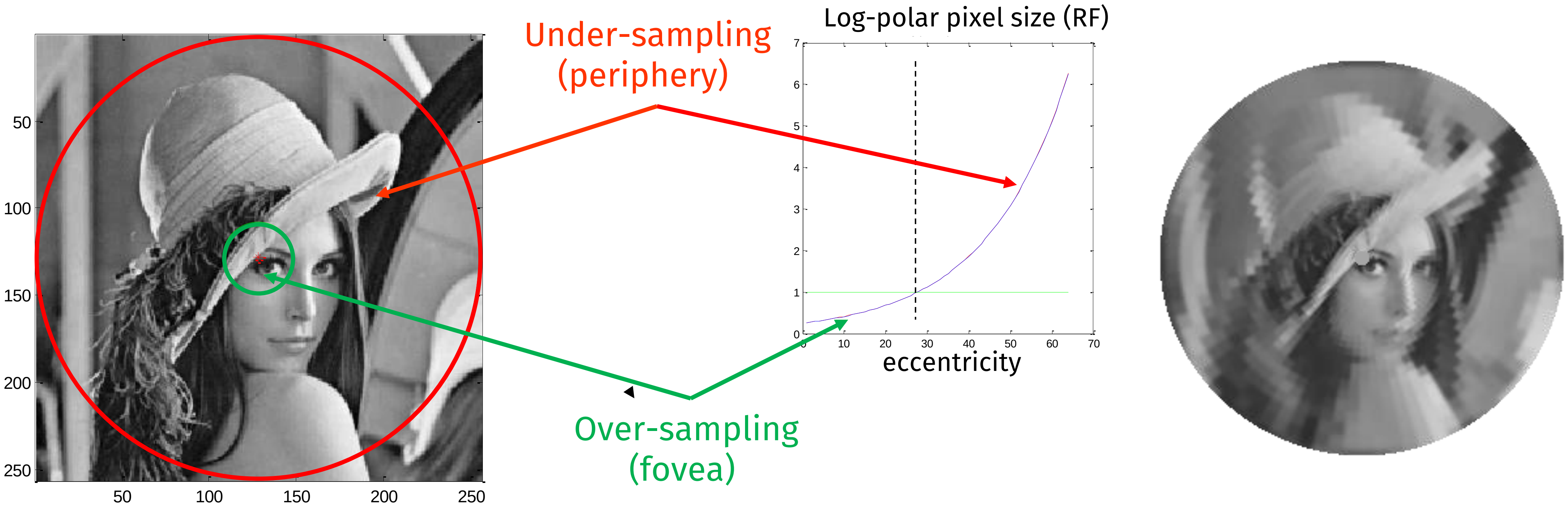
- to measure the computational load;
- to assess the degradation of the visual information in the transformed image.

Log-polar mapping: model

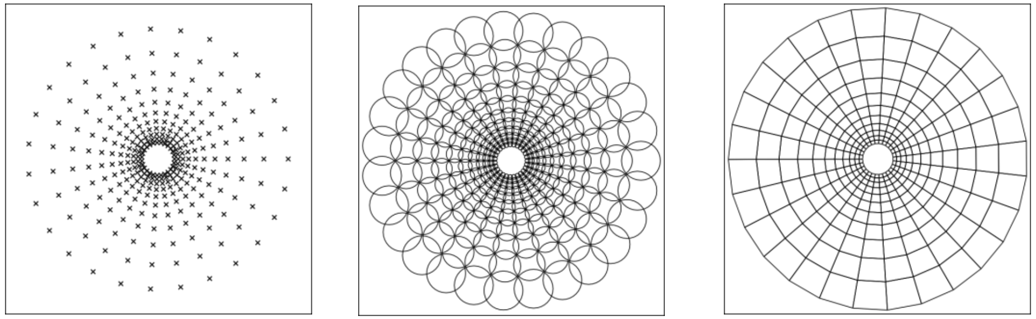


M. Chessa, F. Solari. *Log-polar BlindSpotModel*. Software modules available in the OpenCV library

Discrete log-polar mapping



We have to deal with a discrete transformation, since we consider images acquired by a conventional camera.
Given a compression ratio, the *different log-polar techniques* preserve *different amount of visual information.*



Log-polar mapping: implementation

Computational load

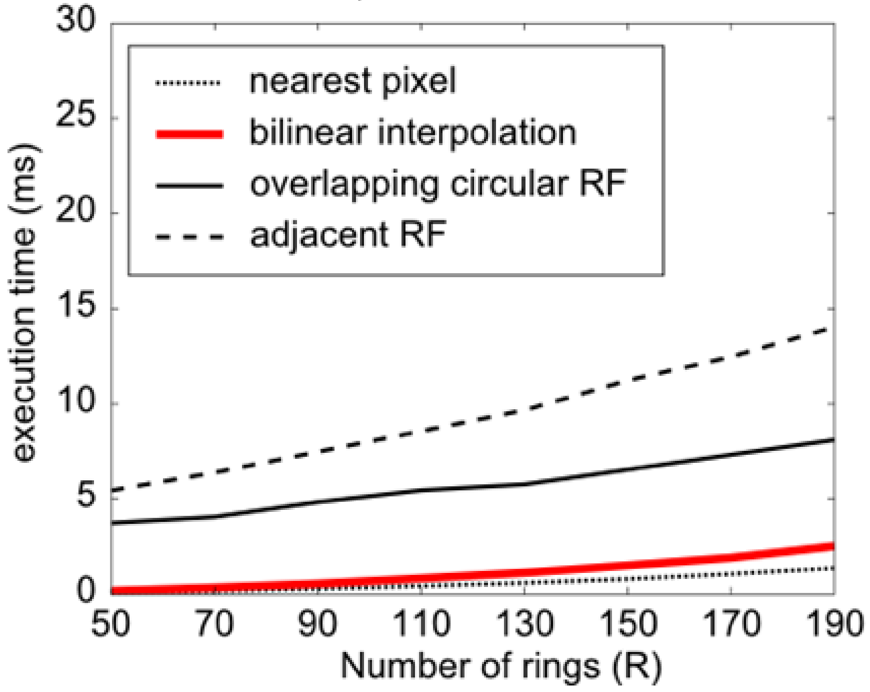
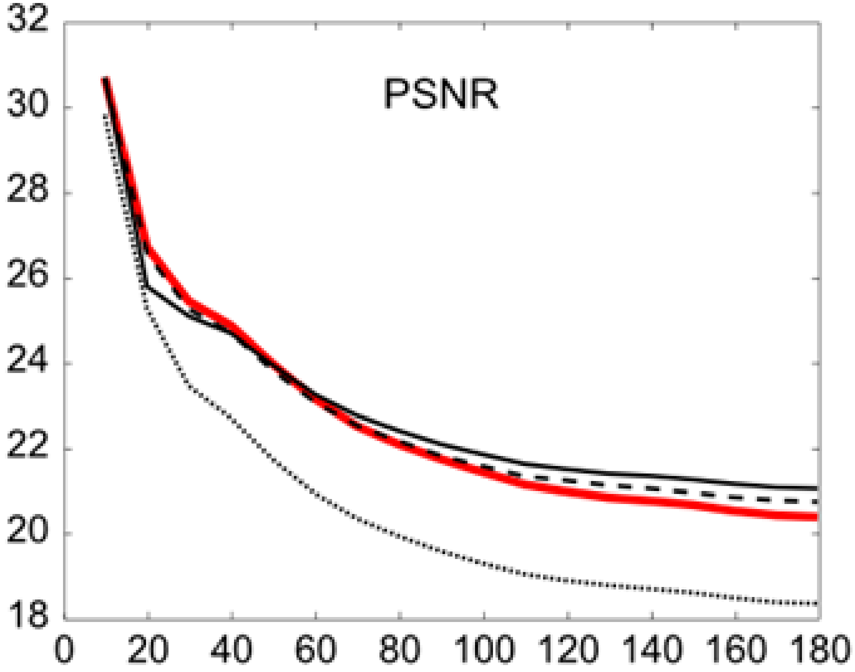


Image quality

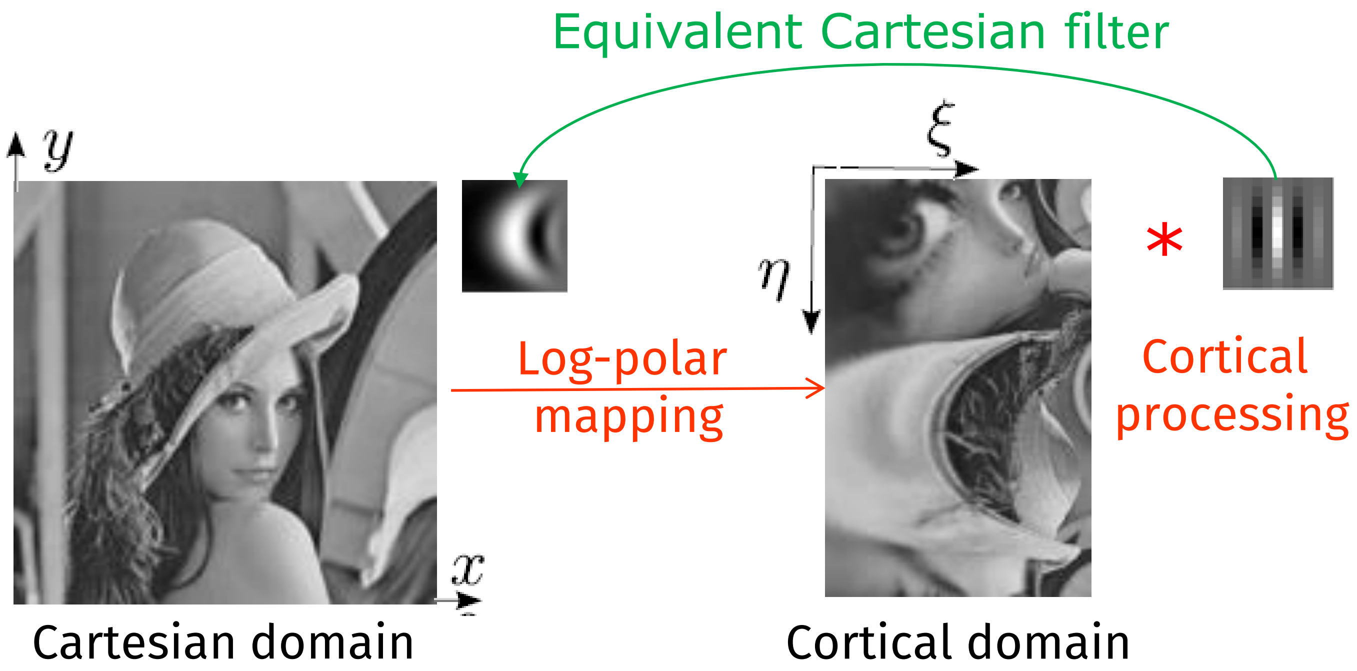


The bilinear interpolation solution of the blind spot model is the best trade-off for all the applications that require a fast and reliable processing of the images.

M. Chessa, S. P. Sabatini, F. Solari and F. Tatti. *A Quantitative Comparison of Speed and Reliability for Log-Polar Mapping Techniques*. Computer Vision Systems - 8th International Conference, 2011.

Log-polar mapping: local operators

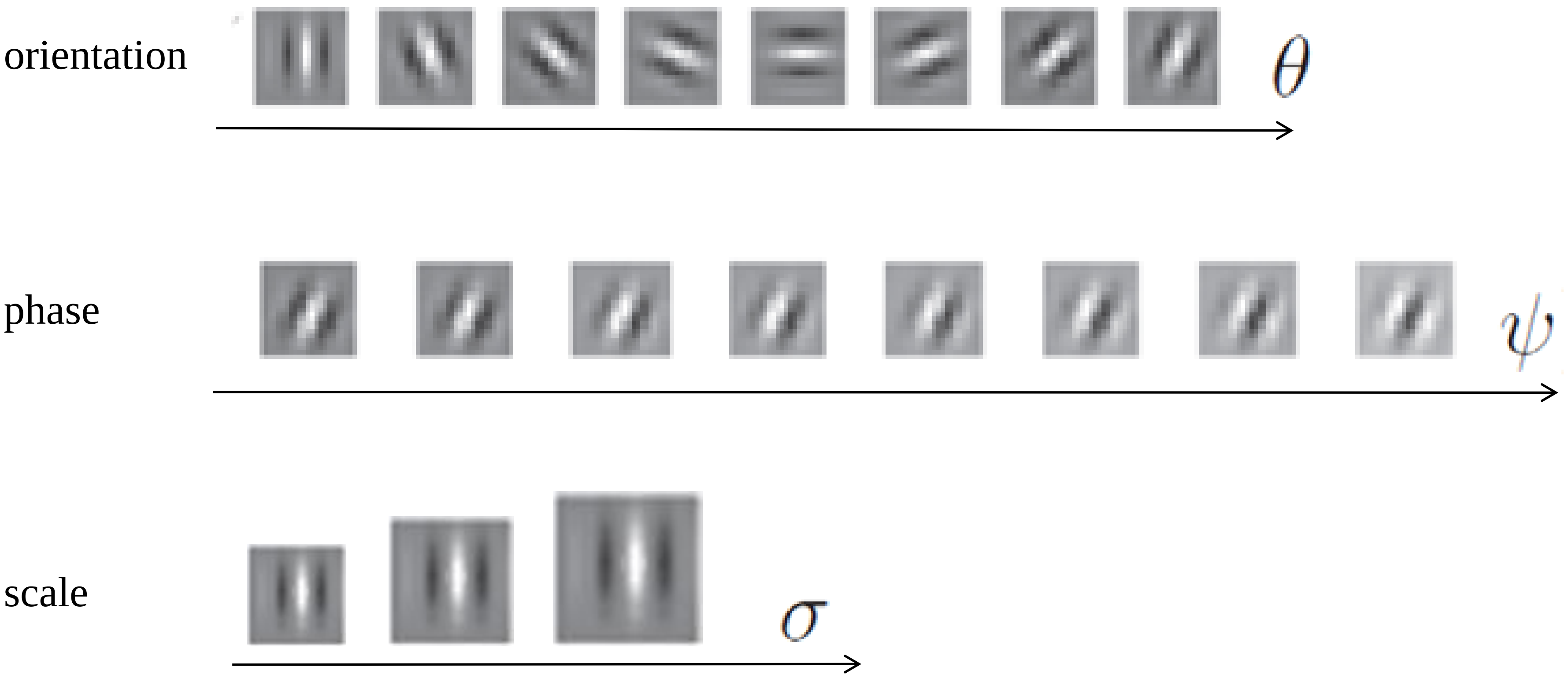
The problem of log-polar mapping is the warping of the shapes of the Cartesian local operators (e.g., spatio-temporal filtering), when applying local operators at cortical level.



Log-polar mapping: computational model

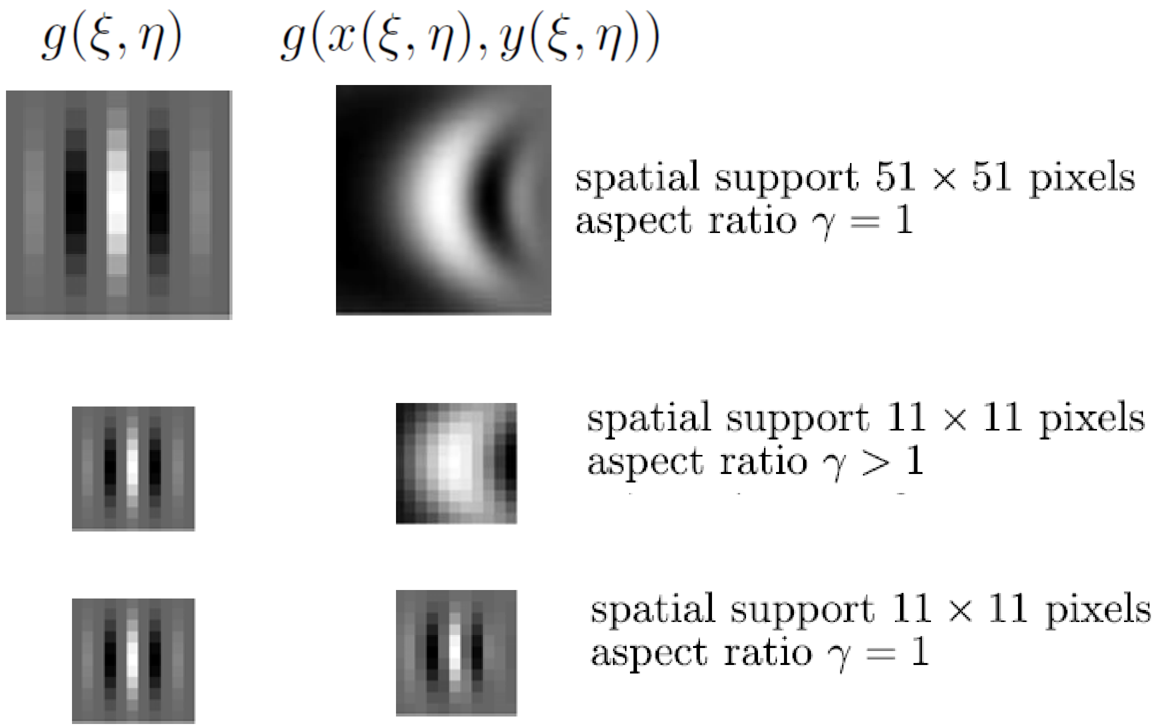
We consider complex-valued spatial Gabor filters

$$g(x, y; \theta, \sigma, \psi) = B e^{\left(\frac{-(x^2+y^2)}{2\sigma^2}\right)} e^{j2\pi(f_s cos(\theta)x + f_s sin(\theta)y + \psi)}$$



Log-polar mapping: computational model

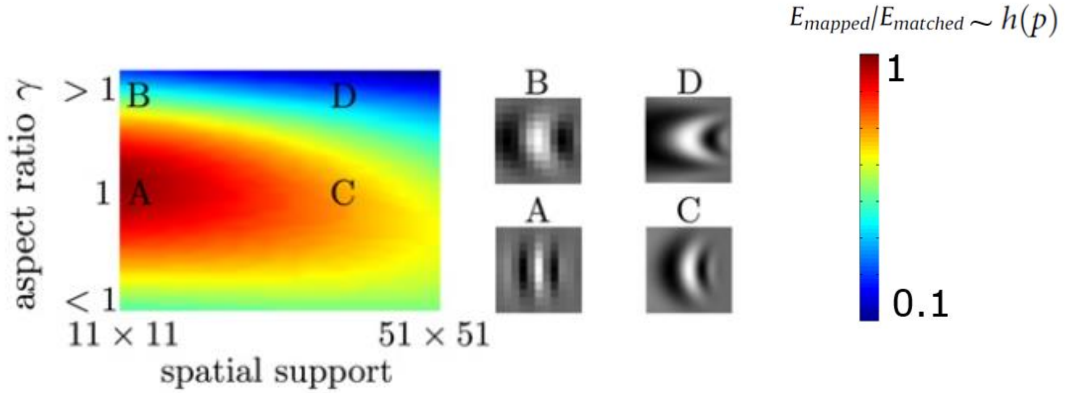
The shape of filters is warped as a function of both the parameters of the log-polar mapping and of the filter.



$$E_{mapped} = \langle g(\xi, \eta), g(x(\xi, \eta), y(\xi, \eta)) \rangle$$

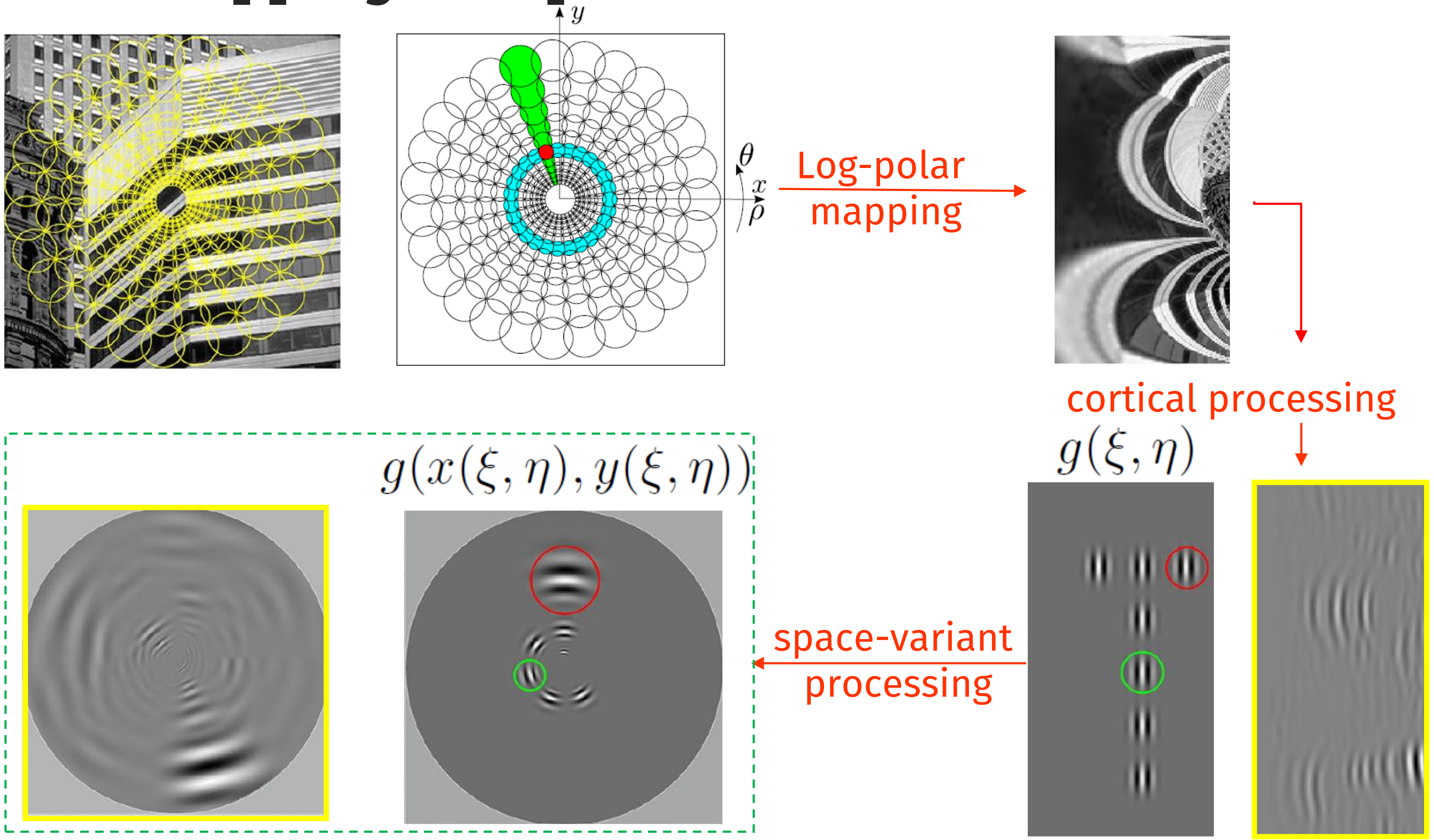
$$E_{matched} = \langle g(\xi, \eta), g(\xi, \eta) \rangle$$

$$h(p) \approx h(p_0) + (p - p_0)^T \nabla h(p_0) + 0.5 (p - p_0)^T H(p_0)(p - p_0)$$



F. Solari, M. Chessa, S.P. Sabatini. *Design strategies for direct multi-scale and multi-orientation feature extraction in the log-polar domain*. Pattern Recognition Letters 33(1), pp. 41-51, 2012

Log-polar mapping: computational model

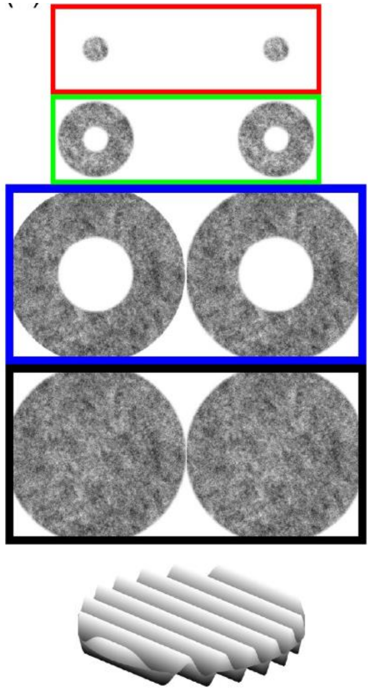


In particular, we have deduced constraints on the aspect ratio of the log-polar pixel and on the spatial support of the filter that allow working at cortical level

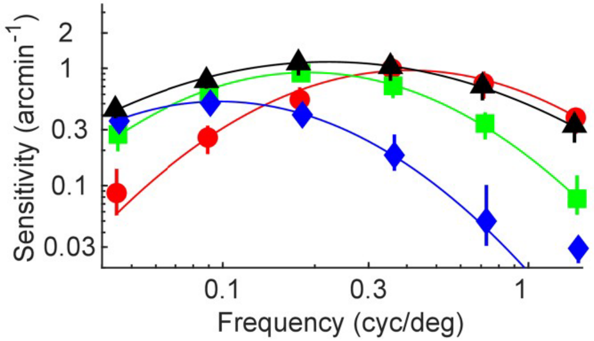
Computational neural model accounts for human behavioral data

Disparity estimation in human observers and the proposed model

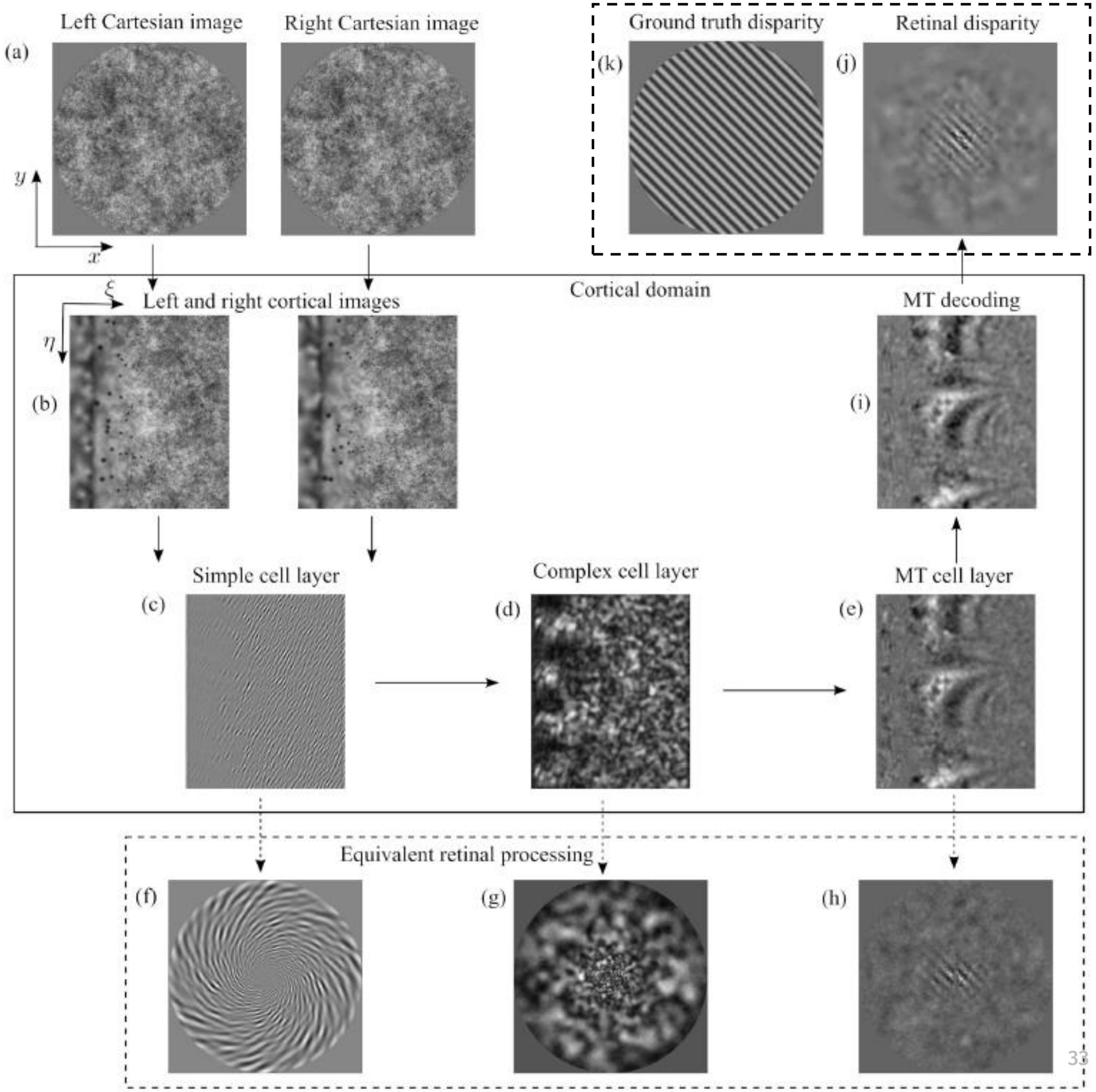
Stimuli



Human DSF



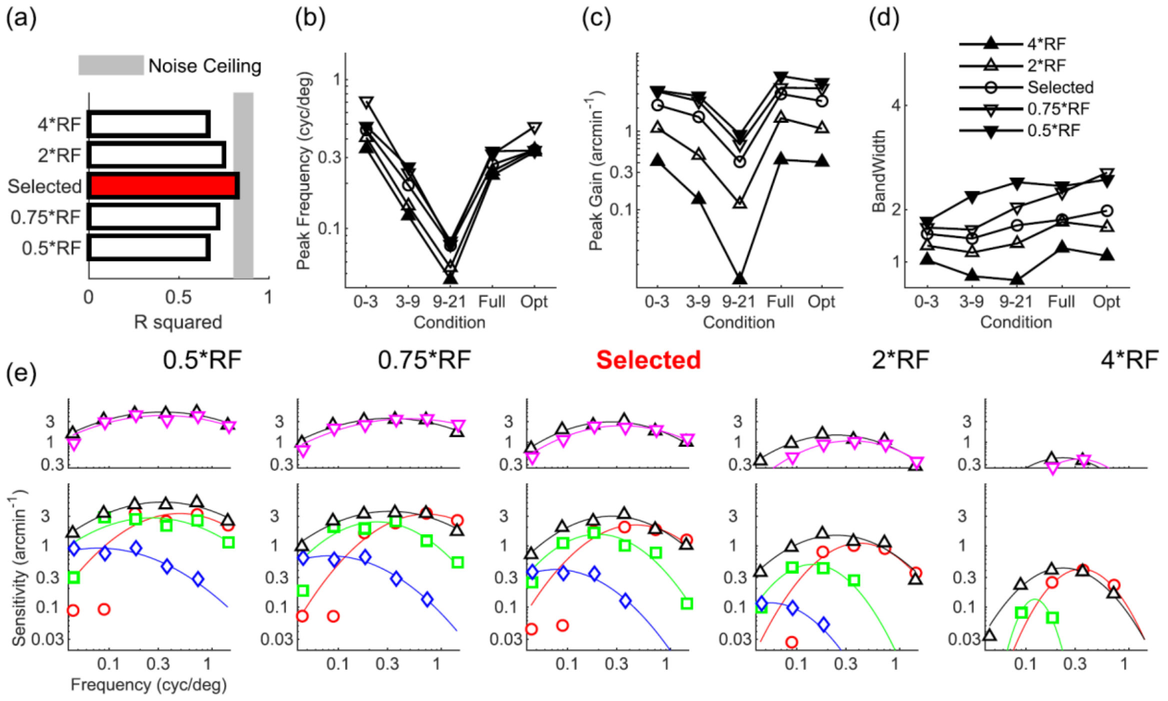
Model's responses

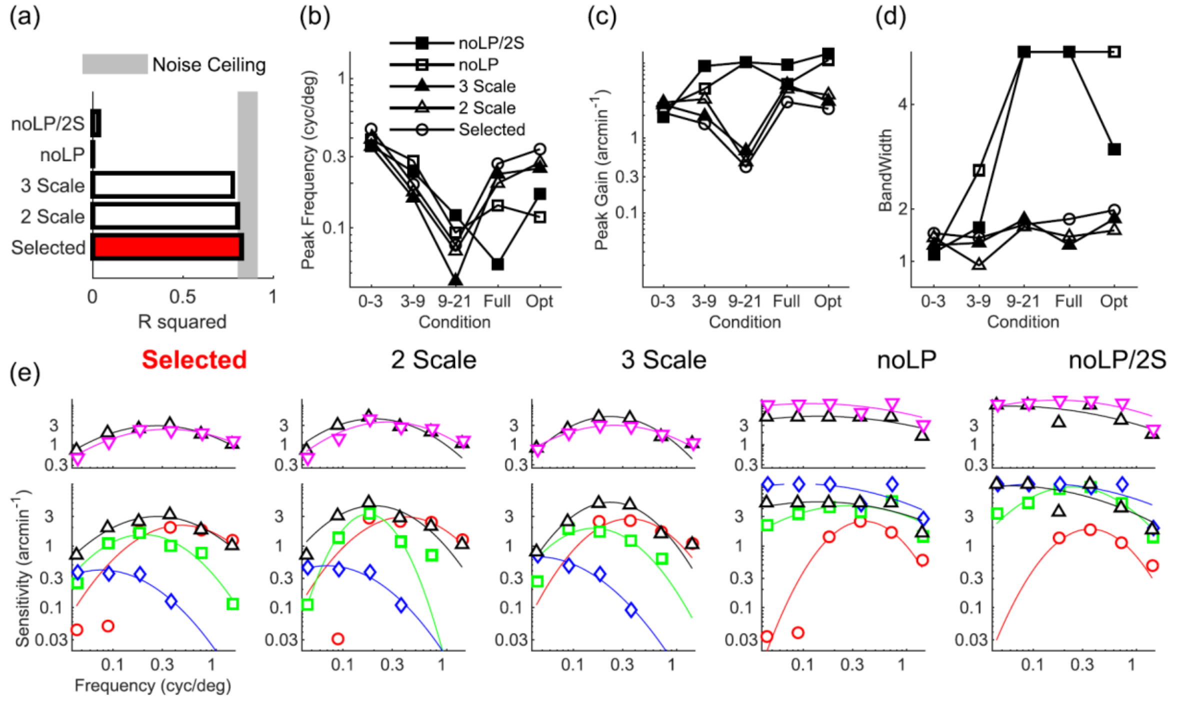


G. Maiello, M. Chessa, P.J. Bex, F. Solari. *Near-optimal combination of disparity across a log-polar scaled visual field*. PLoS Computational Biology 16(4): e1007699, 2020

Computational neural model accounts for human behavioral data

Analysis of the proposed model responses with respect the one of human observers





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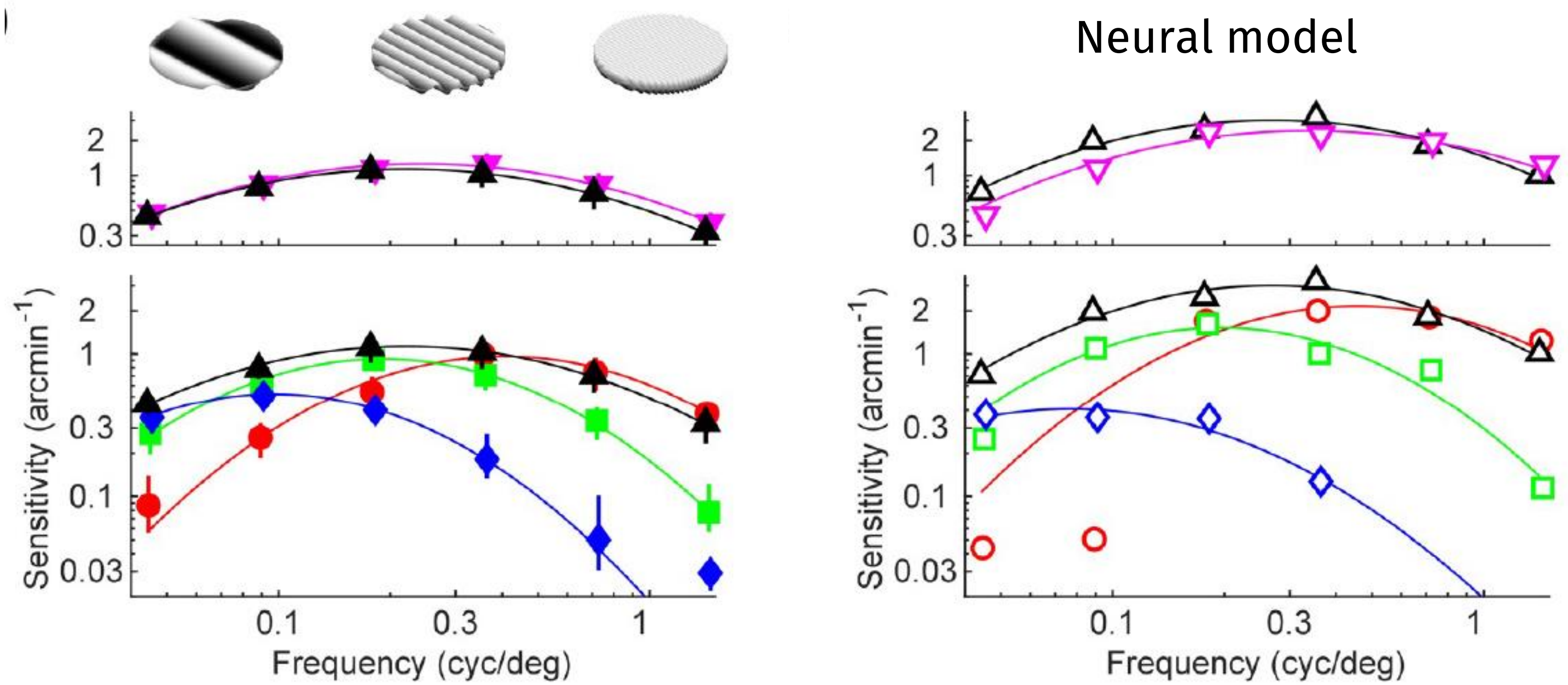
Computational neural model accounts for human behavioral data

Disparity estimation in human observers and the proposed model



The model shows a high level of agreement with the human data ($r = 0.91$; $p = 8.3 \times 10^{-10}$; $r2 = 0.83$).

G. Maiello, M. Chessa, P.J. Bex, F. Solari. *Near-optimal combination of disparity across a log-polar scaled visual field*. PLoS Computational Biology 16(4): e1007699, 2020

Università di Genova | DIBRIS DIPARTIMENTO DI INFORMATICA, BIOINGEGNERIA, ROBOTICA E INGEGNERIA DEI SISTEMI

Computational neural models to improve XR applications

- Mitigating cybersickness through foveated rendering and depth of field
- Mitigating misperception of depth through addressing vergence-accommodation conflict

Mitigating cybersickness

Researchers have proposed many techniques to reduce the level of induced cybersickness.

Such approaches could limit the sense of presence in the virtual world

Fernandes, A.S.; Feiner, S.K. *Combating VR sickness through subtle dynamic field-of-view modification*. In Proceedings of the 2016 IEEE Symposium on 3D User Interfaces (3DUI), Greenville, SC, USA, pp. 201–210, 19–20 March 2016.

Mitigating cybersickness

Researchers have proposed many techniques to reduce the level of induced cybersickness.

Budhiraja, P.; Miller, M.; Modi, A.; Forsyth, D. *Rotation Blurring: Use of Artificial Blurring to Reduce Cybersickness in Virtual Reality First Person Shooters.* arXiv 2017.

G.-Y. Nie, H. B.-L. Duh, Y. Liu, and Y. Wang. *Analysis on mitigation of visually induced motion sickness by applying dynamical blurring on a user's retina*. IEEE transactions on visualization and computer graphics, 2019.

Mitigating cybersickness

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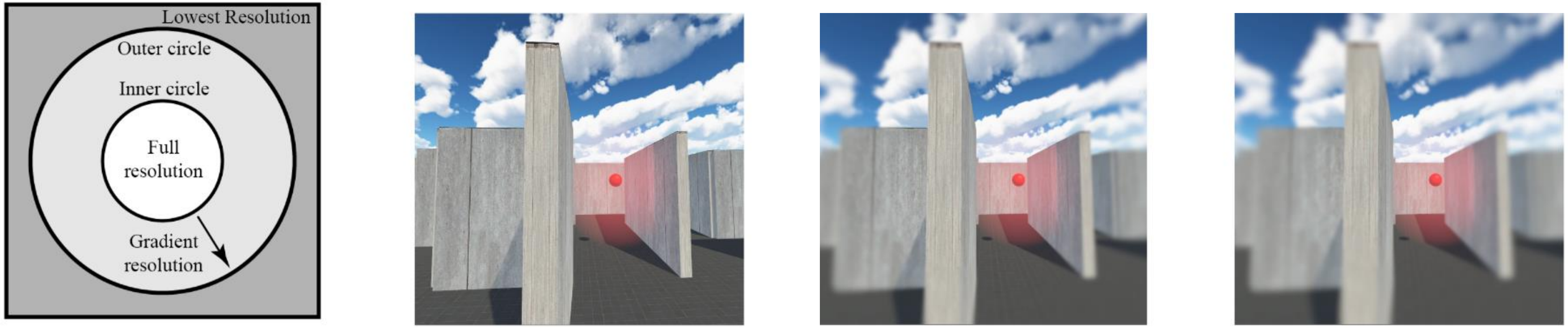


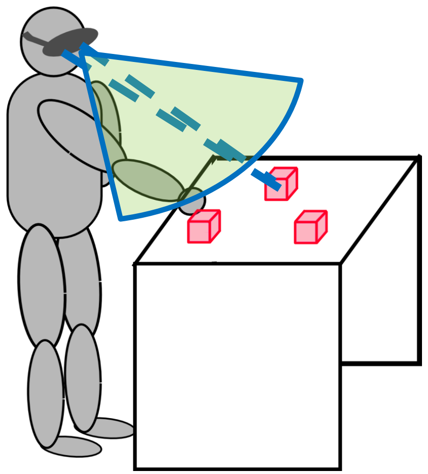
(a) The resolution restrictor. (b) Normal-Viewing. (c) Large-Window. (d) Small-Window.

Lin, Y.X.; Venkatakrishnan, R.; Venkatakrishnan, R.; Ebrahimi, E.; Lin, W.C.; Babu, S.V. *How the Presence and Size of Static Peripheral Blur Affects Cybersickness in Virtual Reality*. ACM Trans. Appl. Percept., 17, 16:1–16:18, 2020.

Computational neural model: XR systems

The modeled perception can suggest how to add natural rendering effects to virtual and augmented reality systems to improve user experience.

- All objects placed at the accommodative distance tend to form a sharp image on the retinae while all other objects appear out-of-focus. This phenomena is referred to as *depth-of-field* (DoF) effect.
- The human visual resolution decreases towards periphery (log-polar mapping). This phenomena is referred to as *foveated imaging*.



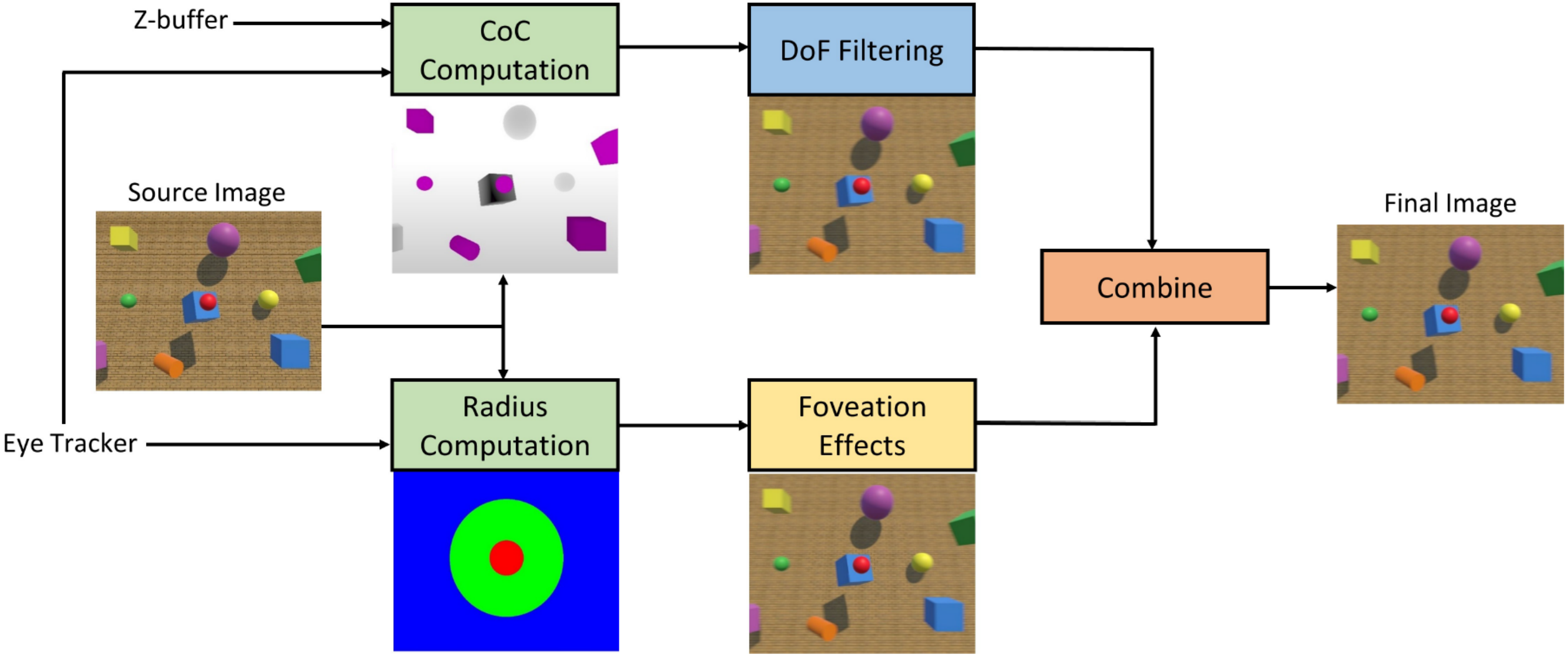
Computational neural model: XR systems

The idea is to have a system that

- combines specific foveation and depth-of-field blurs
- in a real-time gaze contingent application for off-the-shelf HMDs.

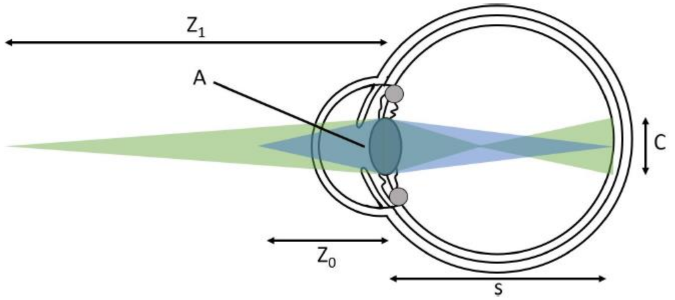
All processing is done pixel-wise in the linear color space at the shader level using image space methods in order to have real-time performance.

Computational neural model: XR systems



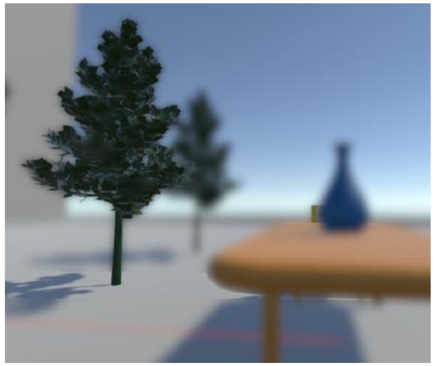
Computational neural model: XR systems

Depth-of-field

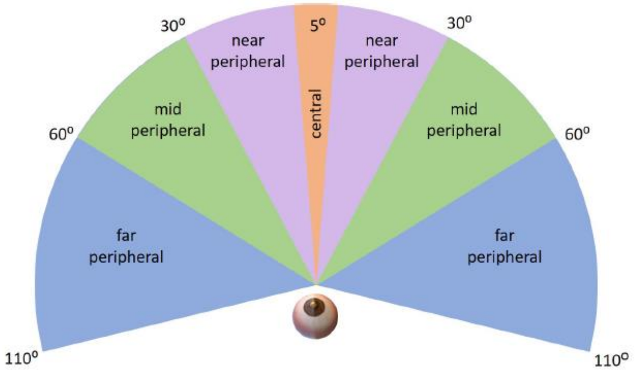


$$C = As\left|\frac{1}{Z_0} - \frac{1}{Z_1}\right|$$

$$\sigma_d = K\left|\frac{1}{Z_f} - \frac{1}{Z_p}\right|$$



Multi-region Foveation
(*log-polar mapping*)



Blur

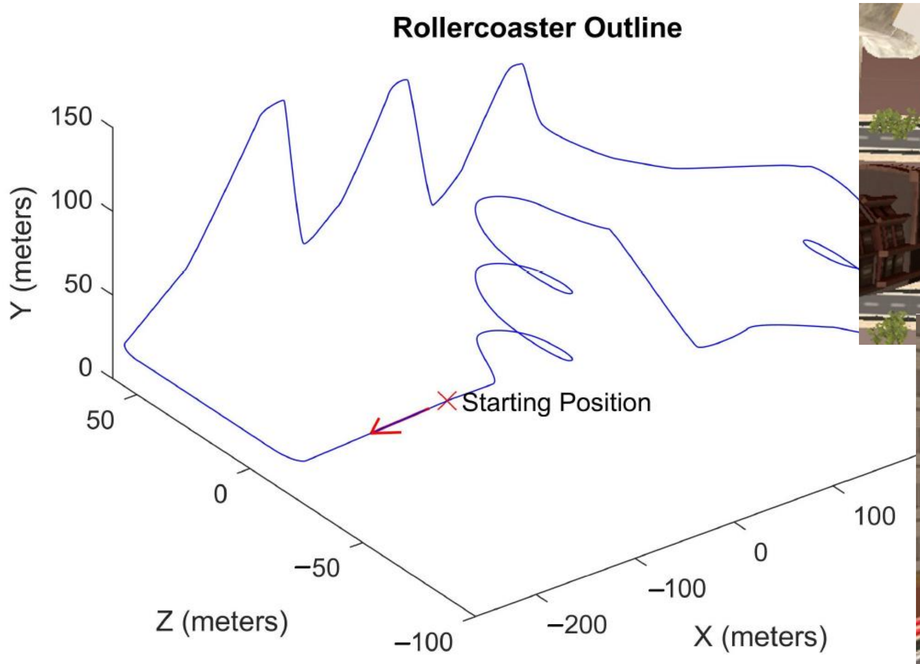
Artifact Removal

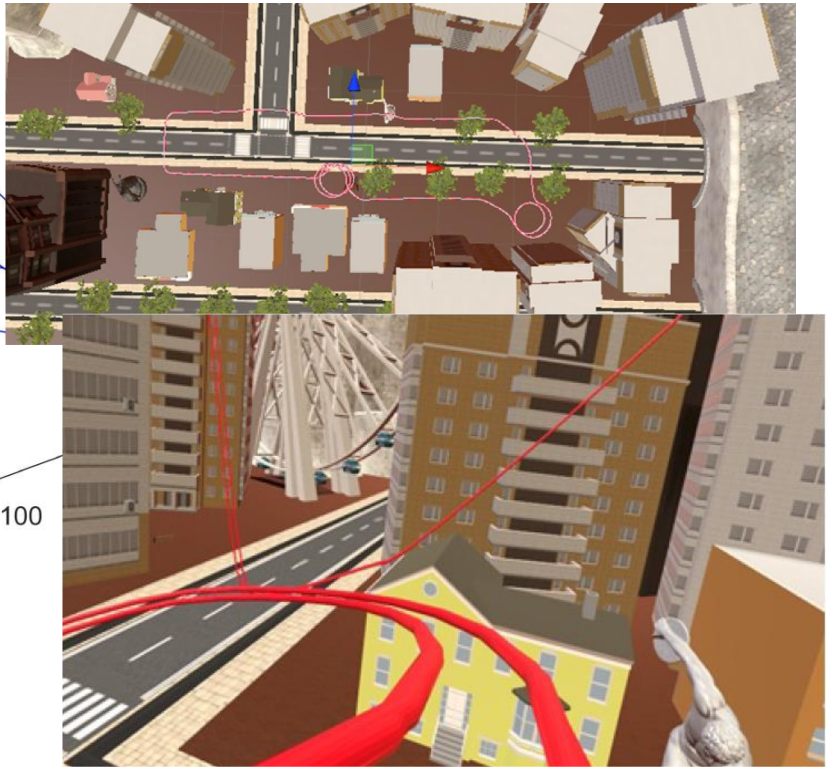
$$B_i(x,y) = \begin{cases} 0 & R(x,y) \le R_i \\ \frac{R(x,y)-R_i}{R_{i-1}-R_i} & R_i < R(x,y) < R_{i-1} \\ 1 & R(x,y) \ge R_{i-1} \end{cases}$$

$$O(x,y) = B_i(x,y)I_i(x,y) + (1 - B_i(x,y))I_{i-1}(x,y)$$

Computational neural model: XR systems

Experimental results : mitigating cybersickness





Participants
18 volunteers (50% females)
aged from 18 to 46 years
(mean 29.3, std 7.6)

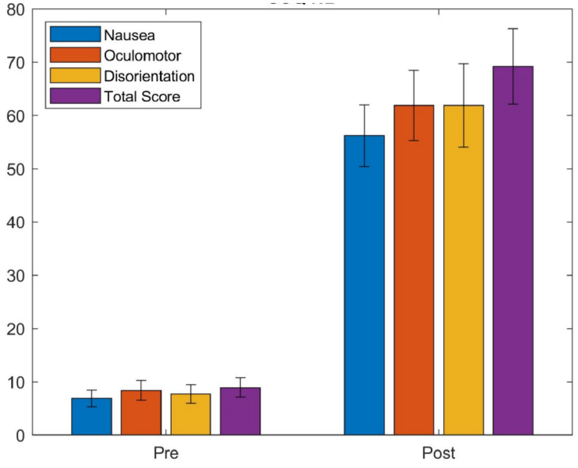
R. Hussein, M. Chessa, F. Solari. *"Mitigating Cybersickness in Virtual Reality Systems through Foveated Depth-of-Field Blur."* Sensors 21, no. 12: 4006, 2021.

Computational neural model: XR systems

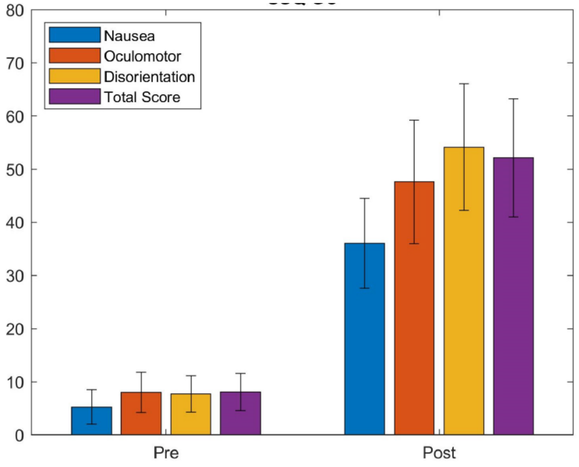
Experimental results : mitigating cybersickness

No blur (NB)

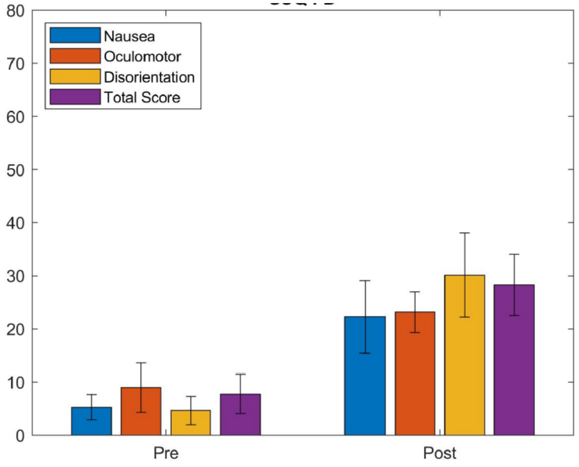
SSQ



Unity blur (GC)

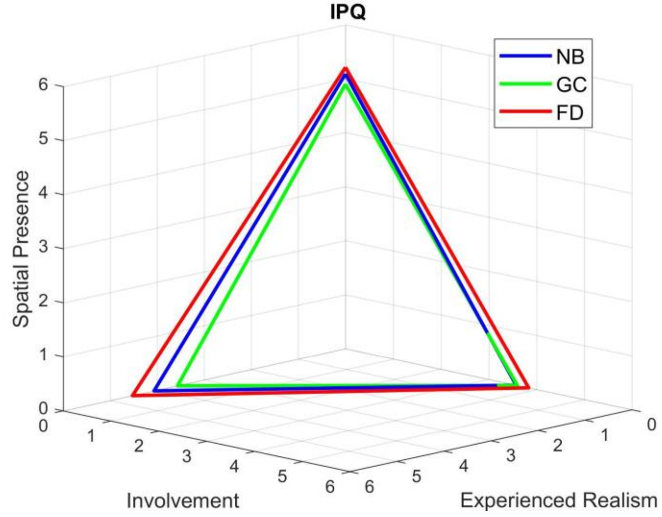


Our blur (FD)



The cross-validation among the pre states of the users who used different blurred systems showed no significant difference between them.

No significant differences in the perceived sense of presence between the users of each type of session.



Computational neural model: XR systems

Experimental results : mitigating cybersickness

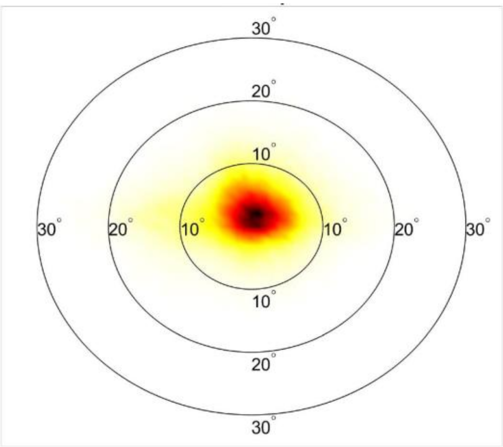
Technique	HMD	VE/Task	ΔS
Dynamic FOV modification [19]	Oculus Rift DK2	Reach waypoints	5.6%
Rotation blurring [22]	Oculus Rift DK2	FPS shooter game	17.9%
Peripheral visual effects [23]	HTC Vive	Find objects	49.1%
FOV reduction (vignetting) [24]	HTC Vive	Follow butterfly	30.1%
Dynamic blurring (saliency) [25]	HTC Vive	Race track	35.2%
Static peripheral blur [43]	HTC Vive Pro	Maze	54.8%
Unity depth blur	HTC Vive Pro Eye	Rollercoaster	26.9%
Foveated DoF (ours)	HTC Vive Pro Eye	Rollercoaster	**66.0**%

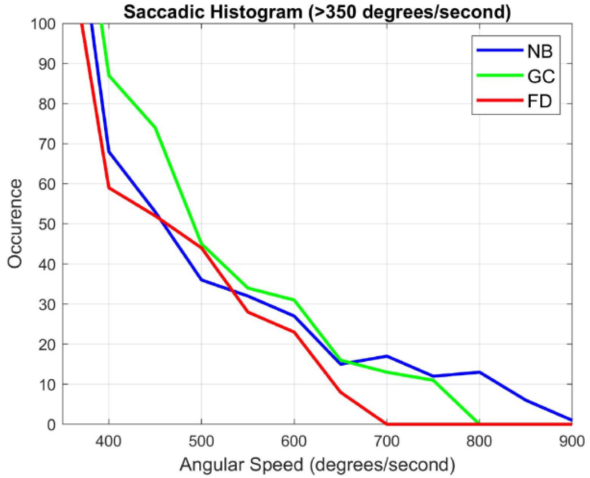
We use the difference in the sickness scores between the no effect and the best performing parameters for each respective technique

Computational neural model: XR systems

Experimental results : mitigating cybersickness

Gaze



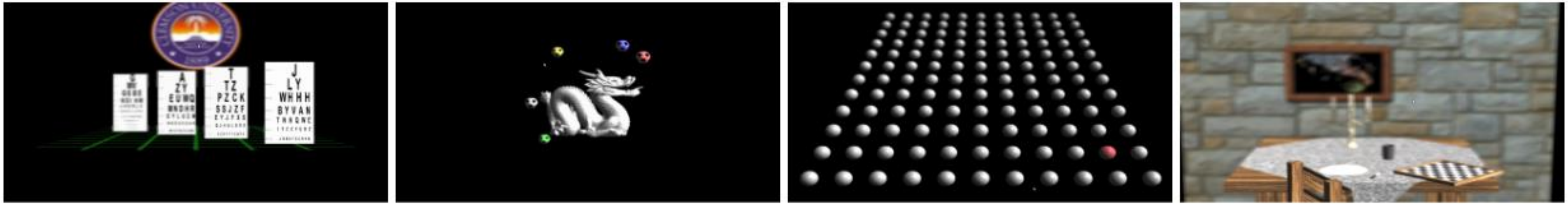


Positional and orientation data of the user revealed that, when they had to focus on an object further away from the center, they preferred to move their heads instead of just the gaze.

It can be noticed that, during our blur algorithm integrated sessions, saccades were shorter/slower as compared to the other sessions.

Mitigating misperception of depth

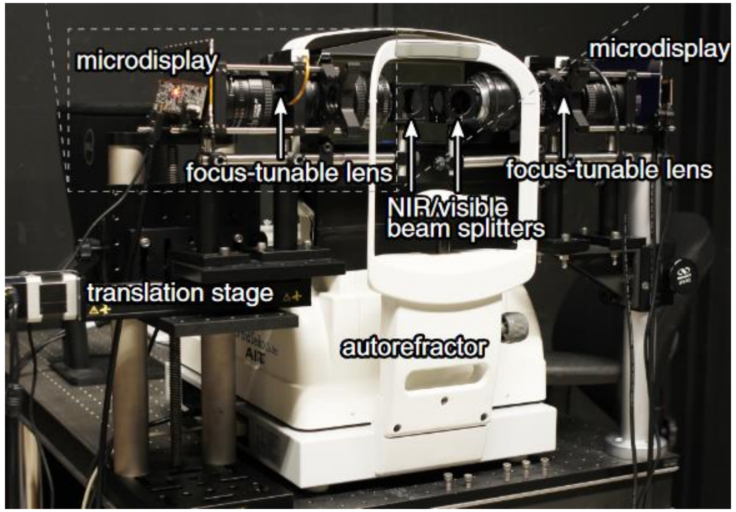
Researchers have proposed many techniques to reduce the misperception of depth.

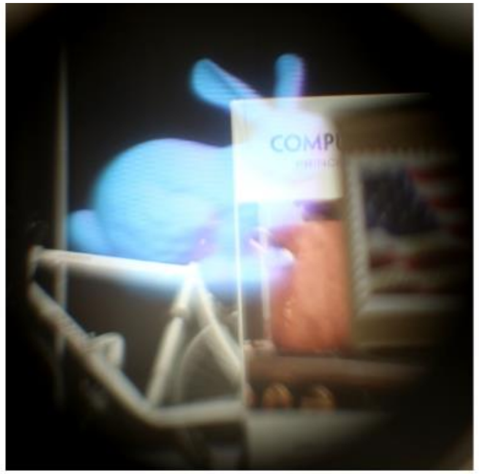


Duchowski, A. T., House, D. H., Gestring, J., Wang, R. I., Krejtz, K., Krejtz, I., ... & Bazyluk, B. *Reducing visual discomfort of 3D stereoscopic displays with gaze-contingent depth-of-field*. In Proceedings of the ACM symposium on Applied Perception (pp. 39-46), 2014.

Mitigating misperception of depth

Researchers have proposed many techniques to reduce the misperception of depth.





Such approaches rely on *specialized hardware* components or sensors that are not typically integrated into modern HMDs

N. Padmanaban, R. Konrad, T. Stramer, E. A. Cooper, and G. Wetzstein. *Optimizing virtual reality for all users through gaze contingent and adaptive focus displays*. Proceedings of the National Academy of Sciences, vol. 114, no. 9, pp. 2183–2188, 2017.
P. Chakravarthula, D. Dunn, K. Aks¸it, and H. Fuchs. *Focusar: Auto-focus augmented reality eyeglasses for both real world and virtual imagery*. IEEE Transactions on Visualization and Computer Graphics, vol. 24, no. 11, pp. 2906–2916, 2018.

Mitigating misperception of depth

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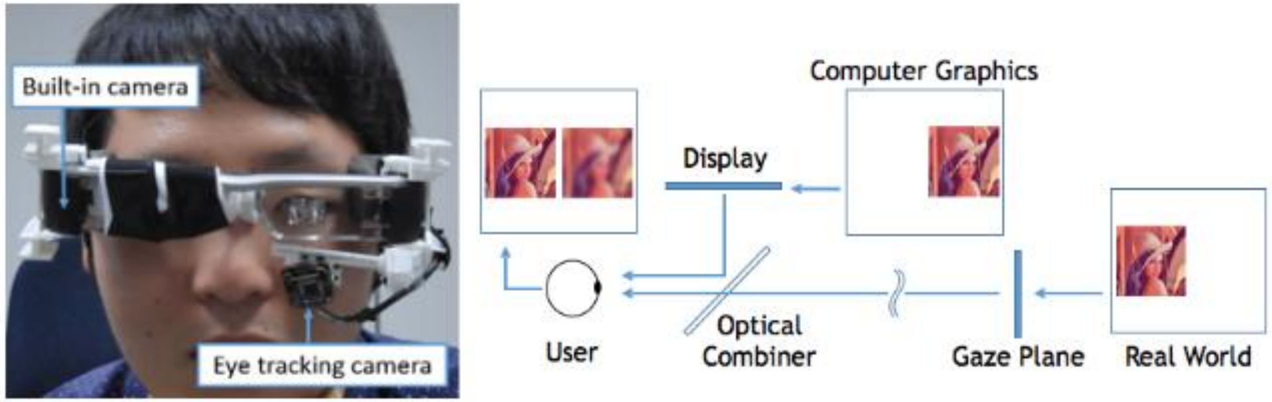
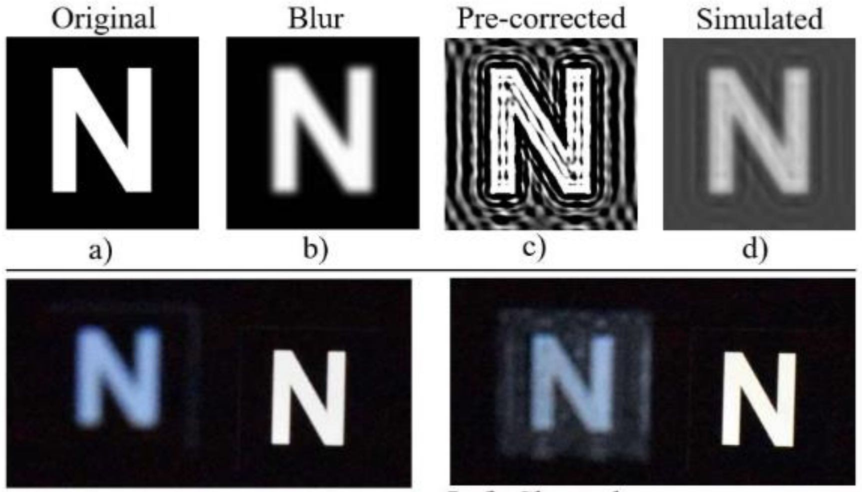




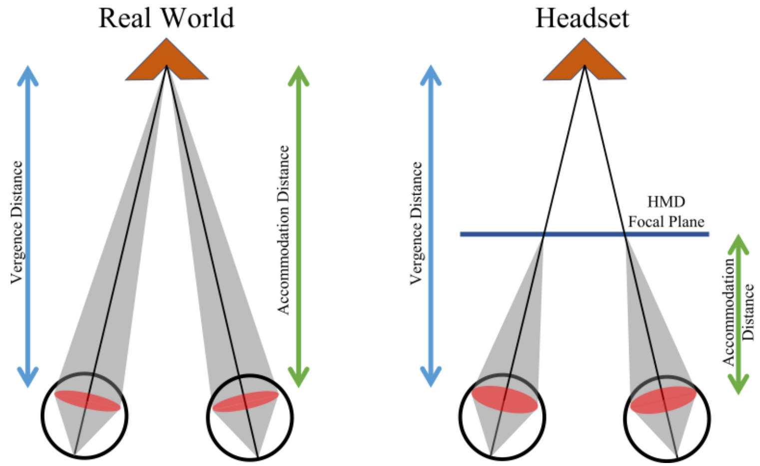
Deconvolution-based techniques have primarily focused on visual clarity

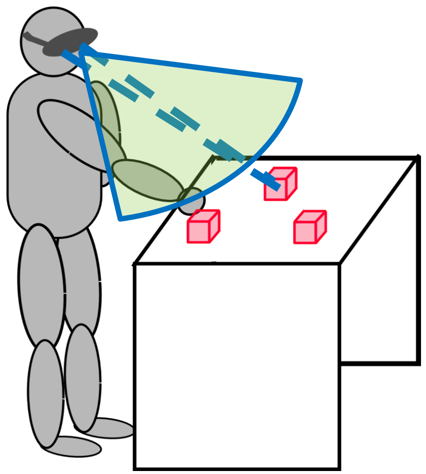
K. Oshima, K. R. Moser, D. C. Rompapas, J. E. Swan, S. Ikeda, G. Yamamoto, T. Taketomi, C. Sandor, and H. Kato. *Sharpview: Improved clarity of defocused content on optical see-through head-mounted displays*. IEEE Symposium on 3D User Interfaces (3DUI), pp. 173–181, 2016.
M. S. Arefin. *[dc] sharpview ar: Enhanced visual acuity for out of focus virtual content*. in IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), pp. 731–732, 2021.

Computational neural model: XR systems

The modeled perception can suggest how to add natural rendering effects to virtual and augmented reality systems to improve user experience. Specifically, by addressing Vergence-Accommodation Conflict (VAC)

- By distorting the visual stimuli, we compensate for the accommodation blurring that occurs when objects are focused outside the focal plane, thus allowing the observer to obtain a more natural perception of the virtual contents.





Computational neural model: XR systems

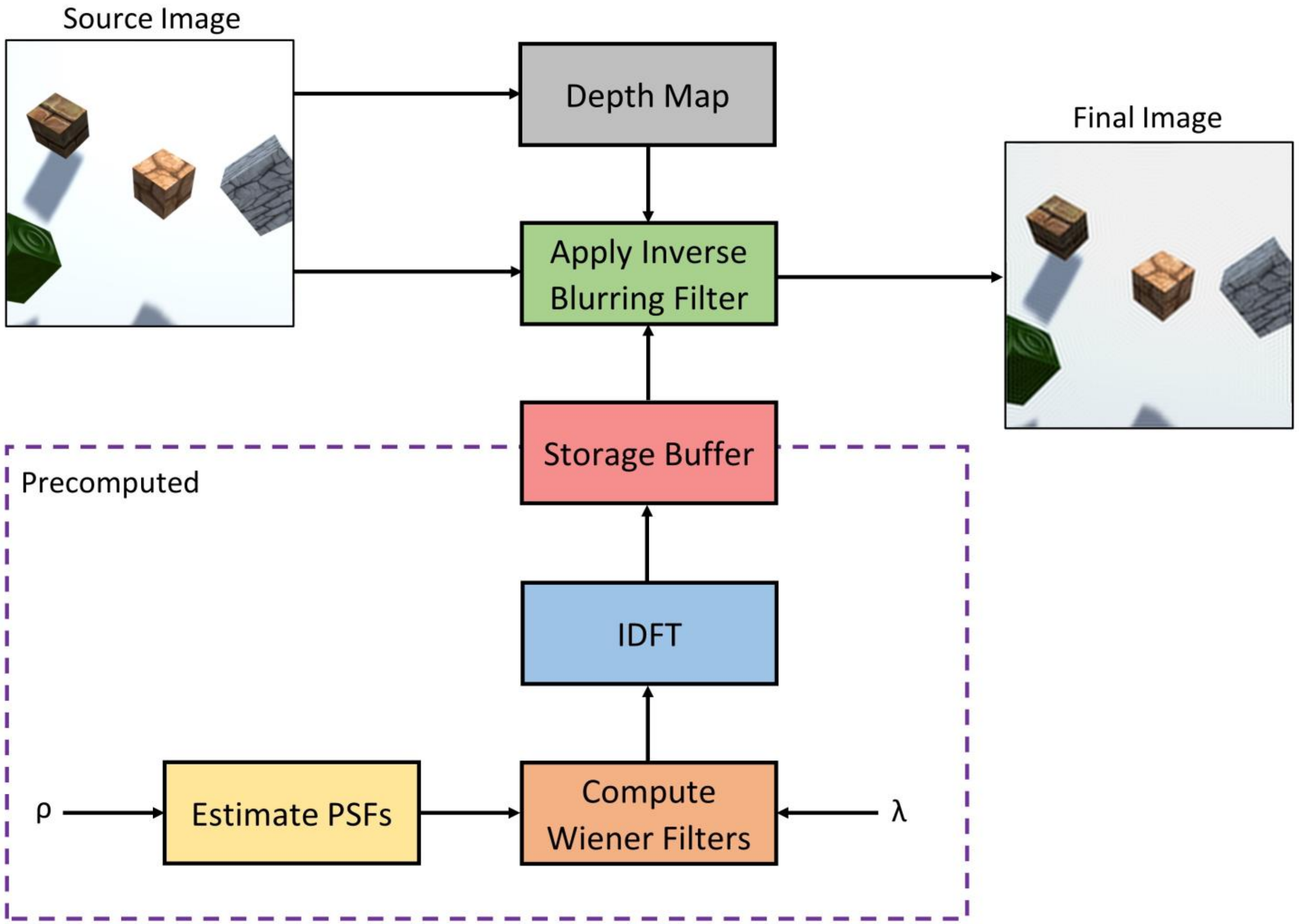
Key contributions:

- a software-based solution to compensate for the discrepancies introduced by VAC in VR environments for off-the-shelf HMDs
- a novel space variant technique that applies an inverse blurring approach to stereoscopic images, without the need for an eye-tracker
- it compensates for accommodation blurring, allowing observers to obtain a more natural perception of virtual contents

Computational neural model: XR systems

Online

Offline



Hussain, R., Chessa, M., & Solari, F.. *Improving Depth Perception in Immersive Media Devices by Addressing Vergence-Accommodation Conflict*. IEEE Transactions on Visualization and Computer Graphics, 2023   DOI: 10.1109/TVCG.2023.3331902

Computational neural model: XR systems

Wiener Deconvolution-based Deblurring

$b = f * i + n$ — the convolution operation of image *i* with a blurring filter *f*

$B = FI + N$ — in the Fourier or frequency domain

$$I' = \frac{B - N}{F}$$

this approach is not optimal as it amplifies the noise in the system

$I' = H_W B$ — H_W is the Wiener filter

$$H_W = \frac{H}{| H |^2 + \frac{1}{\lambda}}$$

λ is the signal-to-noise ratio (SNR) and *H* is the estimate of the PSF of the blur

Computational neural model: XR systems

$$H_W = \frac{H}{| H |^2 + \frac{1}{\lambda}}$$

For a perfect solution, it is required to have the actual PSF of the user's eye.

Estimating the PSF of human eyes is a challenging task due to the intricate nature of the visual system

For out of focus distortions such as those that are naturally present in the human visual system, a circular PSF is considered a good approximation.

Such a PSF can be defined by only one parameter, ρ which is the radius of the circle.

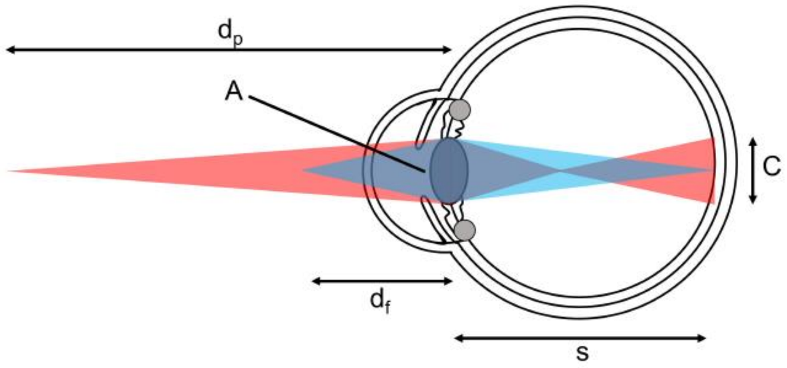
Computational neural model: XR systems

Parameter Tuning

The parameter ρ is dependent on the amount of blur present in the image while λ is a measure based on the noise present in the system.

The parameter ρ can be determined based on the distance between the user and the objects in view (depth of field).

$$C = As \left| \frac{1}{d_f} - \frac{1}{d_p} \right|$$



Computational neural model: XR systems

Parameter Tuning

To obtain the optimal values of λ corresponding to each ρ value, a tuning process was carried out.

A variety of virtual scenes containing virtual objects were created. They were blurred using a spatial blurring technique.

The inverse blurring filter H_W was applied to the resulting blurred images.

This ensured that the original image and the values of parameter ρ are already known and the value of λ corresponding to each value of ρ can be determined.

To assess the quality of deblurring, we used several image quality metrics.

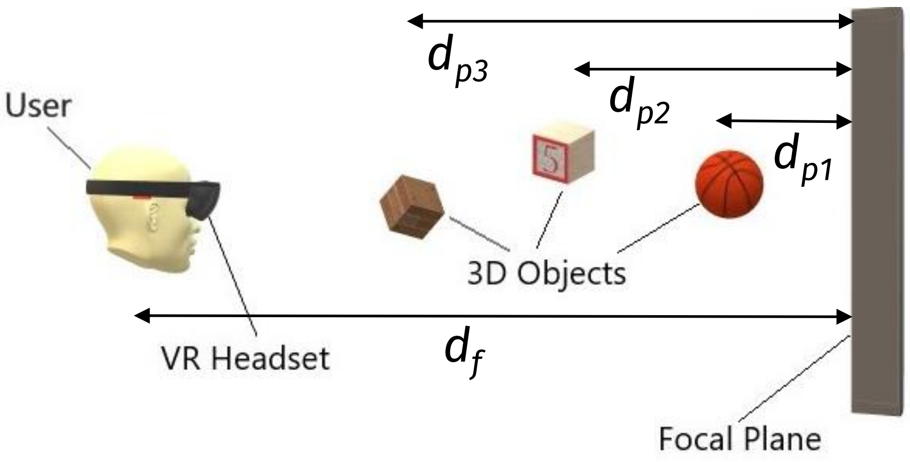
Computational neural model: XR systems

The Space Variant Inverse Blurring Technique

To cater to a larger audience, the technique presented here does not use an eye-tracking system but rather makes use of the virtual scene depth map to calculate the parameter ρ.

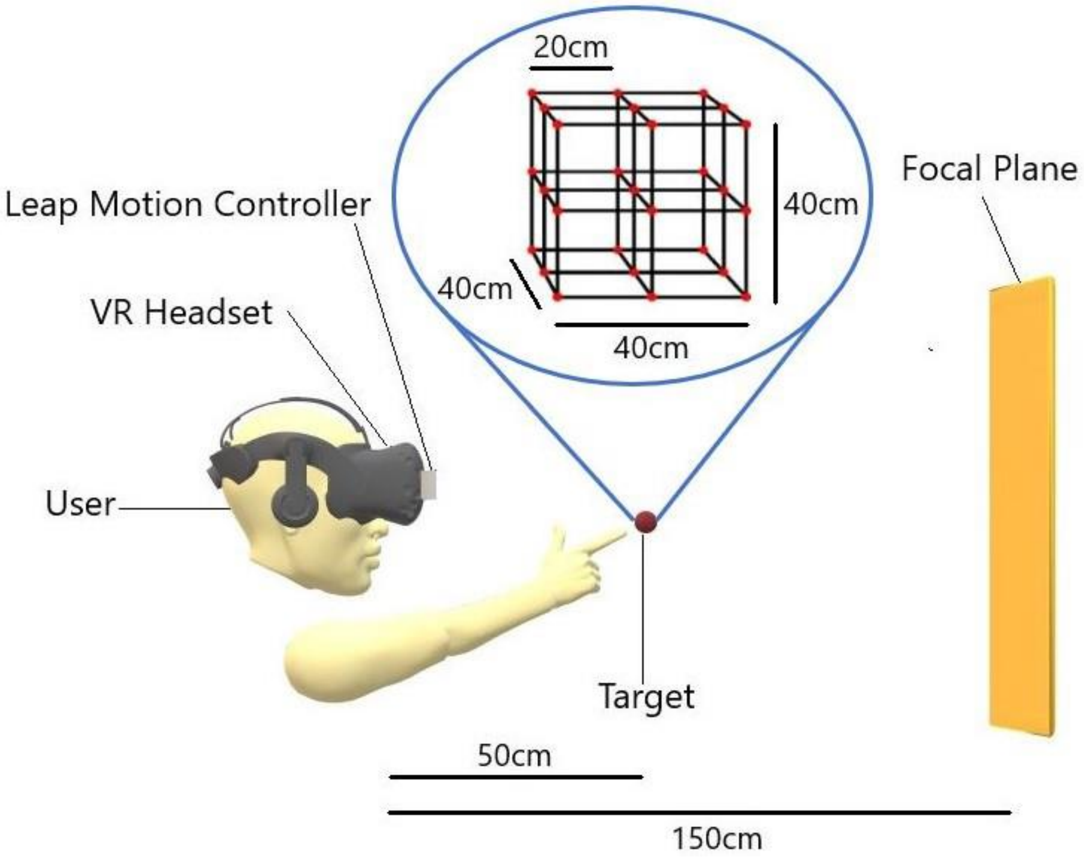
Instead of adjusting the PSF based on where the user is looking, the inverse blurring filter HW is applied based on object distances to the focal plane.

The inverse filters deform parts of the stereoscopic images to compensate for the accommodation blurring that develops when objects are focused outside of the focal plane.



Computational neural model: XR systems

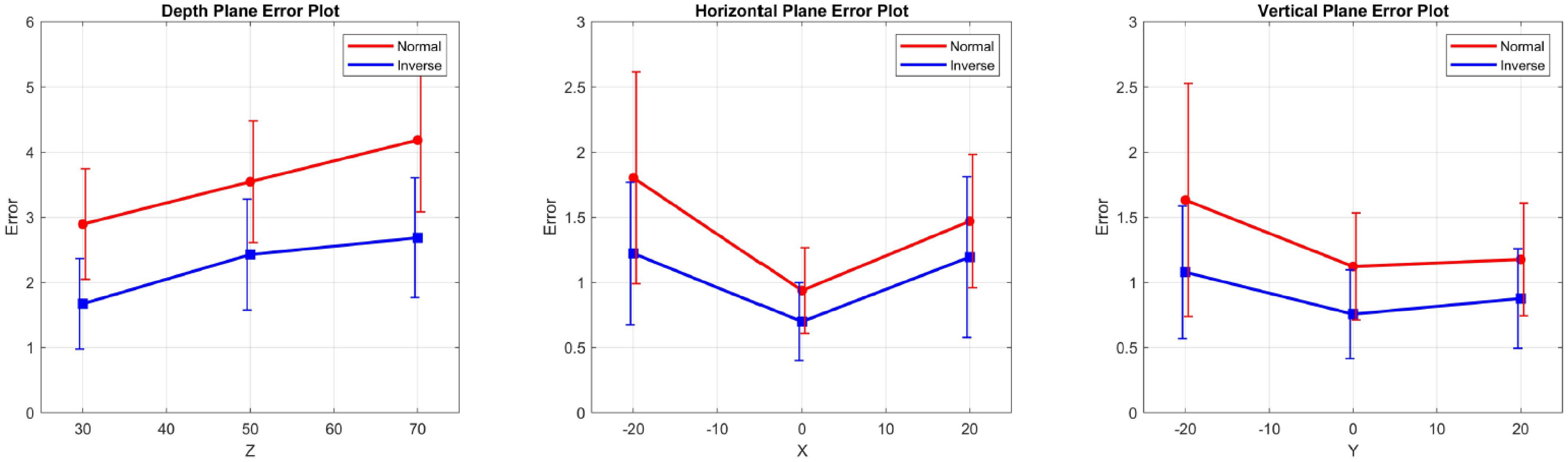
Reaching experiment



Participants
- 20 volunteers (14 males and 6 females) with a mean age of 27.50 and a standard deviation of 6.84
- blind-viewing configuration

Computational neural model: XR systems

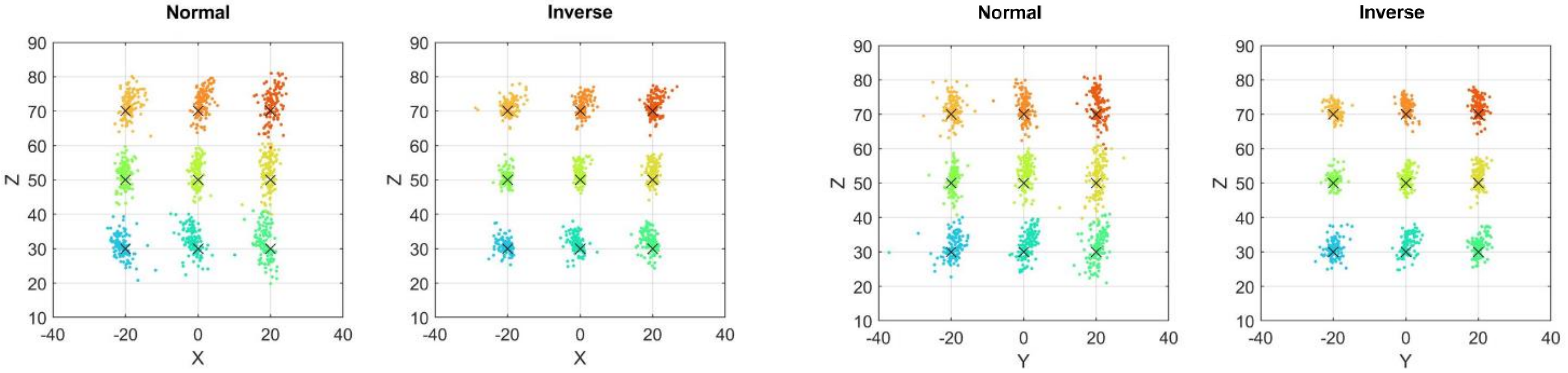
Reaching experiment



A statistically significant difference has been found in the depth plane and in the Euclidean space ($p < 0.05$, Matlab t-test).

Computational neural model: XR systems

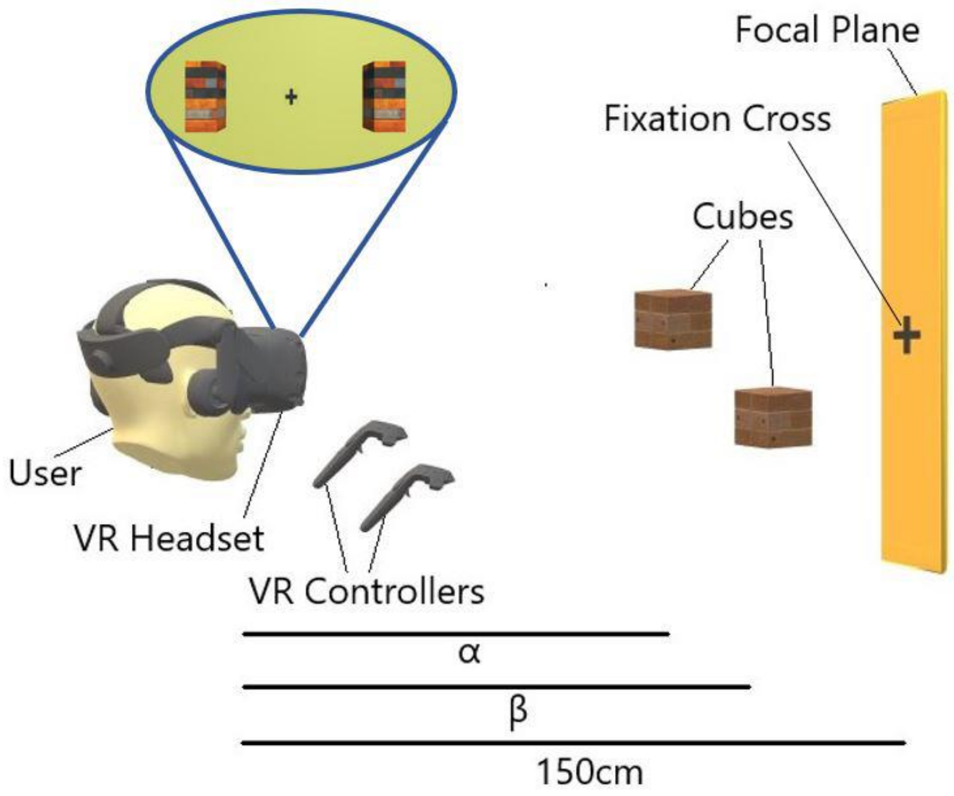
Reaching experiment



It can be observed that with the normal viewing condition, the finger locations are more spread out or less compact as compared to the inverse blurring condition.
We used the circle error probable measurement to show that with inverse blurring the precision is higher.

Computational neural model: XR systems

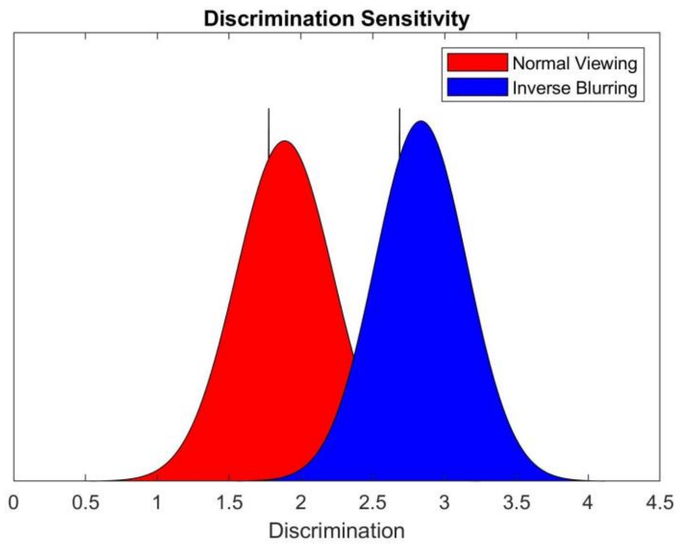
Spatial awareness experiment

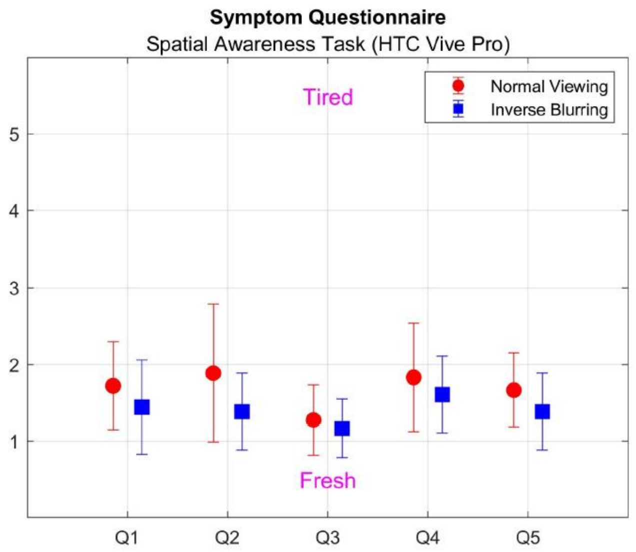


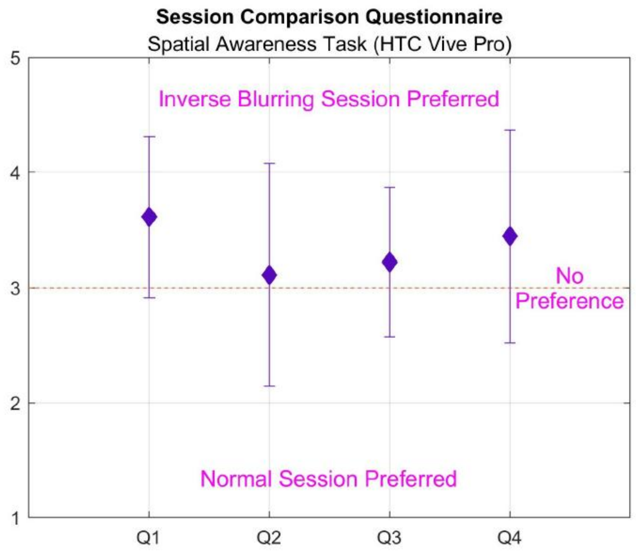
Participants
- 18 volunteers (12 males and 6 females) with a mean age of 25.89 and a standard deviation of 7.52
- 2AFC paradigm

Computational neural model: XR systems

Spatial awareness experiment







The increase is statistically significant ($p < 0.05$, Matlab t-test).

Computational neural model: XR systems

We have shown that

- We can mitigate cybersickness for off-the-shelf HMDs by using foveated rendering and depth of field effects
- We can improve the perception of depth for off-the-shelf HMDs by using inverse blurring that accounts for the vergence accommodation conflict

These two improvements can help the development of effective relaxation in VR for patients with mental disorders and of effective exergames by providing a realistic perception of the virtual object distances

We are planning their implementations in the healthcare context in an ongoing European project.

Case studies: XR applications in the context of clinical psychological field

- Teleconsultations
- An exergame to assess the digital autonomy for web-based applications (WebGL)
- A serious game for the detection of disorders in social interactions

Teleconsultation

Teleconsultation is the possibility to conduct a medical consultation remotely, through secure online communication technologies, such as video conferencing or video call applications.

This is a very simple form of application, nevertheless, it is not completely adopted in the clinical context.

In medical research centers it can be a common practice, but its widespread diffusion in clinical contexts, such as hospitals, is hampered:

- For the difficulties of specific target populations, for medical operators, for the digital system of the hospitals, and the European General Data Protection Regulation (GDPR).
- Moreover, the health systems of the European countries are different, thus it is very difficult to share data and applications.

Teleconsultation: app for video calls

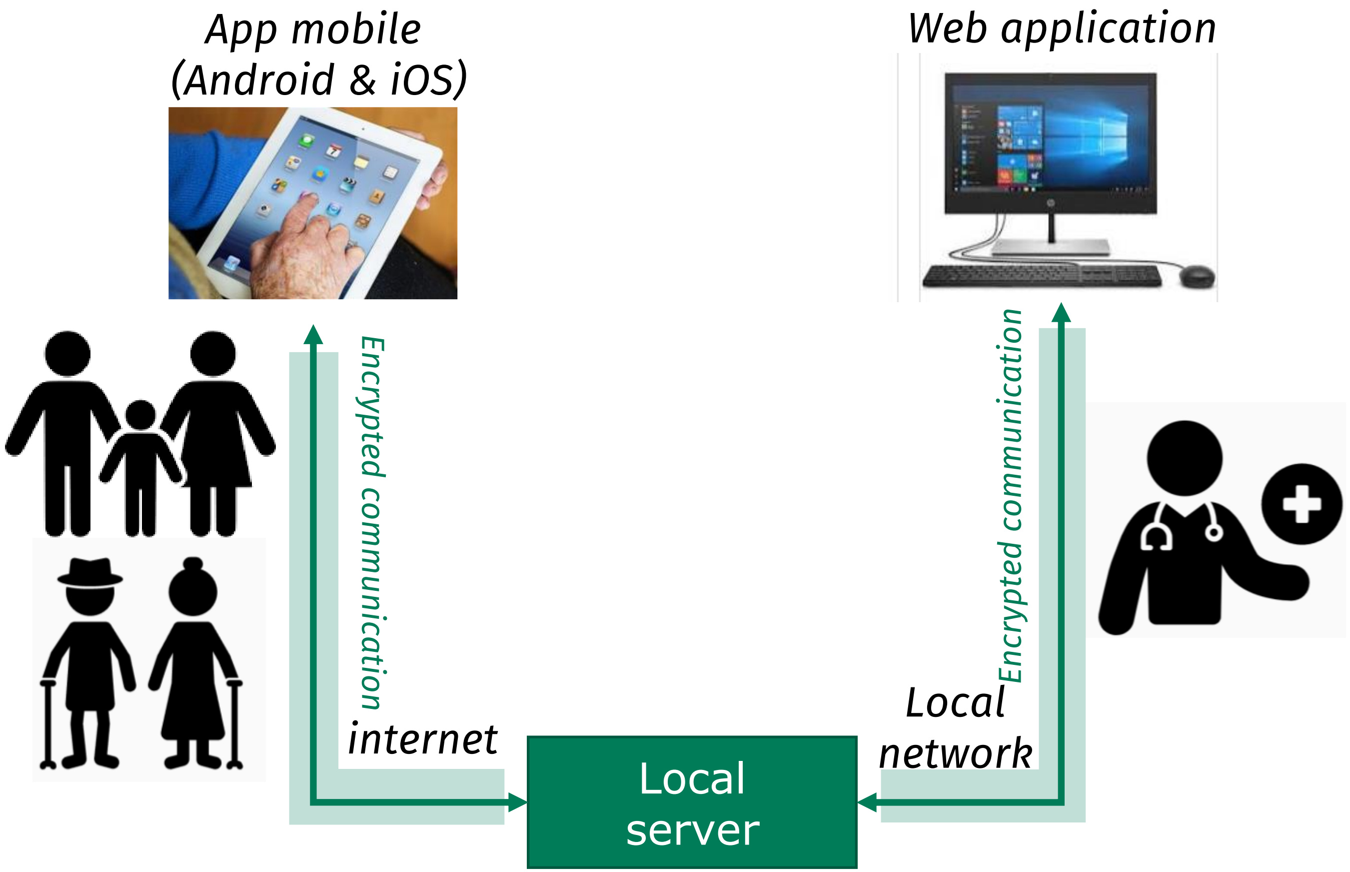
The new technologies allow us to reduce the difference between the services provided in urban and rural areas. For example, both health and social workers and vulnerable people can avoid travel for simple visits, consultations or documents.

In this way, we improve the quality of life of fragile people and reduce healthcare costs.

This is a win-win for the people and the country.

Nevertheless, it is not possible to use the commercial solutions.

Teleconsultation: app for video calls



Mobile application to provide a means of communication and interaction between health and social workers present in the area (with different levels of access to data) and the fragile people cared for by them.

Teleconsultation: app for video calls

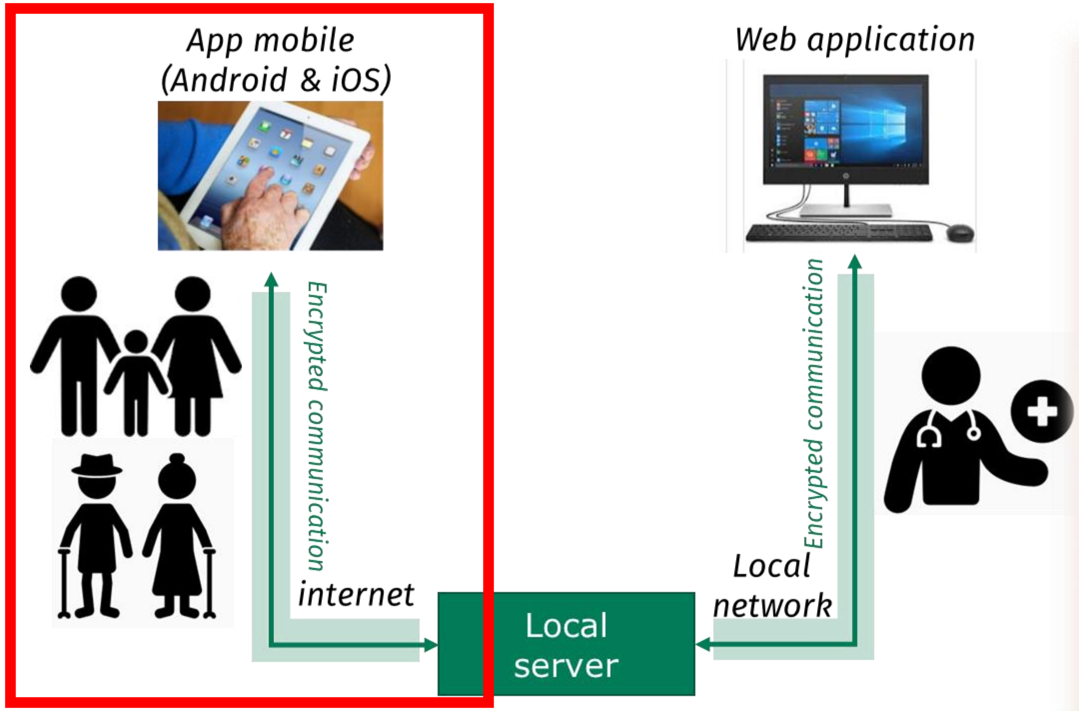
The functions provided consist of the exchange of text messages, video, audio, documents and video calling.

The App interface is specific for each target population: women, young people and the elderly.

Social and healthcare personnel have access to a web App that allows them to communicate with the fragile people they care for and to note down information that can be shared, even partially, with other healthcare workers who care for the same fragile person.

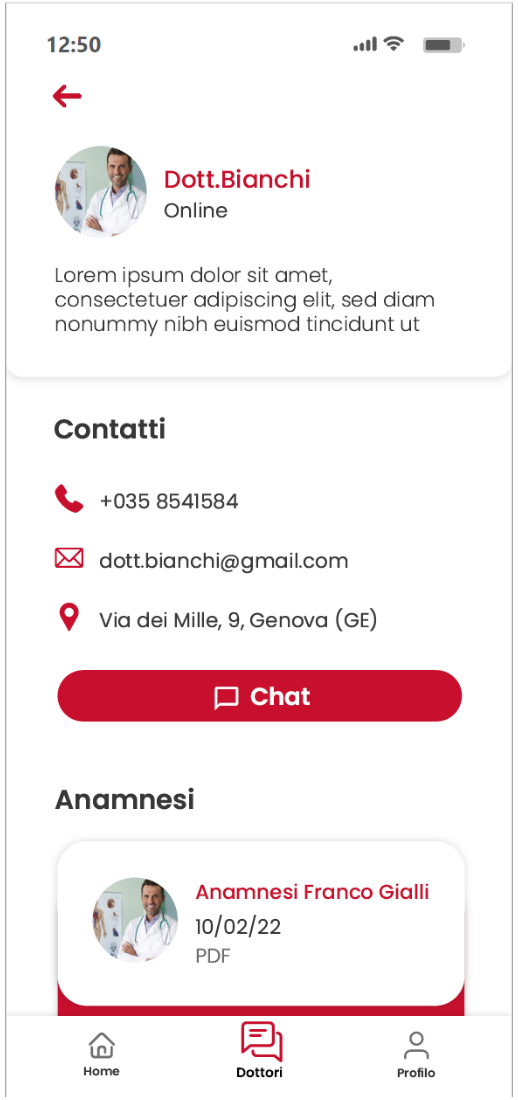
Sensitive data is encrypted and local to preserve the privacy of fragile people.

Teleconsultation: app for video calls

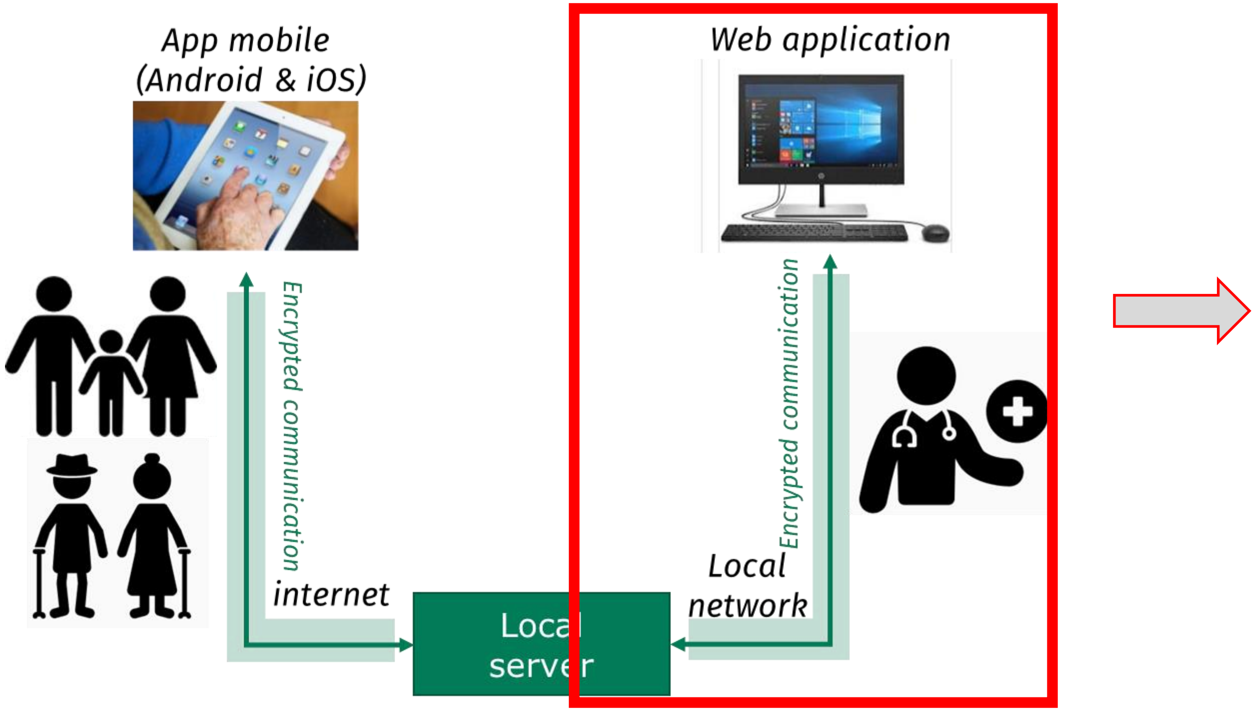


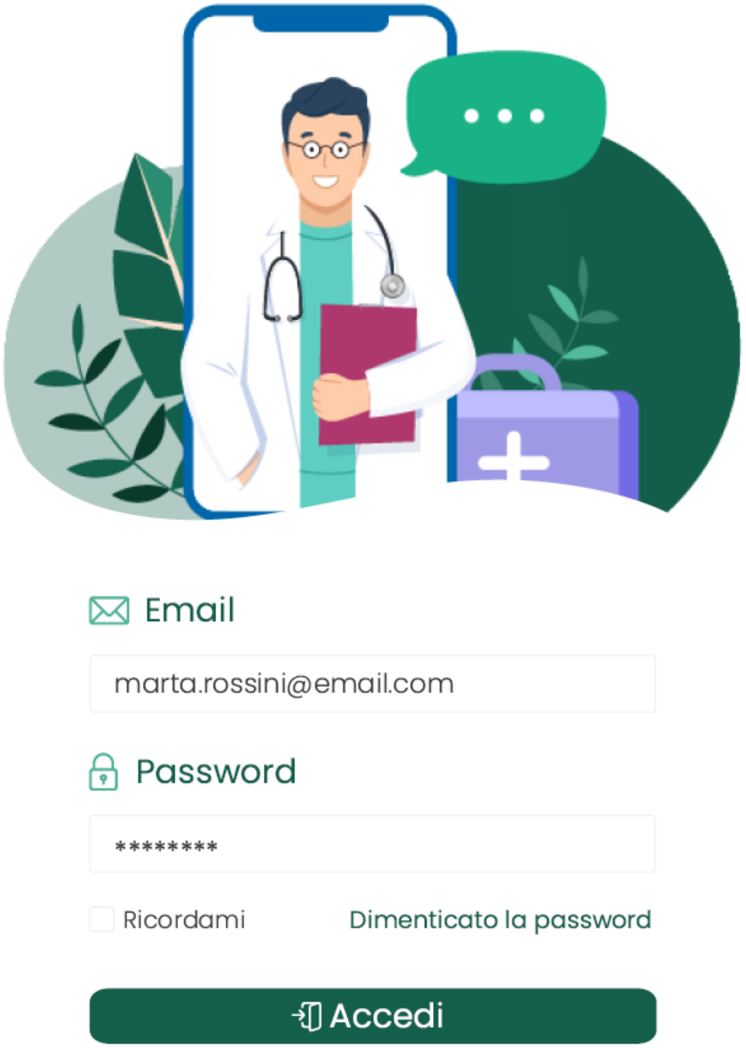
Teleconsultation: app for video calls

Patient's app



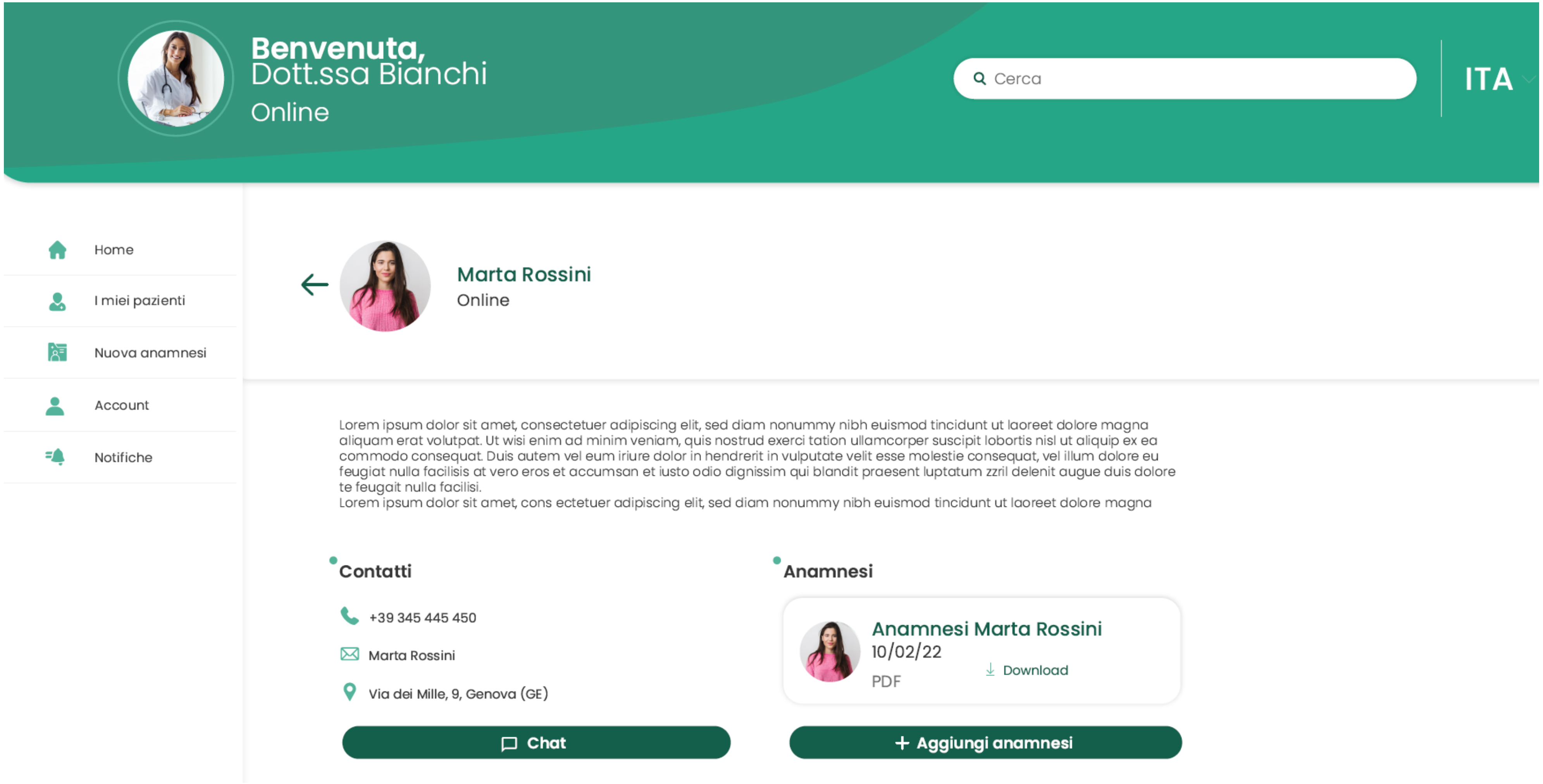
Teleconsultation: app for video calls





Teleconsultation: app for video calls

Doctor's app



Video game therapy

As for teleconsultation, the clinical field has recently started using video games (serious games and exergames).

FDA permitted marketing of first game-based digital therapeutic to improve attention function in children with attention deficit hyperactivity disorder (ADHD) in 2020 only.

Nevertheless, the same issues (e.g. difficulties for the medical operators and for the digital system of the hospitals) hamper their widespread use.

A WebGL virtual reality exergame

- The COVID-19 pandemic and a consistent number of people living in small villages far from big city centers make necessary to develop applications which can be used remotely at the users' homes.

- We propose a WebGL exergame for the assessment of cognitive capabilities of elderly people, and a web-based procedure to offer the game and to collect data.

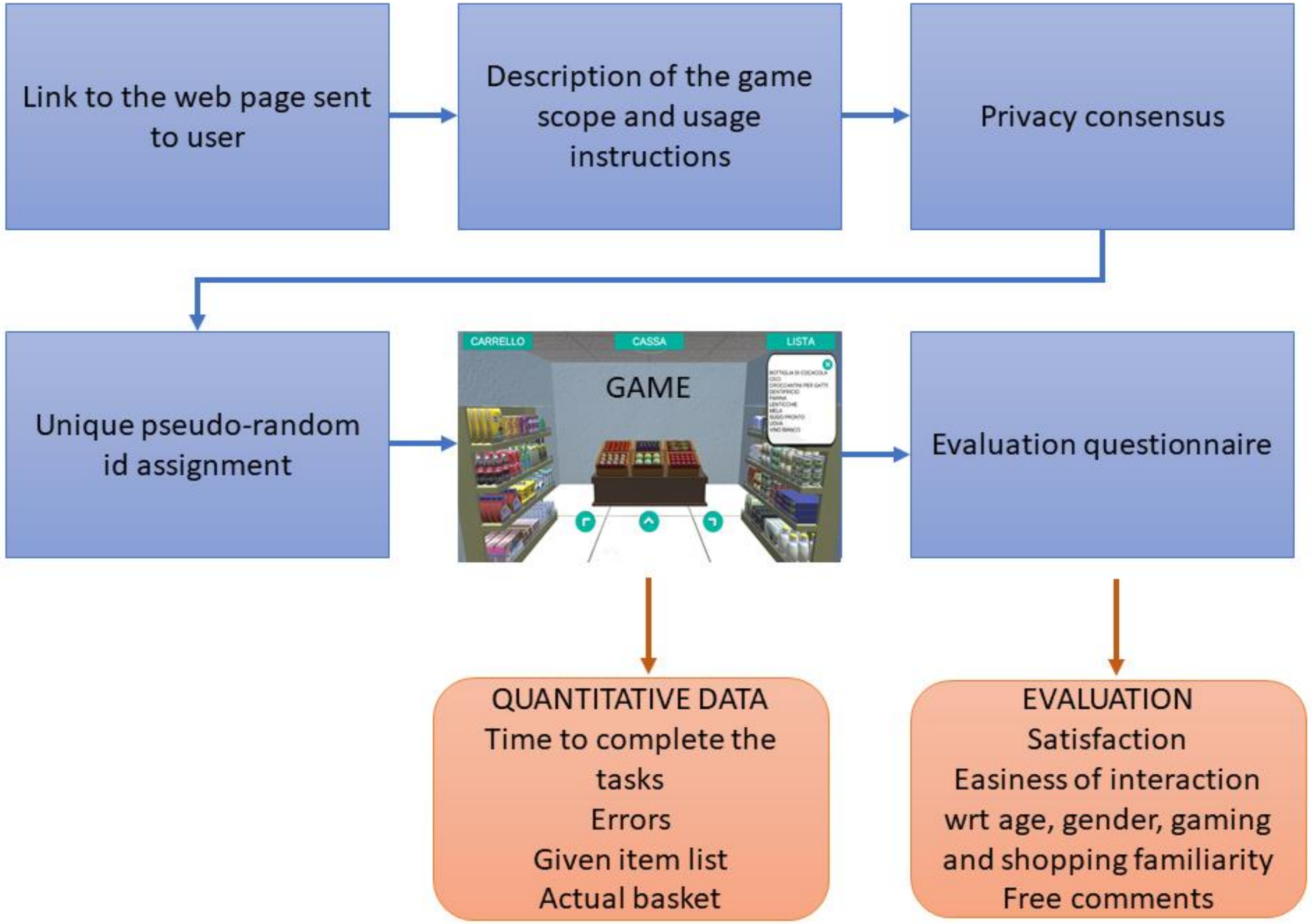
Chessa, M., Bassano, C., & Solari, F. (2021, January). *A WebGL virtual reality exergame for assessing the cognitive capabilities of elderly people: A study about digital autonomy for web-based applications*. In International Conference on Pattern Recognition (pp. 163-170). Cham: Springer International Publishing.

A WebGL virtual reality exergame

- In this study, we assess
- (i) the digital autonomy of a group of volunteers who tested the web-based exergame, and
- (ii) the potentiality of Unity WebGL build to create non-immersive Virtual Reality environments.

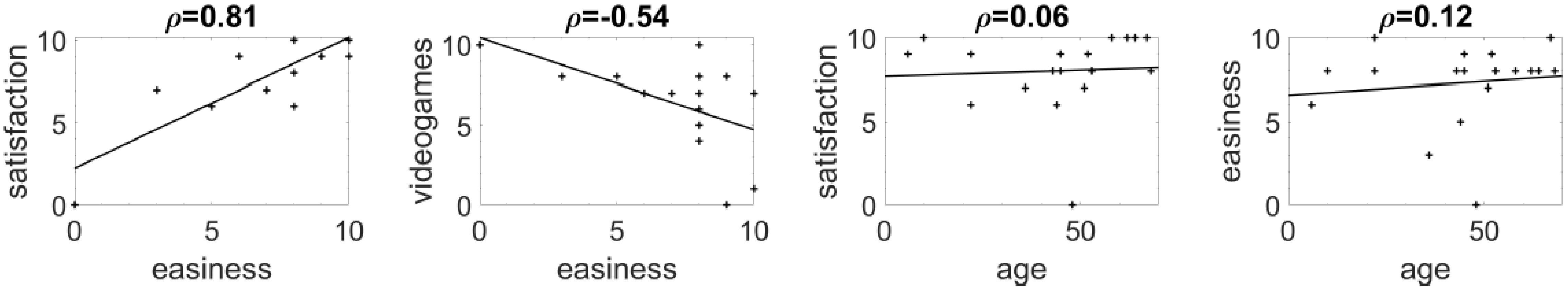
Chessa, M., Bassano, C., & Solari, F. (2021, January). *A WebGL virtual reality exergame for assessing the cognitive capabilities of elderly people: A study about digital autonomy for web-based applications*. In International Conference on Pattern Recognition (pp. 163-170). Cham: Springer International Publishing.

A WebGL virtual reality exergame



Participants
19 volunteers (8 males and 11 females)
with a mean age of 44.3 and
a standard deviation of 18.6

A WebGL virtual reality exergame



Correlation among age, familiarity with videogames, perceived satisfaction in using the exergame and perceived easiness of interaction.
Values on axes are the scores given on a Likert-scale from 1 to 10.

A WebGL virtual reality exergame

- The pipeline for collecting data without the assistance of the experimenter works, but about 20% of the recruited participants encountered problems, which did not allow them to complete the task.
- The Unity WebGL build allowed us to distribute a previously developed game with few modifications. *The game worked properly in most cases*.
- We focused on the usability by considering the WebGL build. One of the main issues was the poor quality of the textures.
- Data were collected in a time span of 24 hours, thus demonstrating the possibility of reaching a large number of participants in an easy way.

A Serious Game to assess social apathy: **Aims**

- To develop a serious game for the early identification of one of dementia's most prevalent and early neuropsychiatric symptoms, apathy
  - Early diagnosis of cognitive impairments is essential
  - Needs for adequate tools for the difficult process of diagnosing apathy

- To assess its feasibility and acceptance by patients and clinicians, by conducting a pilot study
  - A fundamental issue is understanding whether patients and therapists accept the proposed serious game as a diagnostic tool

Fabio Solari, Rachid Guerchouche, Valeria Manera, Rosa Carlotta Sanges, Manuela Chessa. *A Serious Game to assess social apathy: a pilot study*. GSGS, 2023 [in the context of a European project]

Related works

- Dementia has been considered a global public health priority due to its enormous impact on individuals, families, and society [1].
- Serious Games (SGs) seem to be appropriate in this setting as a new paradigm of cognitive evaluation [2,3,4]
- It is fundamental to assess the real acceptability and use of the serious games [5]

[1] Zygouris, S., P. Iliadou, E. Lazarou, et al. "Detection of mild cognitive impairment in an at-risk group of older adults: can a novel self-administered serious game-based screening test improve diagnostic accuracy?" Journal of Alzheimer's Disease 78, no. 1: 405-412, 2020.

[2] Robert, P., K.L. Lanctôt, L. Agüera-Ortiz, et al. "Is it time to revise the diagnostic criteria for apathy in brain disorders? The 2018 international consensus group." European Psychiatry 54: 71-76, 2018.

[3] Manera, V., E. Chapoulie, J. Bourgeois, et al. "A feasibility study with image-based rendered virtual reality in patients with mild cognitive impairment and dementia." PloS One 11, no. 3: e0151487, 2016.

[4] Chessa, M., C. Bassano, and F. Solari. "A WebGL Virtual Reality Exergame for Assessing the Cognitive Capabilities of Elderly People: A Study About Digital Autonomy for Web-Based Applications." In International Conference on Pattern Recognition, pp. 163-170. Springer, Cham, 2021.

[5] Bassano, C., Chessa, M. and Solari, F. "Visualization and Interaction Technologies in Serious and Exergames for Cognitive Assessment and Training: A Survey on Available Solutions and Their Validation." IEEE Access, 10, pp.104295-104312, 2022.

Context

- The frequency of age-related disorders like dementia is dramatically rising because of the longer average lifetime. Alzheimer's disease (AD) is the most prevalent cause of dementia and mild cognitive impairment (MCI) is a pre-dementia stage.
- Early diagnosis of cognitive impairments is essential to improve disease treatment and control reversible causes.
- A new paradigm of cognitive evaluation, which de-medicalizes screenings and links them to a pleasurable pastime by allowing seniors to self-administer them in their preferred setting, is possible with serious games as a screening tool.

Context

The proposed web-based framework was developed in the context of Interreg Alcotra project CLIP E-Santé/Silver Economy, where we tackled the patients' needs and the doctors' requirements with their early involvement.

Doctors required a custom serious game and local data (we paid specific attention to data security).

Faced issues

Therapists' acceptance:

- it is necessary to integrate the SG into *traditional diagnostic protocols* to help them to make an early diagnosis by easily using such a new tool
- the SG needs a specific design to be able to detect the early aspects of apathy in MCI and provides a *solid metric* for apathy detection

Patients' acceptance:

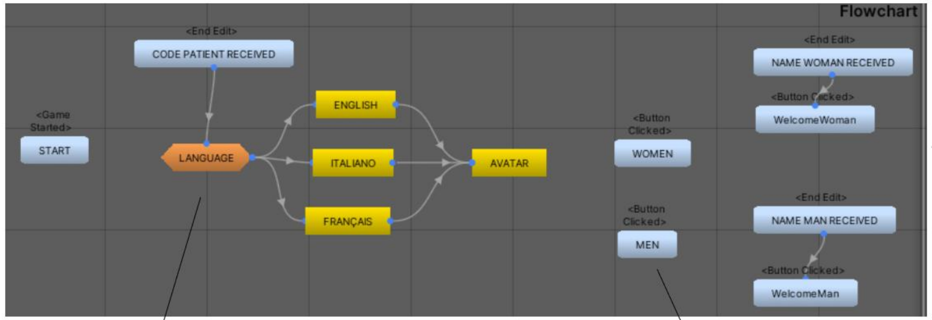
- the SG *interface* needs specific attention since users are *not accustomed* to employing technology
- characters, environments, dialogues, the narrative parts and the menus must be *simple and intuitive* to allow patients to focus on the task to be performed

Proposed solution

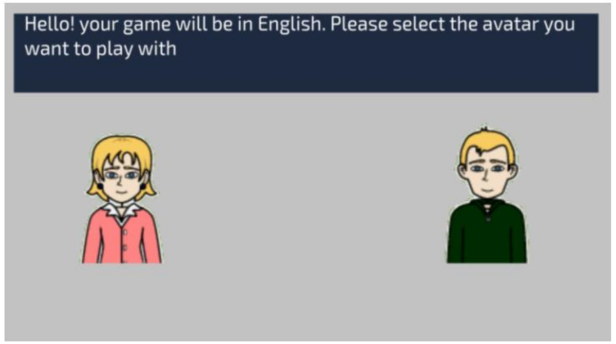
- We propose a game that allows patients to immerse in a series of social situations and to decide whether to interact with other people and how much.
- We devised these social situations to identify loss of, or diminished engagement in social interactions: e.g., spontaneous social initiative, relationship with family members, verbal interaction.
- We used Unity, Visual studio (scripts in C #), and Fungus for developing the tablet SG.

Proposed solution

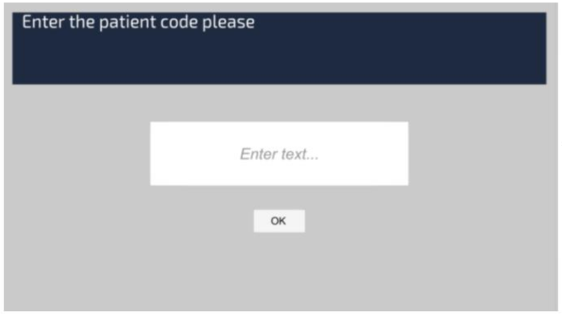
Start scene flowchart showing different kinds of blocks



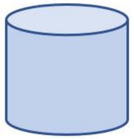
Interface to choose an avatar

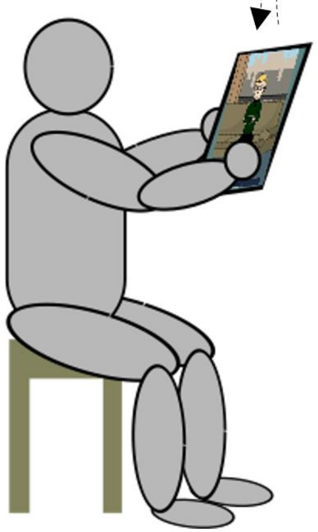


Interface to choose the patient's code



Patient's data saved in a file

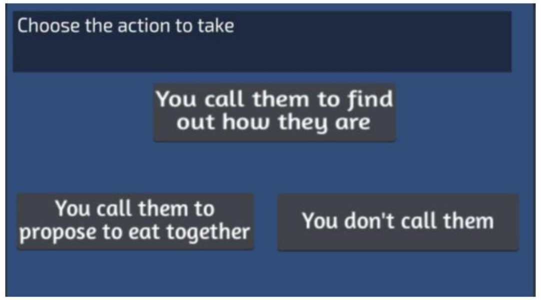




Example of a narrative part of the story

Example of a dialogue part of the story

Example of a choice



Proposed solution

The novelty of our approach is twofold:

(i) Design a serious game for the early detection of MCI by exploiting the social interaction disorder, i.e., social apathy, as a cue for the possible development of a neurocognitive illness;

(ii) Develop the serious game by employing very simple, but engaging graphics, so that patients can focus on the tasks and enjoy the social situations

We paid specific attention to the patients' identification with the game stories to allow them to behave as they do in real life, thus obtaining reliable game outcomes.

The tablet SG allows us to use it in several contexts, from the clinician's room to the patient's home, by increasing the possibility of reaching a large number of people

Implemented system

There are three different game situations with specific social interactions: we measure the patient's performance, based on the degree of apathy detected by the choices the patient makes

Snapshot of the Game1

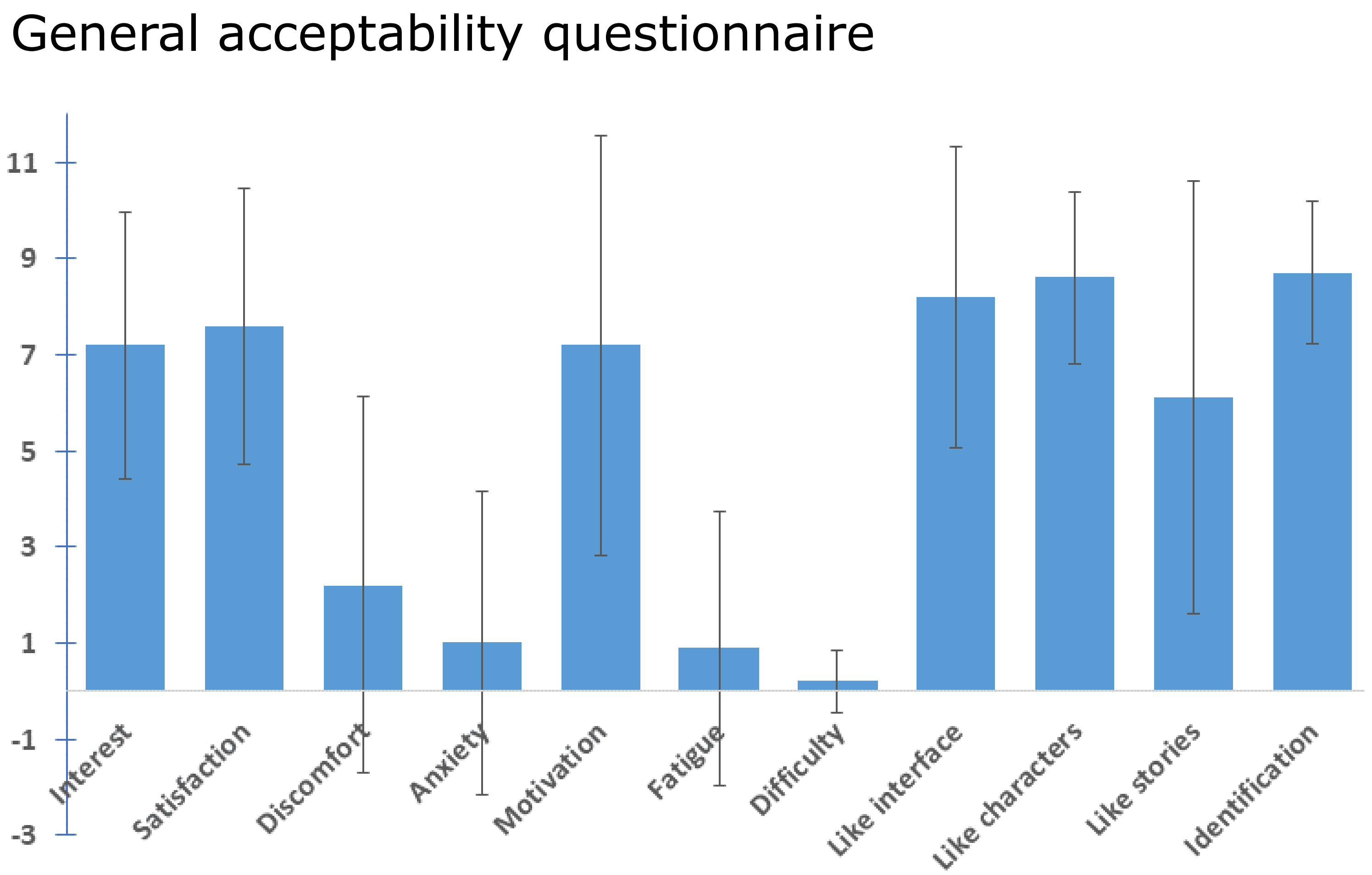
Snapshot of the Game2

Snapshot of the Game3

Results

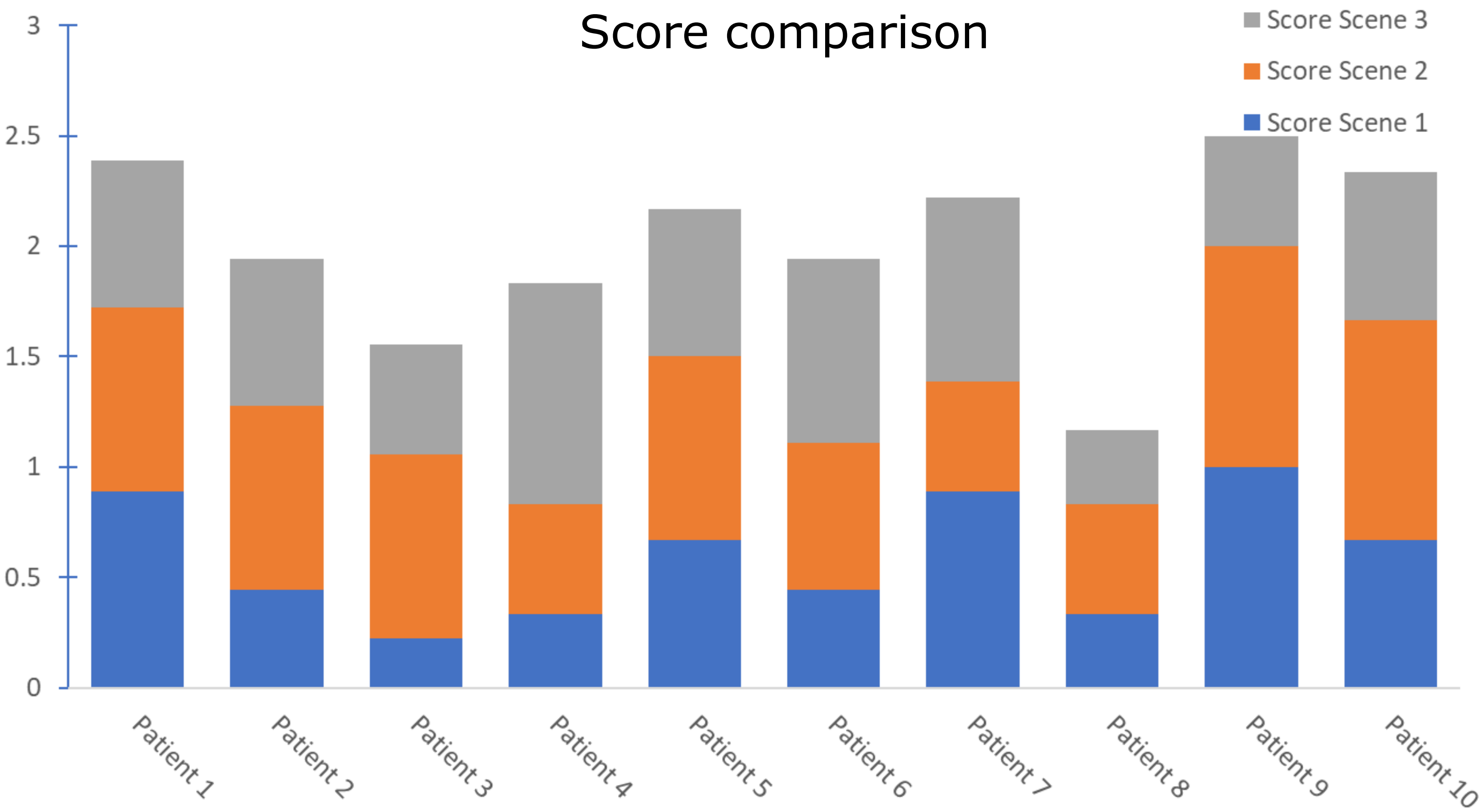
- All participants underwent a standard clinical assessment: the clinical evaluation revealed that 7 patients had MCI and 3 had Subjective Cognitive Decline. Out of the 10 patients, one was apathetic (2 M; 8 M average age: 74.6 years; SD: 5.379; age range= 64-83).
- The game lasted about 10 minutes.
- Then, participants were administered self-report questionnaires to evaluate their experience: specifically, participants were presented with 10 points Likert scale.
- A score was computed based on the patient's social interactions in the game.

Results



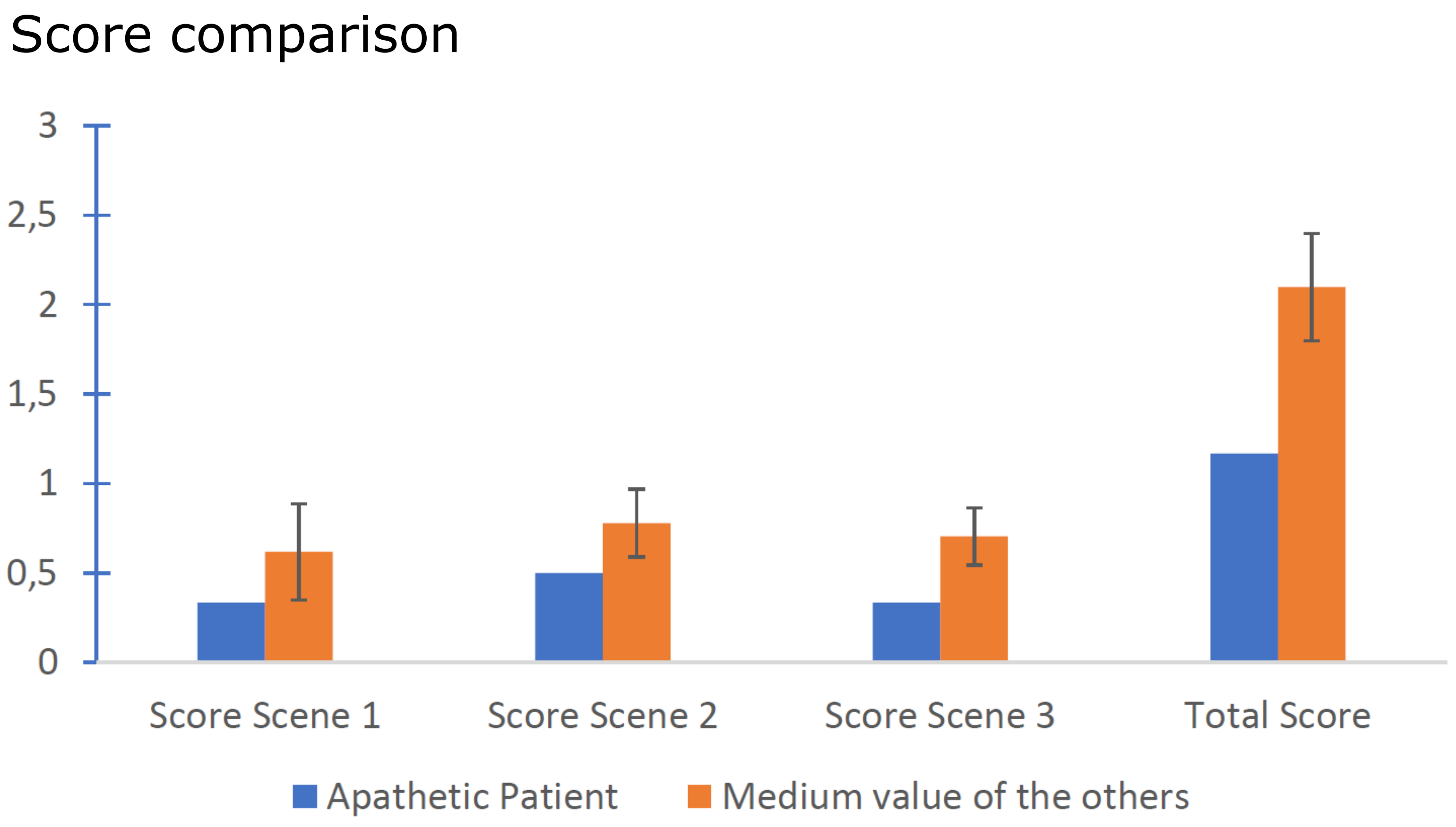
General acceptability questionnaire
11
9
7
5
3
1
-1
-3
Interest
Satisfaction
Discomfort
Anxiety
Motivation
Fatigue
Difficulty
Like interface
Like characters
Like stories
Identification

Results



Score comparison
Score Scene 3
Score Scene 2
Score Scene 1
3
2.5
2
1.5
1
0.5
0
Patient 1
Patient 2
Patient 3
Patient 4
Patient 5
Patient 6
Patient 7
Patient 8
Patient 9
Patient 10

Results



Score comparison
3
2,5
2
1,5
1
0,5
0
Score Scene 1
Score Scene 2
Score Scene 3
Total Score
Apathetic Patient
Medium value of the others

Results

Correlations: SG score wrt AMI

The Apathy Motivation Index (AMI)

Game 1		Game 2		Game 3		Total	
AMI	AMI-social	AMI	AMI-social	AMI	AMI-social	AMI	AMI-social
0.39	0.24	0.41	0.60	-0.25	-0.59	0.37	0.19

Total: Game 1 & 2	
AMI	AMI-social
0.40	0.42

based on the observation of the patients, we deduced that this was the game situation in which they found it harder to identify with the simulated phone calls.

To sum up

- We propose a SG designed for an early detection of the social apathy in the users who play it.
- We carried out a pilot study on the population target: 10 patients suffering from early-stage neurocognitive disorders.
- The results are encouraging:
  - the patients were able to play with the proposed SG and they provided positive feedback through a questionnaire.
  - Moreover, the game scores show a good correlation with a clinical metric and the apathetic participant had a lower score than the other ones.

Conclusions

The modeled perception can support the understanding of human behavioral data.

The modeled perception can improve the design of AR/VR systems:

- To use the log-polar paradigm to simplify the rendering and to decrease cybersickness.
- To address vergence-accommodation conflict to improve depth perception
- To use computational models to assess technologies without human experiments.
- To use computational neural model outcomes to improve VR/AR systems

XR for Healthcare: Immersive and Interactive Technologies for Serious Games Tutorial

Thank You

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