SOMAREALITY

White Paper

EYE TRACKING-BASED COGNITIVE INSIGHTS

Explore the next generation of digitalized cognitive insights based on objective eye tracking analytics.

www.somareality.com

COGNITIVE INSIGHTS

To derive cognitive insights, you need cognitive assessments - a type of psychological evaluations - to assess various aspects of a person's cognitive abilities and functioning. These assessments are used to gain insight into an individual's cognitive strengths and weaknesses, identify potential cognitive impairments or developmental delays, and help inform decisions related to education, clinical diagnosis, treatment planning, and research.

Some Facts

In the US

1 in 9

SUFFERS FROM SUBJECTIVE COGNITIVE DECLINE

It takes around

18 years

FOR COGNITIVE DECLINE TO DEVELOP INTO ALZHEIMERS

With such an early detection

1 in 3

DEMENTIA CASES COULD BE PREVENTABLE

Most clinicians will use an established mental status screening tool such as the Mini-Mental Status Exam (MMSE), Montreal Cognitive Assessment (MoCA) or Mini-Cog to determine if cognitive impairment is present.

Mental status screens are short, efficient, and well-researched modalities designed to evaluate multiple cognitive domains. A cognitive assessment, along with a good history, physical exam, and appropriate labs and imaging, can establish a diagnosis or decide if further evaluation is necessary.

Cognitive Assessments inlcude the following aspects of cognition:

- **Language** (naming, reading, writing, and repeating words)
- **Executive Function** (planning, working memory, mental flexibility, list-making, and executing tasks)
- **Abstract Reasoning** (detecting patterns & solving problems)
- **Memory** (encoding, storing, and retrieving information)
- **Attention / Concentration** (spelling words / serially subtraction)
- **Visuospatial Skills** (manipulate 2D- and 3D objects)

Prominent Cognitive Assessments

Montreal Cognitive Assessment (MoCA):

This test involves memorizing a short list of words, naming objects shown in pictures, copying shapes and performing other tasks. This test takes about 15 minutes to complete.

Mini-Mental State Exam (MMSE)

This test involves counting backward, identifying objects in the room, stating the date and other common, well-known facts. This test takes about 10 minutes.

Mini-Cog

This test involves memorizing and recalling a three-word list of unrelated words and drawing a circle clock — adding all time points, then drawing hands to show a specific time. This test is the shortest (<3 minutes) and easiest to complete.

Eye tracking is poised to revolutionize cognitive assessments, offering an unparalleled window into the mind. By following the gaze, we can uncover the intricate dance of attention, perception, and cognition, unlocking new insights into human thought processes that were once hidden. The future of cognitive assessments lies in the eyes.

Our Vision

We are convinced that eye tracking and the features it provides, represents the key to unobtrusive, accurate and efficient cognitive assessments. We expect innovative and superior technologies such as eye tracking to improve and replace established pen and paper methodologies in the near future.

Our Mission

For this purpose, we explore and build eye tracking-based technologies to analyze, interpret and evaluate cognitive functions for various applications in industry, health care and society, such as, diagnostics, optimization of performance, training and education, as well as safety systems.

Key Benefits with SOMAREALITY

The aspired digitalization of Cognitive Insights based on actual gaze behavior data provides the opportunity to obtain more realistic data in less obstrusive procedures.

With eye gaze being a substantial representative of perception and cognition, analytic systems based on eye tracking - especially with insights from XR environments - allow the creation of more realistic scenarios and thus more expressive scores and features describing human cognition:

- High quality data with mobile headsets as "laboratory in a box"
- Exploitation of technical opportunities provided by innovative technologies (creation of realistic situations via interaction and 3D visualization)
- Overcoming limitations by traditional pen and paper tests (static, non-immersive nature, strong abstraction from reality, limitations of coverable cognitive abilities)
- Increasing Objectivity (less subjective interpretations by examiner)

THE POTENTIALS AND BENEFITS OF EYE TRACKING

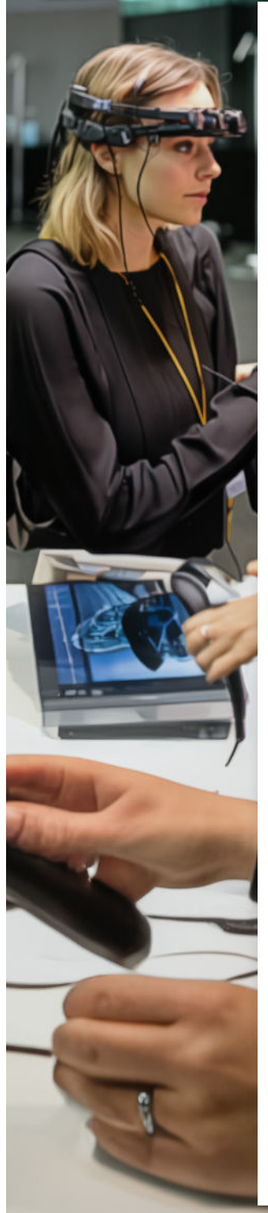
How can eye tracking technology be useful for cognitive assessments? While performing a task, the tracking of eye movements can capture various parameters, such as the features describing the strategies and amount of time used for scanning content, speed and accuracy of eye movements, reaction times to stimuli, etc.

Eye Tracking is a valuable tool because of

- **Objective Data:** Eye tracking provides objective and quantitative data about a person's visual attention and gaze patterns.
- **Real-time Insights:** Eye tracking allows researchers and clinicians to understanding dynamic cognitive tasks and behaviors.
- **Non-Invasive:** Eye tracking does not require physical contact or use of intrusive sensors. This makes it well-suited for children, individuals with cognitive impairments, or other limitations.
- **High Temporal and Spatial Resolution:** Eye tracking provides precise measurement of eye movements and fixations essential for studying rapid cognitive processes and small gaze shifts.
- **Versatility:** It is suitable for a wide range of cognitive interpretations (e.g., attention, memory, decision making, problem solving, language processing, and emotion)
- **Cognitive Workload Assessment:** Eye tracking can be used to assess cognitive workload, which is vital in optimizing task designs and ensuring that cognitive tasks do not overwhelm individuals.
- **Early Detection and Intervention:** In the context of cognitive impairments and disorders, eye tracking can facilitate early detection, leading to timely intervention and support.

Eye Tracking is already being used to assess

- **Attention and Focus:** Eye tracking helps assess how people focus on specific stimuli. This is crucial in understanding attention patterns, distractions, and focus levels.
- **Reading and Language Processing:** Via eye movements analysis, researchers can analyze reading patterns, comprehension levels, and identify reading difficulties like dyslexia.
- **Memory and Recall:** Gaze patterns during recalling details from memory, provide insights into memory retrieval strategies.
- **Decision Making and Problem Solving:** Eye movements offers valuable information about how individuals process information, evaluate options, and make choices in problem-solving.
- **Emotional Responses:** Gaze patterns show emotional engagement, and emotional regulation strategies.
- **Disorders & Cognitive Impairments:** Specific gaze patterns can be indicative of certain conditions (e.g. Alzheimers, dementia, autism), aiding in early diagnosis and treatment planning.
- **Cognitive Workload:** Assessing cognitive load via gaze patterns and pupil dilation allows optimizing task designs and ensuring that cognitive tasks do not overload individuals, leading to more accurate cognitive insights.



Eye tracking technology provides new levels of understanding of various cognitive processes, making it a powerful tool in the field of cognitive assessments and research. It offers a unique and valuable perspective by providing real-time, objective, and detailed data on visual attention and gaze behavior, making it a powerful tool for researchers, clinicians, educators, and industry professionals working in various cognitive domains.

Eye Tracking paves the way for future of cognitive assessments and diagnostics

Eye tracking-based cognitive assessments have significant potential and can have a substantial impact across various domains, including education, clinical psychology, human-computer interaction, and research.

To enable the breakthrough of these technologies, it's essential address challenges such as the need for standardized protocols, consideration of cultural and individual differences, and ethical concerns related to privacy and data security in parallel to the technologic challenges. As technology continues to advance, eye tracking is likely to play an increasingly prominent role in understanding and assessing cognitive processes in various contexts.

Most Relevant Applications

Neurological Disorders and Cognitive Impairments: Diagnosing & monitoring neurological disorders and cognitive impairments, such as Alzheimer's disease and autism spectrum disorders.

Usability Testing: Assessing the usability of websites, software interfaces, and other digital products. By tracking users' eye movements, researchers identify areas of interest, navigation challenges, and user preferences, leading to improved designs.

Training and Skill Development: Analyzing how novices and experts differ in their visual attention patterns. This information helps design effective training programs and simulations, enhancing skill development in various fields.

Research on Learning and Education: Understanding how students engage with educational materials. It helps in studying learning processes, identifying challenges faced by students, and developing targeted interventions to improve learning outcomes.

FROM PEN & PAPER ...

Pen & Paper is limited by

Subjectivity & Bias
Pen and paper tests can be influenced by subjectivity and examiner bias, as the interpretation of answers may vary among examiners.

Limited Range of Cognitive Abilities
Traditional tests often focus on a limited range of cognitive abilities, such as verbal and mathematical skills, while neglecting other important cognitive domains.

Lack Ecological Validity
Pen and paper tests may lack ecological validity, meaning they do not always reflect a person's cognitive abilities in real-world settings.

Time Consuming
Traditional cognitive tests can be time-consuming, requiring a significant amount of time to administer and score.

Test Anxiety
The awareness of being in a test situation can induce test anxiety, affecting performance and the validity of results.

Outdated Content
Some pen and paper tests may contain outdated or culturally irrelevant content.

Limited Accessibility
Pen and paper tests may not be accessible to individuals with disabilities, such as those with motor impairments.

... TO EYE TRACKING

Eye Tracking allows to

Diversify Assessment Methods
Expand the range of assessment methods beyond traditional pen and paper tests. Incorporate performance-based assessments, simulations, situational judgment tests, project-based assessments, and portfolios to better capture real-world cognitive abilities.

Broaden the Cognitive Domains Assessed
Ensure that assessments cover a wide spectrum of cognitive domains, including problem-solving, creativity, emotional intelligence, visual-spatial reasoning, critical thinking, and adaptability.

Increase Ecological Validaty
Develop assessments that mirror real-life scenarios and challenges to improve ecological validity. This could involve using simulations, case studies, and immersive virtual environments.

Embrace Technology
Utilize computer-based assessments to automate scoring, reduce testing time, and provide instant results. Implement adaptive testing, which tailors questions to the individual's ability level.

Reduce Test Anxiety
Implement test anxiety reduction strategies, offer practice assessments, and create a supportive testing environment to mitigate the impact of test-related stress on performance.

Update and Validate Assessments
Continuously review and update assessment content to keep it current and relevant. Regular validation studies ensure that assessments accurately measure the intended cognitive constructs.

Wide Accessibility
Overcoming limitations of motor skills, eye tracking technologies increase the access and applicability of Cognitive Assessment Tests to larger audiences

THE DEPTH OF EYE TRACKING

Eye Tracking Data holds a lot of valuable information about the location, intensity, and effectiveness of assessing and processing information, but as well about underlying cognitive processes and strategies as well as achieved cognitive performance. In the ongoing, we will introduce the most important features and interpretations that SOMAREALITY provides based on eye tracking data.

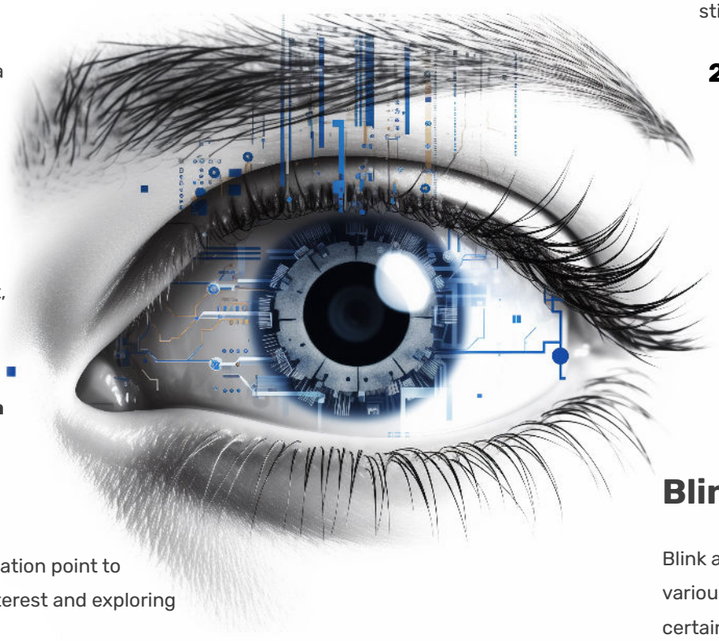
Fixations & Saccades

Eye gaze can be characterized by fixations and saccades, which are fundamental components of eye movement patterns. Understanding these elements provides insights into how individuals allocate visual attention and process information.

1. Fixations

Fixations refer to periods during which the eyes remain **relatively stable and focused** on a specific location in the visual field. During fixations, the retina receives a steady stream of visual information, allowing for detailed processing of the scene.

- Fixations are associated with detailed visual processing, allowing the brain to extract information from the attended area.
- The duration of fixations can vary but typically ranges from a few hundred milliseconds to a few seconds.
- Fixations are often observed when individuals examine specific objects, read text, or focus on detailed features of a scene.



Analyzing fixations helps identify **areas of interest**, determine the **duration of attention** to specific stimuli, and u**nderstand cognitive processes associated with visual exploration**.

2. Saccades

Saccades are **rapid, jerky eye movements** that involve shifting the gaze from one fixation point to another. Saccades play a crucial role in redirecting the line of sight to new areas of interest and exploring the visual environment.

- Saccades are quick, ballistic movements that occur in between fixations.
- The duration of saccades is typically very short, ranging from about 20 to 200 milliseconds.
- Saccades can cover both short distances within a scene and longer distances when individuals shift their gaze between different objects or regions.

Analyzing saccades provides information about the dynamics of eye movement, the **speed and efficiency of visual scanning**, and the **sequence of transitions between fixations.**

Distributions, Statistics and Sequences

1. Heatmaps

Aggregating fixation data allows to create eye gaze heatmaps. These visualizations represent the areas of a scene that attract the most visual attention. Hotter regions on the heatmap indicate higher fixation density, revealing the most salient or interesting parts of a visual stimulus.

2. Statistical Derivatives

Statistical features derived from fixations and saccades are able to provide scores describing the spatial distribution of gaze behavior mathematically, enabling to identify and quantify e.g., search behavior, task switching or competency levels in task executions by comparing these normalized scores to reference results.

3. Gaze Behavior Sequences

Typical eye gaze sequence involves a series of fixations and saccades. Analyzing the speed, accuracy, order and strategy of such sequences in a scene allows interpretations of visual search strategies such as s ystematic scanning or focused exploration.

Blinks

Blink analytics, which involve the study of eye blink events and blink rates, can provide insights into various cognitive and physiological aspects. While blinks are primarily a physiological phenomenon, certain patterns or behaviors related to blinking can be associated with cognitive functions and states.

Cognitive Load from Pupil Dilation

Pupil dilation is a physiological response that has been found to be associated with changes in cognitive load and mental effort. As cognitive load increases, the pupil tends to dilate, and as cognitive load decreases, the pupil tends to constrict. **Together with the Research Studios Austria, SOMAREALITY has developed a unique approach to cognitive load analysis which is capable of compensating effects from environmental brightness and provides cognitive load analysis live during runtime.** This allows the transfer of established analytics from cognitive science into real world scenarios.

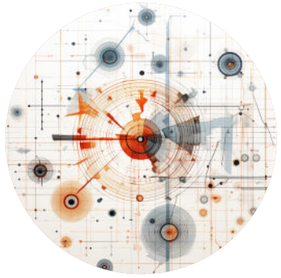
WHAT'S INSIDE SOMAREALITY

1

Objective Eye Tracking Data

Eye tracking data can significantly contribute to cognitive assessments by providing detailed and quantifiable information about an individual's visual attention, gaze patterns, and eye movements. Eye tracking technology allows for the precise measurement and analysis of ocular behavior, offering insights into cognitive processes and performance.

Analysis of eye movements, can reveal where an individual directs their attention, how efficiently an individual scans and searches for specific information, or how information is encoded into memory during exposure to stimuli. This information is valuable for understanding various kinds of cognitive processes.



2

Advanced Eye Gaze Metrics

3

Cognitive Load

Changes in pupil size represent a qualitative and quantitative indicator of cognitive load and mental effort. The SOMAREALITY solution allows the analysis of cognitive load and compensation of environmental brightness during run-time, thus enabling the transfer of established cognitive load analysis into real-world applications.

The integration of Extended Reality (XR) with eye tracking-based cognitive assessments adds a special dimension by combining immersive environments with precise gaze tracking capabilities. This convergence enhances the ecological validity of cognitive assessments, allowing researchers and practitioners to study cognitive processes in more realistic and immersive contexts.

4

Digital Cognitive Assessments

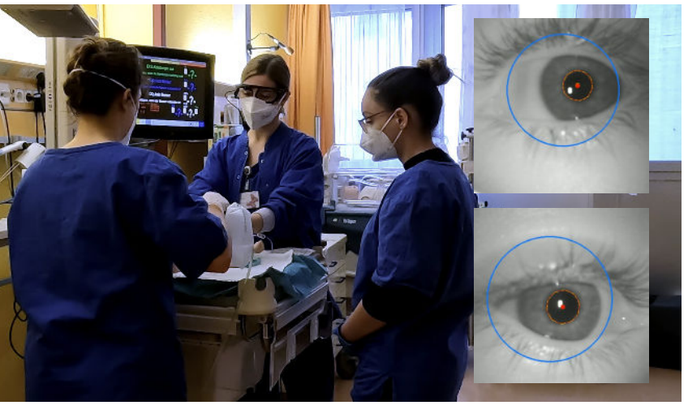
5

Embedded Cognitive Assessments

Frequent, embedded cognitive assessments help monitor changes in cognitive function over time. This is particularly crucial for optimizing individual performance and detecting early signs of cognitive decline or neurological disorders. Timely identification allows for early intervention and management of cognitive health issues.

USE-CASE SCENARIOS

SOMAREALITY is actively developing solutions for various use-cases based on eye tracking technologies in various fields of application. These range from professional training scenarios, over usability and safety use-cases to health and diagnostic applications and cover industrial, medical as well as social settings.



MEDIZINISCHE UNIVERSITÄT WIEN

Medical Training:

SOMAREALITY is developing and integrating Adaptive Training principles into the training processes at MedUni Vienna based on cognitive assessments. This allows to individualize and optimize training to achieve best possible training results while minimizing required resources.

Need:

Training medical professionals for their daily duties requires highest possible training quality, while at the same time aiming for optimal use of available resources, as acquisition and usage of simulators is very expensive.

To obtain optimal performance in critical situations, **trainings need to be adapted to individual requirements** that allow every student to learn and improve efficiently and to their individual performance maximum.

Adaptive Training Concepts:

Best learning performance can be achieved via training which keeps students in a range of being challenged while avoiding cognitive overload.

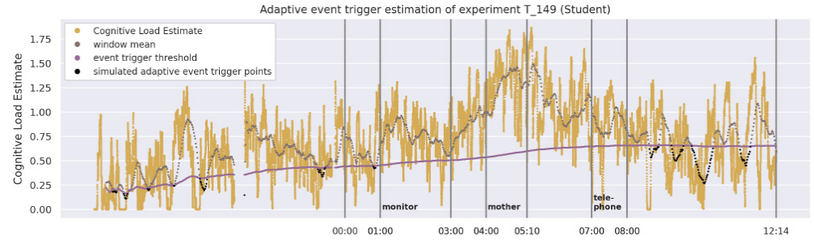
SOMAREALITY has realized an assessment system, which allows the monitoring of cognitive load in real-time. **Based on the cognitive load levels, the complexity and the structure of the training can be adapted if it shows to be too simple or too challenging for the student.**

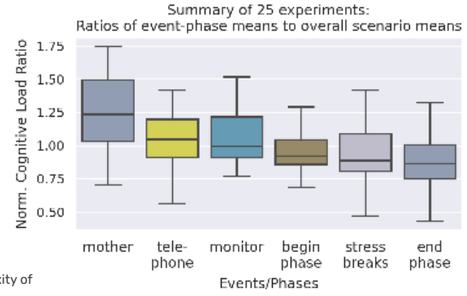
Product & Impact:

Based on their cognitive insights, SOMAREALITY enables VR-based or real-world-based Adaptive Trainings that allow the targeted training and education of individuals, thus **promising best possible training quality.**

The individualization of the training enables an **optimal usage of training resources**

- optimal utilization of training infrastructure
- time of trainee and supervisors





Sample Data from validation studies: (right) added cognitive load via stress events (mother, telephone, monitor error) can be clearly identified, (left) cognitive load falling under the dynamic threshold (black dots), triggers event of adapting the complexity of the training schedule. For details please refer to:
Thomay et al., Towards Cognitive Load-based Decision Making in VR Training, CVR 2023, IEEE 2nd International Conference on Cognitive Aspects of Virtual Reality, Oct 26-27, Veszprèm, Hungary, 2023

INTUITIVE SURGICAL®

Supporting Communication in Surgical Robotics:

In robotic surgery applications, the surgeon is seated at a remote console, often impeding oral communication, while necessary equipment (ie, video monitors, the surgical console) disrupts sight-lines, limiting the use of visible behaviour (ie, gesture, eye gaze) in communication. In collaboration with Intuitive, we investigate the suitability of gaze and cognitive load visualization for improving team collaboration and operative efficiency during robot-assisted minimally invasive surgery (RAMIS) .

Lufthansa Aviation Training

Competency-based Pilot Training:

Cognitive Assessments are used to optimize the training and performance of pilots in a project together with Lufthansa Aviation Training and the Research Studios Austria FG. Eye tracking based assessments of perception and interaction are used to actively manage pilots attention for optimized training experience.

tech 2 people

Rehabilitation:

Eye tracking-based biomarkers can be a great addition to conventional rehabilitation methods that can not only assist patient recovery but also create a gateway from stationary to remote therapy methods. Using smart digital tools in native environments adds a completely new layer of user insight and thereby understanding of how the broad field of cognitive and motor skill rehabilitation is linked to neurological processes.

VAMED

Healthcare:

Eye Tracking based assessments open the door for early diagnosis of various severe neurodegenerative diseases like dementia and Parkinsons. SOMAREALITY is actively pushing developments towards the creation of tests and detectors of cognitive functions that can be embedded into everyday lives, thus providing continuous, and therefore invaluable data for early successful individualized treatments.

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The Team

At SOMAREALITY, we believe in a world where everyone can unlock their full cognitive potential. Therefore, we develop scientifically validated digital biomarkers to enable technologies in industry, health care, society and beyond.

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