Module VII.3

Early intervention and application of smart resources (IoT, IPA, Health Smart, AI): use of eye tracking technology and the eEarlyCare web application.

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e-EarlyCare-T

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Module VII.3. Early intervention and application of smart resources: eye tracking and eEarlyCare

Module VII.3 refers to the use of intelligent resources for observation, analysis and intervention at early ages. Specifically, in this part of Module VII, an introduction to the use of eye tracking technology applied to the assessment of children at an early age will be given. Likewise, a web application, eEarlyCare, will be presented, which facilitates both the recording of observational analysis and the interpretation of the results through a Learning Analytics system that allows finding personalised profiles for each user and, in relation to this, making proposals for individualised programmes for therapeutic intervention.

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Module VII.3. Early intervention and application of smart resources: eye tracking and eEarlyCare

1. Eye tracking applied to early care
    - 1.1. What is eye tracking technology?
    - 1.2. Registration metrics in eye tracking and their significance in information processing
    - 1.3. Synchronisation of eye tracking with other registers
    - 1.4. Biometric markers for assessment and intervention with young children.
2. eEarlyCare web application functionality: representative studies

1.1. What is eye tracking technology?

Eye tracking technology is based on **eye tracking and measures eye movements**. The explanation is basically the capture of eye tracking while the user performs a task through a pattern of infrared light directed towards the eyes. The infrared light is reflected by the eyes and the eye reflections are captured by the eye-tracker cameras. Then, from the application of algorithms, the eye tracker recognises where the user is looking. In Figure 1, you can see how it works, there is a stimulus on the computer screen, the eye perceives the image in a position of axes in coordinates (these can be in 3D, x,y,z, or 2D x,y) in the position of the right eye and the left eye.

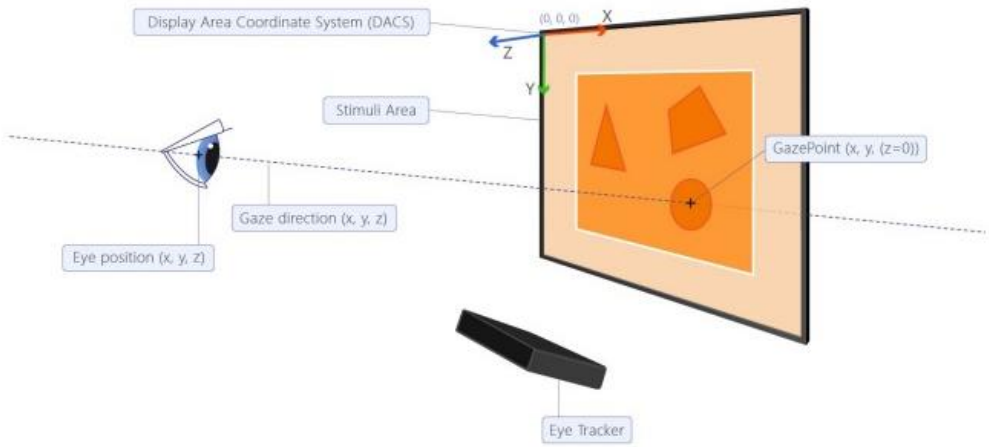


Figure 22. Display Area Coordinate System (DACS)

Figure 1. Taken from Tobii Pro Lab Manual v. 1.194 p. 155

1.1. What is eye tracking technology?

Also, eye movement can be recorded without the need for the subject to look at a screen, they can look at a blackboard, an object, a surface, etc. (see Figure 2).

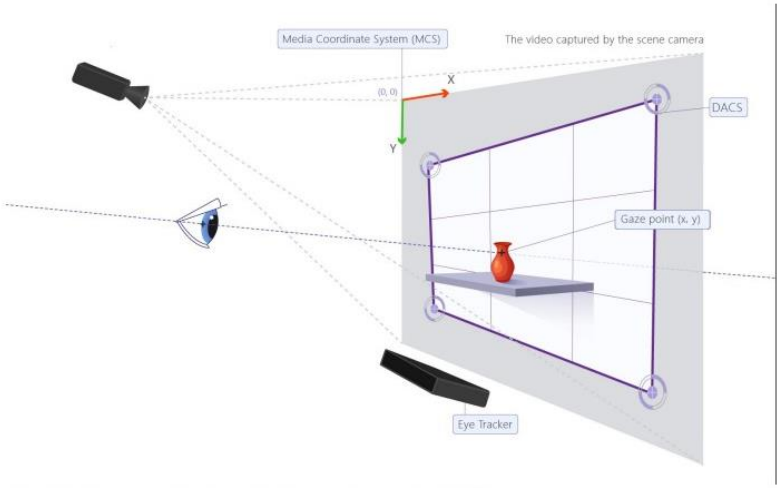


Figure 24. Scene Camera Projects and the Media Coordinate System (MCS)

Figure 2. Taken from the Tobii Pro Lab Manual v. 1.194 p. 158

1.1. What is eye tracking technology?

This is a useful option in observation and assessment of young children. An example of such an assessment can be seen in Figure 3 and Figure 4. In this case only the 2D coordinates, x, y coordinates, will be analysed. These devices are very powerful and have a high capacity to adjust head movements. They are therefore recommended for the assessment of young children. They can capture eye movement data at speeds from 60 Hz to 1200 Hz.

Figure 3. Image taken from Tobii information on web link

Figure 4. Image taken from Tobii information on web link

1.1. What is eye tracking technology?

Another possibility is using glasses that incorporate eye tracking software (see Figure 5). The glasses can measure using a 3D coordinate system. The eye position and gaze vectors are calculated from images of the eye on a 3D model. The gaze point is calculated as the vergence point between the two gaze vectors.

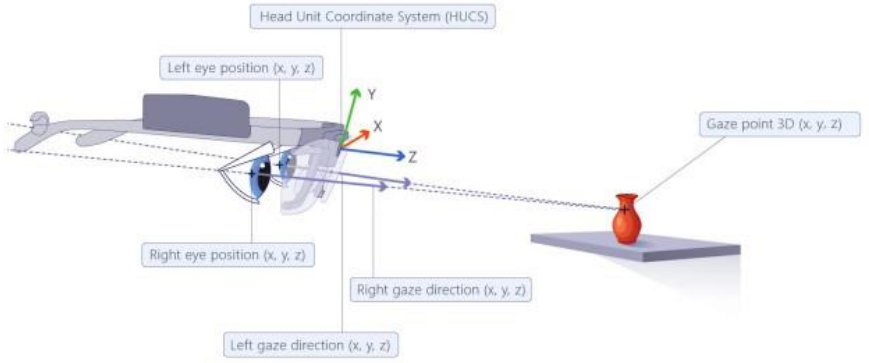


Figure 25. Head Unit Coordinate System (HUCS)

Figure 5. Taken from the Tobii Pro Lab Manual v. 1.194 p. 159

1.1. What is eye tracking technology?

In this process it is important to correctly calibrate the gaze positioning. An example of a gaze adjustment positioning analysis can be found in Figure 6.

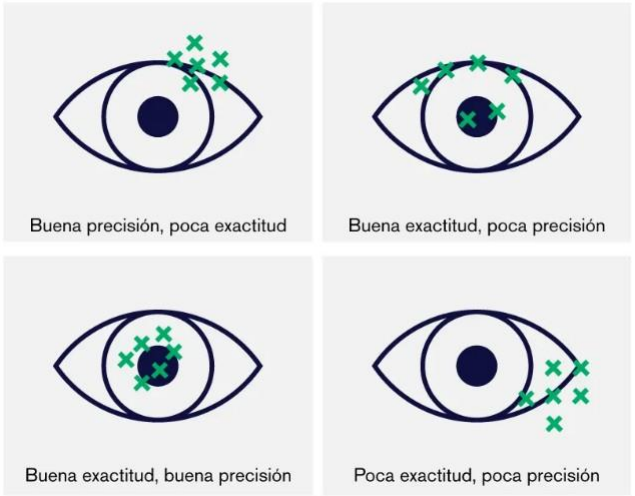
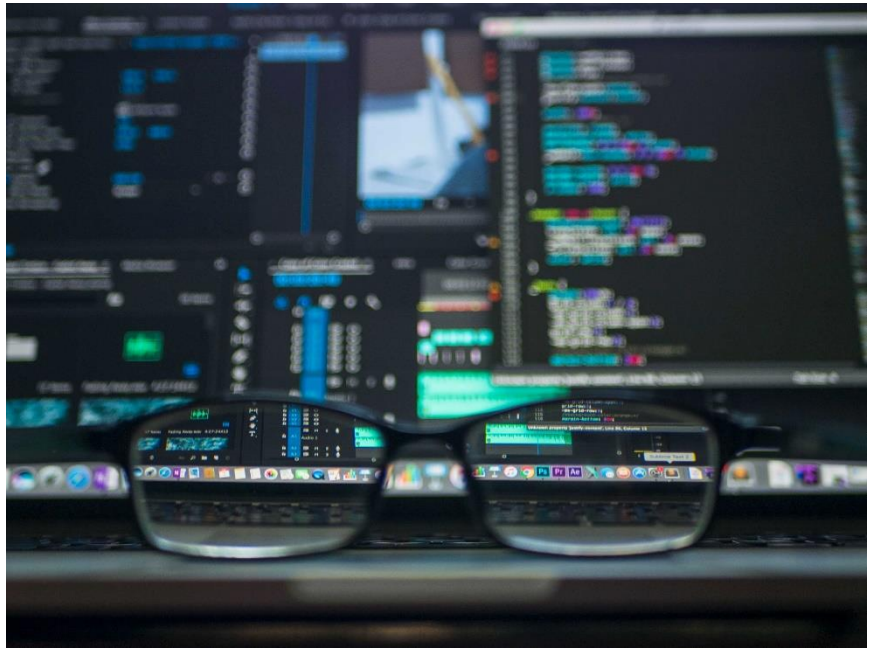


Figure 6. Taken from Tobii dynavox link

1.2. Registration metrics in eye tracking and their significance in information processing

Eye tracking can record many metrics, which can be classified into static and dynamic metrics (Sáiz-Manzanares et al., 2020). The former are related to the **parameters of fixation, saccade and glance**. All **have different extensions (frequency, speed, average durations, etc.)**. Dynamic metrics refer to the recording of the positional pattern of eye tracking performed and, depending on the type of technology, they can be called scan path or gaze point.



1.2. Registration metrics in eye tracking and their significance in information processing

Metric	Acronym	Meaning	IP Correspondence
Duration of interval	DI	Duration of all intervals of cas Time of Interest, with means, medians, sums, frequencies, variances and standard deviations.	
Start of interval	YES	The start time of all interval times for each Time of Interest, with means, medians, sums, frequencies, variances and standard deviations.	
Number of Events	NE	Customised events and Live logged events, for each event time, with means, medians, sums, frequencies, variances and standard deviations.	
Validity of eye data	VED	Refers to whether the eyes have been correctly identified. That is, whether the calibration is correct.	
Calibration	C	Information on calibration adjustment.	
Fixation Count	FC	Number of fixations of all selected stimuli.	A high HR means a higher number of fixations on a stimulus, indicating that participants may possess less task knowledge or have difficulty discriminating between relevant and non-relevant information.

1.2. Registration metrics in eye tracking and their significance for information processing

Metric	Acronym	Meaning	IP Correspondence
Fixation Duration	**FD**		**Gives an indication of the user's level of interest and reaction times. Longer duration is usually associated with deeper cognitive processing and greater effort. The duration of the fixation also provides information on the search process.**
Fixation Duration Average	FDA	Average duration of fixation	A longer FDA means that the participant spends more time analysing and interpreting the information content within the different AOIs.
Fixation Duration Maximum	FDMa	Maximum duration of fixation	Refers to reaction times.
Fixation Duration Minimum	FDMi	Minimum duration of fixation	Refers to reaction times.
Fixation Dispersion Total	FDT	Sums all dispersions on the fixation axes (x,y or x,y,z) depending on whether the device measures in 2D or 3D.	It refers to the perception of the information in different components of the task.

1.2. Registration metrics in eye tracking and their significance in information processing

Metric	Acronym	Meaning	IP Correspondence
Saccades Count	**SC**	**Total number of saccades in each of the stimuli.**	**More saccades mean more search strategies. The greater the amplitude of the saccade, the lower the effort. cognitive effort. It may also refer to problems in understanding information.**
Saccade Frequency Count	SFC	Sum of the frequency of all saccades	Refers to the frequency of use of saccades which are related to with search strategies.
Saccade Duration Total	SDT	Sum of the duration of all saccades	Refers to the frequency of use of saccades which are related to with search strategies.

1.2. Registration metrics in eye tracking and their significance for information processing

Metric	Acronym	Meaning	IP Correspondence
Saccades Duration Average	**SDA**	**Average duration of saccades in each AOI**	**This data allows the discrimination of dependent or independent field users.**
Saccade Duration Maximum	SDMa	Maximum duration of the saccade	Novice users in the execution of a task have shorter saccades.
Saccade Duration Minimum	SDMi	Minimum duration of the saccade	Novice users in the execution of a task have shorter saccades.
Saccade Amplitude Total	SAT	Sum of the amplitude of all saccades	Novice users in the execution of a task have shorter saccades.

1.2. Registration metrics in eye tracking and their significance in information processing

Metric	Acronym	Meaning	IP Correspondence
Saccade Amplitude Maximum	**SAMa**		**Novice users in the execution of a task have shorter saccades.**
Saccade Amplitude Minimum	SAMi		Novice users in the execution of a task have shorter saccades.
Saccade Velocity Total	SVT	Sum of the speed of each saccade	It is directly related to the speed of information processing. when moving from one element to another within a stimulus.
Saccade Velocity Maximum	SVMa	Maximum value of the recorded speed of the saccade	It is directly related to the speed of information processing. when moving from one element to another within a stimulus.

1.2. Registration metrics in eye tracking and their significance for information processing

Metric	Acronym	Meaning	IP Correspondence
Saccade Velocity Minimum	**SVMi**	**Minimum value of the recorded speed of the saccade**	**It is directly related to the speed of information processing. when moving from one element to another within a stimulus.**
Saccade Latency Average	SLA	It is equal to the time between the end of one saccade and the start of the next saccade.	It is directly related to the reaction times in the information processing. The initial latency of the saccade provides information temporary information on the search process.
Blink Count	BC	Number of flashes during activity	Flickering is related to information processing during exposure. to a stimulus to generate the next action. Users with faster information processing may have shorter flashes and shorter duration. duration. However, this action can also occur where there is of attention. These results will have to compared with those obtained in the other metrics for adjusting the explanation of these results within the analysis of an learning pattern.
Blink Frequency Count	BFC	Number of blinks of all selected tests trials per second divided by number of selected trials	

1.2. Registration metrics in eye tracking and their significance for information processing

Metric	Acronym	Meaning	IP Correspondence
Blink Duration Average	BDA	The sum of the duration of all the flashing of all selected tests divided by the number of selected tests	
Blink Duration Maximum	BDMa		
Blink Duration Minimum	BDMi		
Pupil diameter	PS	Pupil diameter	Refers to the interest that a stimulus or part of it can attract the user's attention.

1.2. Registration metrics in eye tracking and their significance in information processing

Metric	Acronym	Meaning	IP Correspondence
Total duration of Visit	TDV	Total time each participant has visited the AOI house.	Gives data on attention to a stimulus or part of a stimulus.
Average duration of Visit	ADV	Average duration of each participant for each AOI over the total average.	
Number of Visits	NV	Number of visits within each AOI.	

1.2. Registration metrics in eye tracking and their significance in information processing

Metric	Acronym	Meaning	IP Correspondence
Scan Path Length	**SPL**	**Provides the learning pattern user's behavioural behaviour during task resolution**	**The study of behavioural patterns of learning will facilitate guidance on how to learn. The length of the scan path provides information on reaction times in tasks without predetermined duration.**
Dwell Time	DWT	Duration in time of all fixations and saccades within an AOI, including revisits (exits and re-entries) of all participants in the study divided by the number of participants.	DWT refers to a participant's interest in a stimulus within a given AOI.
Glance Duration	GD	Duration of the saccade when entering the AOI plus the sum of all fixation and saccade durations before leaving the AOI.	GD indicates reaction times when processing information within a stimulus and an AOI. It will help to distinguish between field dependent vs. field independent participants.

1.2. Registration metrics in eye tracking and their significance in information processing

Metric	Acronym	Meaning	IP Correspondence
Scan Path Length	**SPL**	**Provides the learning pattern user's behavioural behaviour during task resolution**	**The study of behavioural patterns of learning will facilitate guidance on how to learn. The length of the scan path provides information on reaction times in tasks without predetermined duration.**
Fun Duration	DD	The sum of all durations of saccades into and out of the AOI plus the sum of all durations of fixations and saccades within the AOI before exiting.	DD can be used to analyse the input, dwell time and output time of each stimulus inserted into each AOI.
Glance Count	GC	Number of glances at a target (taken from the outside) in a given period with both eyes.	QA helps to analyse reaction times and their duration for different stimuli. This provides information about how information is processed in different participants.

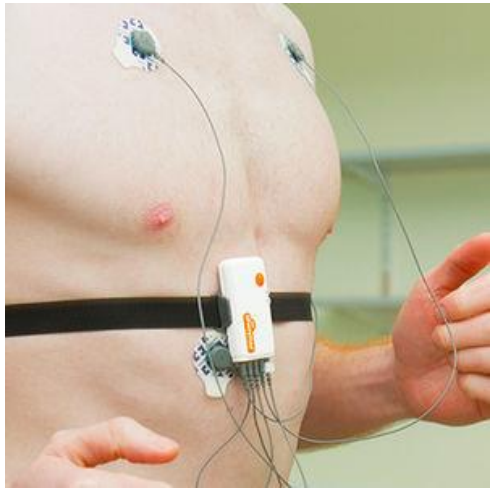
1.3. Synchronisation of eye tracking with other records

a) Psychogalvanic Skin Response Recording (GSR)

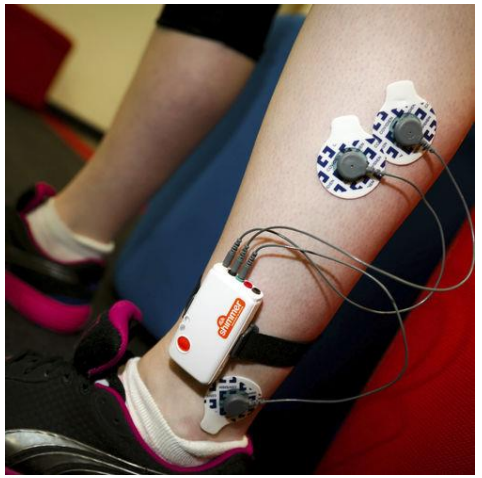
Nowadays, eye tracking technology allows synchronisation of eye tracking information with other recording channels such as Psychogalvanic Skin Response (GSR). The traditional theory of galvanic skin response analysis is based on the assumption that skin resistance varies with the state of the sweat glands. Sweating in the human body is regulated by the autonomic nervous system (ANS). In particular, if the sympathetic branch (SNS) of the ANS is highly aroused, sweat gland activity also increases, which in turn increases skin conductance, and vice versa.

1.3. Synchronisation of eye tracking with other records

a) Psychogalvanic Skin Response Recording (GSR)



Thus, skin conductance can be a measure of human SNS responses. This system is directly involved in the regulation of emotional behaviour in humans. Other studies have highlighted the relationship between the GSR signal and some physical states that can influence mental states, such as stress, fatigue and activity engagement. The GSR signal is recorded with two electrodes placed on the second and third fingers of one hand. The variation of an applied low voltage current between the two electrodes is used as a measure of electrodermal activity (EDA).



1.3. Synchronisation of eye tracking with other records

a) Psychogalvanic Skin Response Recording (GSR)

Measures offered by GSR

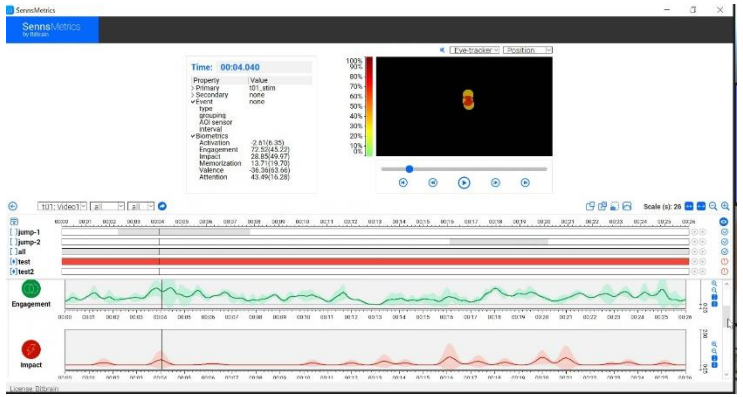
Activation: This refers to the baseline level of physiological arousal produced by a stimulus or situation. Emotional arousal may be due to a positive or negative emotional response. Activation is expressed in percentages from a defined baseline during calibration stimuli. Values below 0 are associated with a relaxed or calm state. Values above 0 are associated with a state of arousal. A value of -100% refers to the maximum relaxation response observed during calibration. A value of 100% refers to the maximum response observed in response to the calibration media. A value greater than 100% is possible if the calculated response exceeds that measured during calibration.

1.3. Synchronisation of eye tracking with other records

a) Psychogalvanic Skin Response Recording (GSR)

Measures offered by GSR

Impact: Emotional impact measures the number and intensity of one-off changes in emotional state produced by a stimulus, external event or during task performance. In other words, impact identifies something that is striking or produces arousal or stress. Impact is expressed as a percentage. A value of 0% means that there is no impact. A value of 100% equals the value measured in response to the calibration means. A value higher than 100% is possible if the calculated reaction exceeds that measured during calibration.



1.3. Synchronisation of eye tracking with other records

b) Encephalographic recording (EEG)

EEG recordings, depending on the device, can record information from 8, 16, 32 and 64 channels via dry or semi-dry electrodes. These sensors are designed for versatile monitoring with respect to a wide variety of monitoring environments from a high level of accuracy even in moving situations. An example of the recording areas can be seen in Figure 7, taken from a free Bitbrain data. Specifically, 16 channels in developmental, frontal, prefrontal and occipital areas are analysed in this image.

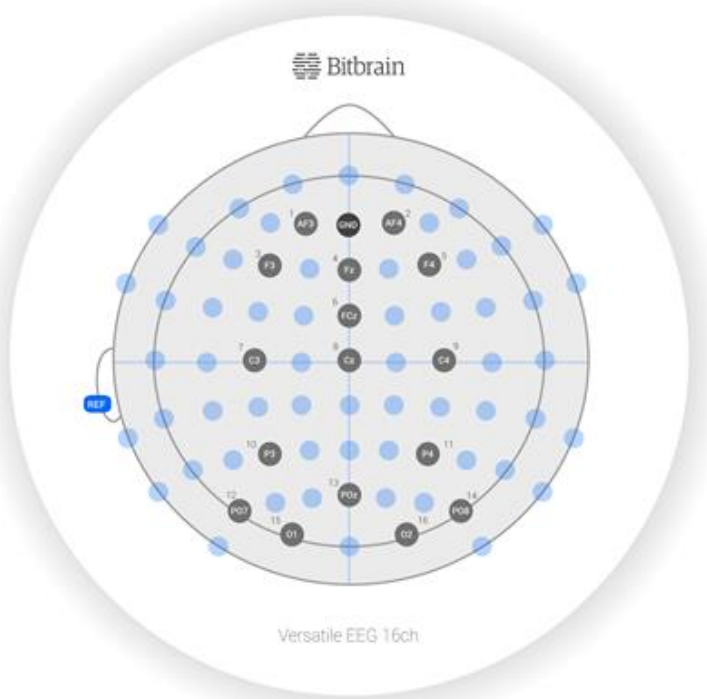
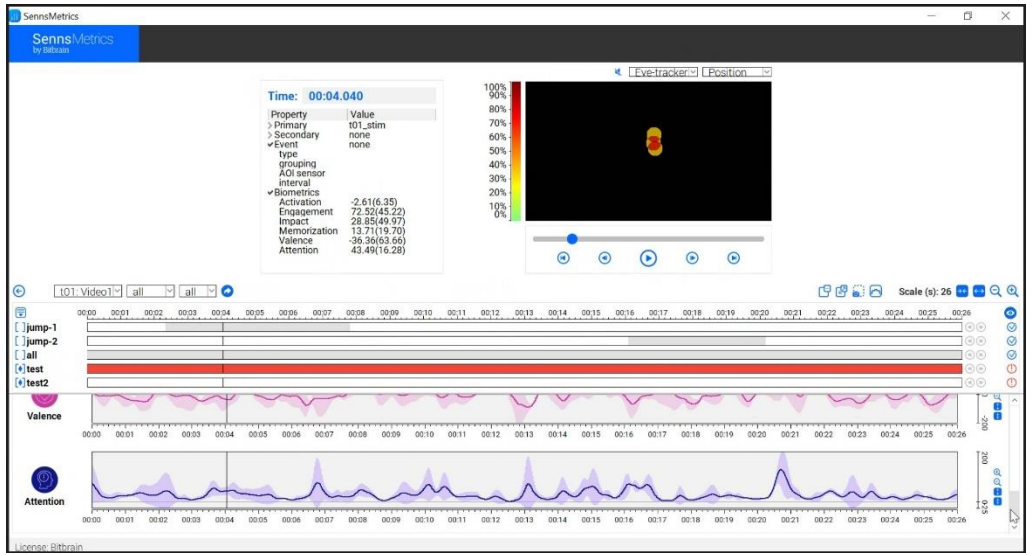


Figure 7. 16-channel EEG recording image taken from Bitbrain link.

1.3. Synchronisation of eye tracking with other records

b) Encephalographic recording (EEG)



The metrics that can be extracted from EEG are:

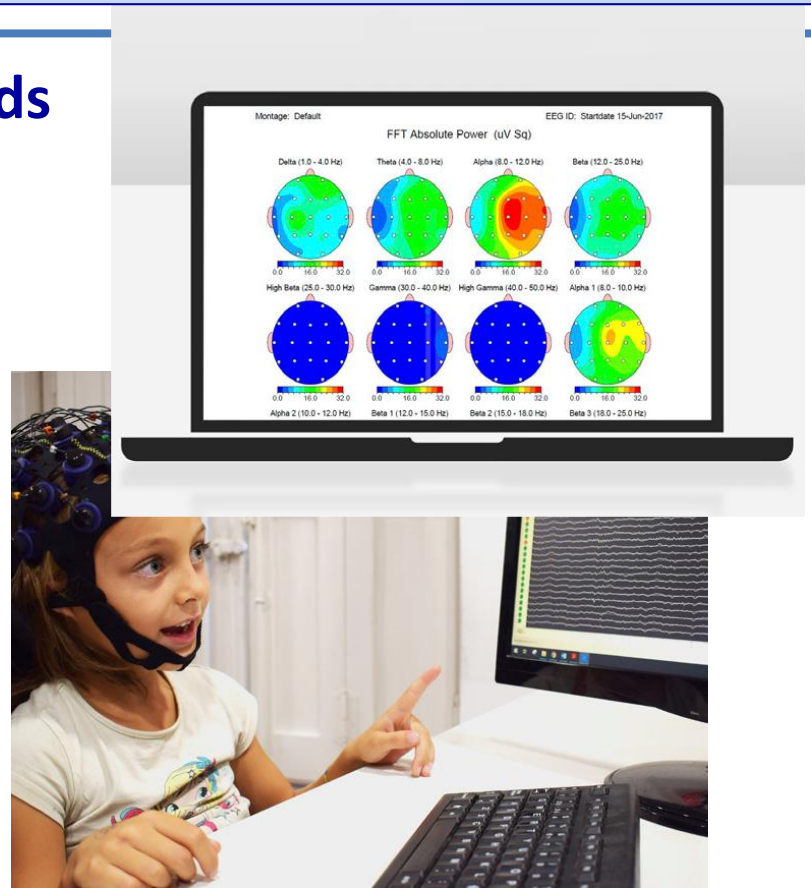
Valence: measures the degree of attraction experienced in response to stimuli or a situation, ranging from a positive/unpleasant reaction to a negative/unpleasant reaction. Valence is expressed as a percentage. A value of 100% positive or negative is equivalent to the value measured in response to the calibration medium. A valence level higher than 100% (positive or negative) is possible if the calculated reaction exceeds that measured during calibration.

1.3. Synchronisation of eye tracking with other records

b) Encephalographic recording (EEG)

The metrics that can be extracted from EEG are:

Memorisation: refers to workload, measuring the neurological focus or concentration of a participant when presented with stimuli or during experiences. In other words, it represents the use of cognitive resources to perform a task or visualise a stimulus. Workload is expressed as a percentage. Values close to 0% indicate that the participant is very distracted, while a value close to 100% indicates that the participant is very attentive to the stimulus.



Figures. Taken from Bitbrain catalogue link

1.3. Synchronisation of eye tracking with other records

b) Encephalographic recording (EEG)

The metrics that can be extracted from EEG are:

Engagement: refers to the degree of involvement or connection between the participant and the stimulus or task. It is a more complex indicator than attention, as a participant may be attentive to a task even if they do not find the information presented to them interesting. Involvement is expressed as a percentage. A value close to 0% indicates that there is no connection or link to the stimuli. A value close to 100% indicates high engagement with the stimuli or task.

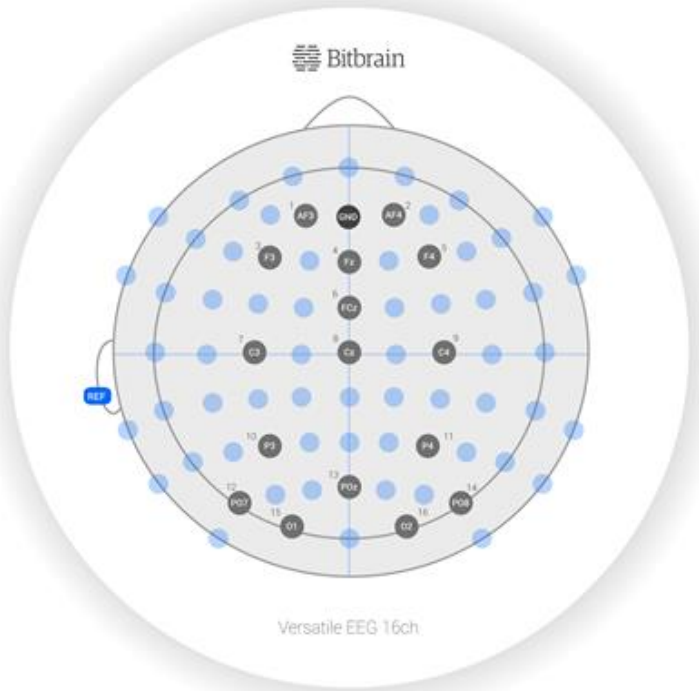


Figure 7. 16-channel EEG recording image from Bitbrain link.

1.3. Synchronisation of eye tracking with other records

b) Encephalographic recording (EEG)

All metrics can be integrated and analysed in the logging of the different logging channels, an example of which can be seen in Figure 8.

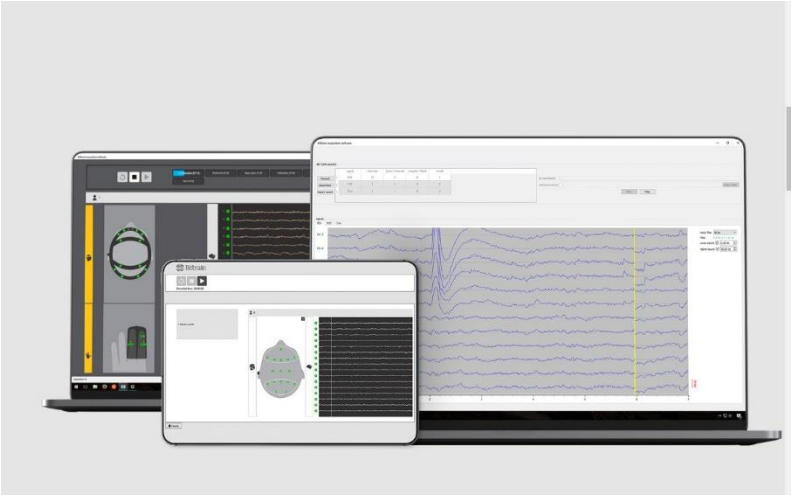


Figure 8. Multi-channel log analysis Taken from Bitbrain web

In particular, the application of this technology can be found in the studies by Dollion et al. (2021); Boxhoorn et al. (2019); Murias et al. (2017) and Leckey et al. (2020).

1.4. Biometric markers for assessment and intervention with young children.

The results of recent studies on the use of biometric measures applied to the analysis of information processing are promising. Biometric measures allow capturing people's unconscious and involuntary behaviours (Borgianni and Maccioni, 2020). The use of biometric measures is useful for understanding the ways in which humans process information and emotional responses. Also, different studies are being carried out to test the effectiveness of the application of different Machine Learning techniques with respect to the accuracy in the analysis of the results of different biometric records (Borgianni and Maccioni, 2020). Specifically, a high effectiveness of regression machine learning techniques has been found with respect to the use of Naive Bayes algorithms and the J48 and Random Forest decision tree algorithms (see Module IV.1).

1.4. Biometric markers for assessment and intervention with young children.

Recent research

- Gastmann, F., and Poarch, G.J. (2022). Cross-language activation during word recognition in child second-language learners and the role of executive function. Journal of Experimental Child Psychology, 221, 105443. https://doi.org/10.1016/j.jecp.2022.105443
- Gepner, B., Charrier, A., Arciszewski, T., & Tardif, C. (2022). Slowness Therapy for Children with Autism Spectrum Disorder: A Blind Longitudinal Randomized Controlled Study. Journal of Autism and Developmental Disorders, 52, 3102-3115. https://doi.org/10.1007/s10803-021-05183-6
- King, J., and Markant, J. (2022). Selective attention to lesson-relevant contextual information promotes 3- to 5-year-old children's learning. Developmental Science, 25, e13237. https://doi.org/10.1111/desc.13237
- Kong, X-J., Wei, Z., Sun, B., Tu, Y., Huang, Y., Cheng, M., Yu, S., Wilson, G., Park, J., Feng, Z., Vangel, M., Kong, J and Wan, G (2022) Different Eye Tracking Patterns in Autism Spectrum Disorder in Toddler and Preschool Children. Front. Psychiatry, 13, 899521. https://doi.org/10.1111/desc.13237

1.4. Biometric markers for assessment and intervention with young children.

Recent research

- Mulder, H., Oudgenoeg-Paz, O., Verhagen, J., van der Ham, I.J.M., and Van der Stigcheld, S. (2022). Infant walking experience is related to the development of selective attention. Journal of Experimental Child Psychology, 220, 105425. https://doi.org/10.1016/j.jecp.2022.105425
- Ståhlberg-Forsén, E., Latvab, R., Leppänen, J., Lehtonen, L., & Stolta, S. (2022). Eye tracking based assessment of lexical processing and early lexical development in very preterm children. Early Human Development, 170, 10. https://doi.org/10.1016/j.earlhumdev.2022.105603
- Tan, S.H.J., Kalashnikova, M., Di Liberto, M., Crosse, M.J., and Burnham, D.(2022). Seeing a talking face matters: The relationship between cortical tracking of continuous auditory-visual speech and gaze behaviour in infants, children and adults. NeuroImage, 256, 119217. https://doi.org/10.1016/j.neuroimage.2022.119217

3.2. eEarlyCare web application

eEarlyCare is a web application developed in several proof-of-concept phases financed with FEDER funds through the Junta de Castilla y León and the University of Burgos (Spain) (Sáiz-Manzanares, Marticorena-Sánchez and Arnaiz-González, and Díez-Pastor, 2020a; Sáiz-Manzanares, Marticorena-Sánchez and Arnaiz-González, 2020b). e-EarlyCare, incorporates an assessment scale of functional skills for ages 0-6 years and measures 11 functional areas (Autonomy in feeding, Personal care and hygiene, Dressing and undressing autonomy, Sphincter control, Functional mobility, Communication and language, Task resolution in social contexts, Interactive and symbolic play, Daily life routines, Adaptive behaviour, and Attention). The application allows the recording of the assessment(s) and the interpretation of the data obtained from an integrated Learning Analytics system. This system analyses the results from a comparison with the chronological ages assigned to each assessed behaviour (for this purpose, a scale of developmental ages accepted by the scientific community has been used, based on developmental scales and inventories such as the Brunet Lézine Scale, the Batelle Development Inventory, the Portage Guide, the PDI scale, etc.).

3.2. eEarlyCare web application

In other words, it offers a comparison profile between the expected score at the chronological age and the actual score obtained. The professional can also choose the number of standard deviations to apply with respect to the mean assigned to each assessed behaviour. Then, depending on the results in the assessment phase, the web application offers a possible therapeutic intervention programme. This programme detects the area or areas of functional development and the most affected behaviours (i.e. where there are the largest gaps compared to the chronological reference age). In addition, for each area, functional sub-area and behaviour, activities are proposed to initiate the therapeutic intervention programme. The application allows three evaluations per year (initial evaluation or baseline, intermediate evaluation or follow-up 1 and final evaluation or follow-up 2). The application also offers developmental analysis profiles that can be individual and/or grouped for each assessment carried out. Similarly, the tool allows for a longitudinal analysis of the three evaluations.

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Module VII.3. Early intervention and application of smart resources: eye tracking and eEarlyCare

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