Novel Interactive BRAINTEASER Tools for Amyotrophic Lateral Sclerosis (ALS) and Multiple Sclerosis (MS) Management

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Abstract. The presented demonstrated working tools in the initial version constitute the foundation of the novel ALS and MS management and monitoring, leveraging extended IoT sensing and emerging instruments infrastructure, and a basis for integration of more advanced and effective AI models (in development) for disease progression prediction, patient stratification and ambiental exposure assessment.

Keywords: Amyotrophic lateral sclerosis · ALS · Multiple sclerosis · MS · REST services design · Architecture · Optimization · AI models · Rich interactive web applications · Disease progression · Relapse · Big Data · Environment · Ambient · Daily living activities · Exposure · Exploratory analytics · Neurodegenerative · Smartwatches · Well-being · Wearable sensors · IoT integration

1 Introduction and Scientific/Technological Background

The BRAINTEASER Project (**BR**inging **A**rtificial **INTE**lligence home for a better care of **A**myotrophic lateral **S**clerosis and multiple scl**ER**osis), funded from the European Commission Horizon 2020 programme grant number GA101017598 until 2024, aims to integrate societal, environmental and health data to develop patient stratification and disease progression models for Amyotrophic Lateral Sclerosis (ALS) and Multiple Sclerosis (MS). ALS and MS are both very complex chronic progressively degenerative neurological diseases significantly disrupting the quality of life of the patients and their families, but with very different clinical picture, evolution, prognosis and therapies.

BRAINTEASER integrates detailed retrospective and prospective clinical datasets with comprehensive heterogeneous personal health, activity, lifestyle, habitual/behavioural, and environmental data collected using commonly available sensing/IoT devices and the demonstrated first release of developed interactive tools for disease monitoring and management.

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The collected data drive the development of Artificial Intelligence (AI) models able to address the needs of precision medicine, enabling early risk prediction of disease fast progression and adverse events, and the next planned releases of the tools currently in development will focus on the integration of the AI models and their outputs into generated specific highly complex feedbacks to the users (digital gamified coaching and recommendations to improve the patient's and caregiver's daily routines and overall well-being, and the analytics suite for full patient cohorts management according to stratifications output of the AI models and for interactive visual data exploration and detailed understanding of the disease progress and evolution of patient's conditions).

The demonstrated tools are being devised and developed embracing an agile user-centered multidisciplinary co-design approach, accounting for the specific technical, medical (including psychological/cognitive) and societal needs of the users. Proof-of-concept of their validated use in real clinical settings in 4 clinical study validation sites (Lisbon, Madrid, Pavia & Turin) aims to provide quantitative evidence of benefits and effectiveness of leveraging AI models in healthcare pathways for dire neurodegenerative diseases, and a set of recommendations for the health authorities to support the transition of the current approach to healthcare from reactive to predictive, paving the path towards a healthier and more fulfilling life as long as possible.

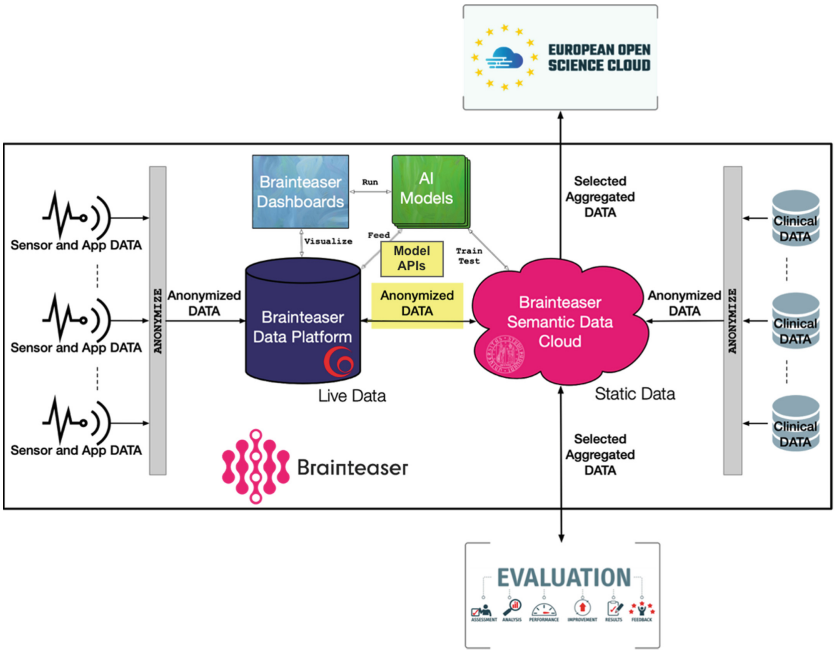

Fig. 1. Main data streams across the high-level BRAINTEASER ecosystem organization.

The presented tools are primary end-user-oriented components of the overall BRAINTEASER platform ecosystem, supported by the underlying unified Data Platform, Semantic Cloud, middle tier of integration service APIs, and others as presented

on Fig. 1 above with relevant main data streams and the involved external relations, including Project Open Science and Evaluation Challenge actions already underway. All together in turn provide support for the identified processes enhancing the management of ALS and MS both throughout the Project demonstration study and the care provision practice beyond, differentiated and structured through comprehensive analysis and co-design with relevant stakeholders as presented on Fig. 2 below, and progressing beyond the thoroughly analyzed key features of current relevant state-of-the-art ALS & MS management tools and applications like Emilyn[1], Cleo[2], and over 50 others relevant analyzed and compared in terms of specific features and functionalities.

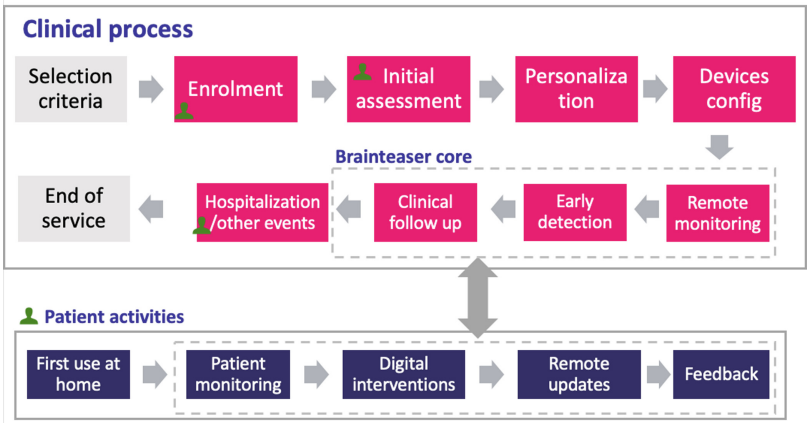

Fig. 2. Overall BRAINTEASER process flows enhancing disease management of ALS and MS.

Some of the platform functionalities and architecture build and extend upon preceding and parallel related projects and initiatives tackling common issues and exploiting applicable methods in neurodegenerative progression management [7], well-being [8], functional decline prevention [9], and public health [4, 5], such as PULSE[3], City4Age[4], NEVERMIND[5], or VERITAS[6].

One of the set out goals of BRAINTEASER is also to analyze the possible effects and influences of environmental and daily living ambient factors (primarily air pollution) on the aetiology and progression of neurodegenerative sclerotic diseases like MS, as has been intensely studied in recent years [1–3] along with water and soil pollution, and the role of these factors on progression and relapse of MS and ALS, feeding the relevant collected environmental data into the dedicated developed AI models for patient exposure to the ambiental factors, complementing the models for disease progression and stratification. The cities with clinical trial sites involved in the project (Lisbon, Madrid, Pavia,

[1] https://play.google.com/store/apps/details?id=com.bxh_mvp&hl=es.
[2] https://www.cleo-app.es/index.html.
[3] https://www.project-pulse.eu.
[4] https://cordis.europa.eu/project/id/689731.
[5] https://www.nevermindproject.org.
[6] https://cordis.europa.eu/project/id/247765.

Torino) have established extensive environmental sensing and measuring infrastructure, ingesting data both from public environmental measuring stations wherever open or available, as well as from connected IoT sensing devices deployed by BRAINTEASER and previous or parallel relevant projects like (again) PULSE, eMOTIONAL Cities[7], Sharing Cities[8], ACROSSING[9] and others [4–6], and complemented also with data from portable/wearable compact sensing devices (carried on or with patients) deployed by the project, mostly Atmotube PRO monitors[10].

2 Interactive Disease Management and Monitoring Tools Features

Three main interactive tools are being developed to support the processes illustrated on Fig. 2 above, differentiated and tailored towards specific target end-user roles and distinctly siloed functionality groups required for each group of roles:

1. Native mobile app. for patients and informal caregivers (family members, relatives, home nursing/assistance…)
2. Clinical Tool web application for specialist clinicians and/or physicians
3. Data Management and Exploration (Dashboard-based) Tool, a hybrid application for clinical study managers or administrators, care provision executives or policy-makers, and researchers to explore data and trends from selected studied patient cohorts down to individual levels, where meaningful and not obfuscated or unavailable due to indirect anonymization necessary for personal data protection purposes, and experiment with AI models execution and parameter tweaking/fine-tuning.

In this initial release, the mobile app. for patients/caregivers and the Clinical web Tool are primary, to support the key required functionalities of the Project study, enrolling the patients and:

- quantitative and qualitative information collection, consolidation and fusion (of heterogeneous data from IoT wearable trackers and environmental sensing networks, combined with data from digitalized standardized and innovative evolving instruments and questionnaires for ALS and MS (and comorbidities) clinical evaluation and remote disease progress assessment),
- elementary multimodal disease management, monitoring and assistance in daily patient and caregiver needs in remote and clinical settings, enabling follow-up, symptoms and health issues resolving, and feedback from the clinicians and caregivers to the patient through interactive GUI types,

as diagrammed on Fig. 3 below.

Next subsequent version in current development is focused on key "intervention-related" features listed on bottom left and bottom right of Fig. 3, providing support to

[7] https://emotionalcities-h2020.eu.
[8] www.sharingcities.eu
[9] www.acrossing-itn.eu
[10] https://atmotube.com/atmotube-pro.

patients, caregivers and clinicians to fully manage, prevent and mitigate disease progression, from basic advisory guidance and instructions to advanced cognitive games and exercises, or voice/speech assessment in evolution of bulbar symptoms.

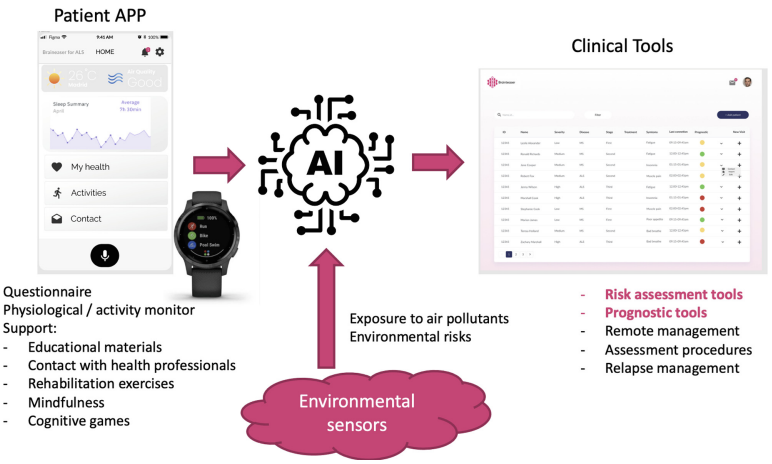

Fig. 3. Conceptual schema of primary functionalities of the BRAINTEASER Patient App. and Clinical Tool, with key data flows.

Example screen form for support service configuration in the MS-specific variant of the Clinical Tool is provided on Fig. 4 below and the detailed breakdown of UML use cases notation of basic functionalities of the Patient App. on Fig. 5 below.

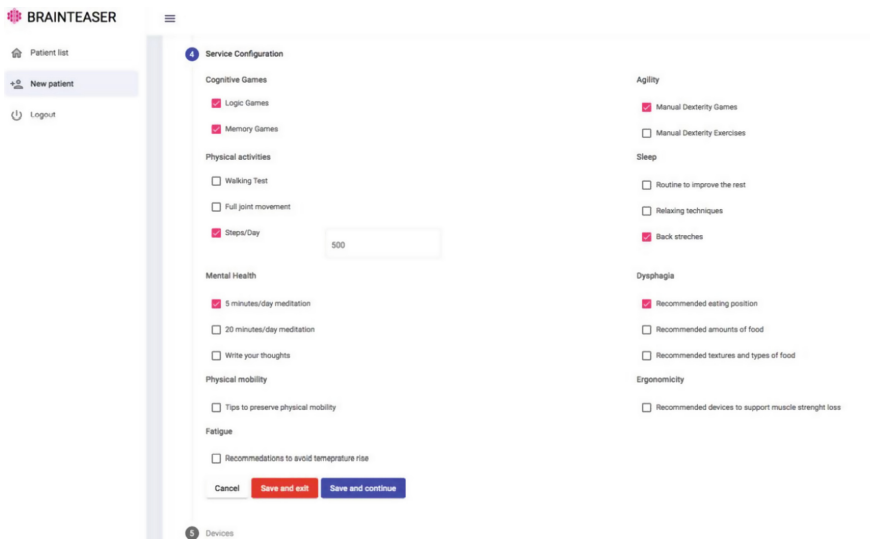

Fig. 4. Clinical Tool screen example for MS service configuration.

Fig. 5. UML notation of use cases covering key functionalities of the Patient/caregiver app.

The third listed Interactive Data Management and Exploration (dashboard-based) Tool is in initial version development as it significantly depends on and is intended to integrate substantial output from the AI models which are still in development and testing, but at this stage provides at least rich interactive visual exploration of arbitrary selection of collected temporal and heterogeneous data variables (including categorized and continuous), with values evaluated or compared combined together in multimodal and multidimensional composite 2D and 3D visualizations, as exemplified on Fig. 6 below.

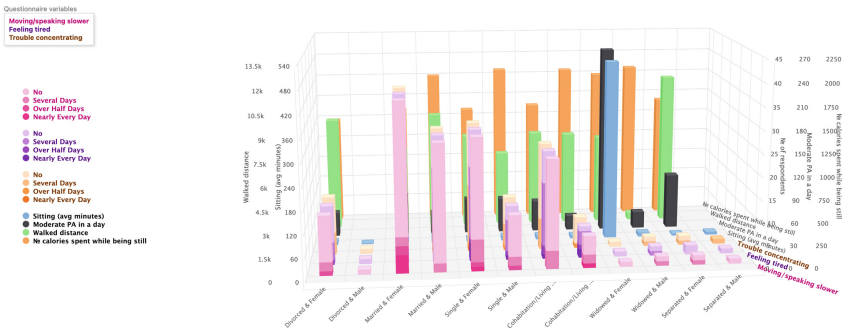

Fig. 6. Multivariate composite 3D interactive exploratory data visualization of 7 different combined continuous and categorized variables, additionally stratified per gender and marital status demographics.

3 Key Architectural and Service Design Challenges

The tools are designed to be modular, dynamically adaptable, personalized and supporting alternative user interaction modalities (with significantly higher accessibility than common for "ordinary" apps, adapting to the increasing manual dexterity impairments of the patients), with simple and scalable navigation structure, optimal balance between menu structure and dynamic interaction flows, and designed for long-term usage, in the UI/UX aspects.

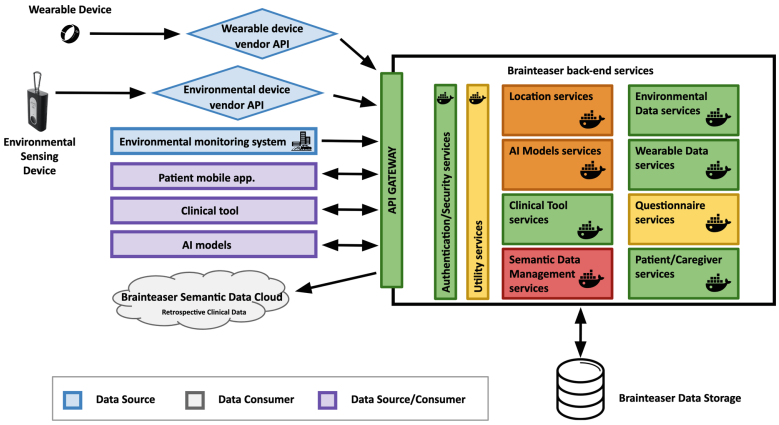

Fig. 7. BRAINTEASER ecosystem architecture with main data sources, consumers and flows, and detailed service tier breakdown.

In the overall architecture of the underlying supporting BRAINTEASER data collection, management, and provision ecosystem (Fig. 7 above), similar microservice modularity methodological principles have been followed, including the separation between domain-specific and infrastructural/utility orthogonal logic, and taking into account the

system and service performance and security aspects built into the design and architecture from the start, employing loose coupling and service orchestration patterns like the baseline *API Gateway* facade pattern that may evolve into more comprehensive orchestration pattern (like ESB) if complexity or performance criticality increases in the ongoing iterative further advancement of the architecture.

4 Conclusion

The presented demonstrated working tools in the initial version constitute the foundation of the novel ALS and MS management and monitoring leveraging extended IoT sensing and emerging instruments infrastructure, and a basis for integration of more advanced and effective AI models (in development) for disease progression prediction, patient stratification and ambiental exposure assessment.

References

1. Bergamaschi, R., Pichiecchio, A., Borrelli, P., et al.: Air pollution associated to the multiple sclerosis inflammatory activity as measured by brain MRI. Mult. Scler. J. **24**(12), 1578–1584 (2018)
2. Cortese, A., Lova, L., Comoli, P., et al.: Air pollution as a contributor to the inflammatory activity of multiple sclerosis. J. Neuroinflammation **17**, 334 (2020)
3. Türk Börü, Ü., Bölük, C., Taşdemir, M., et al.: Air pollution, a possible risk factor for multiple sclerosis. Acta Neurol. Scand. **141**, 431–437 (2020)
4. Ottaviano, M., Beltrán-Jaunsarás, M.E., Teriús-Padrón, J.G., et al.: Empowering citizens through perceptual sensing of urban environmental and health data following a participative citizen science approach. Sensors **19**(13), 2940 (2019)
5. Vito, D., Ottaviano, M., Cabrera, M.F., et al.: Public health observatories: a learning community model to foster knowledge transfer for sustainable cities. In: Proceedings of the 6th International Conference on Higher Education Advances (Valencia), pp. 1383–1390 (2020)
6. Ottaviano, M., Teriús-Padrón, J.G., Gonzalez-Martinez, S., et al.: Participative app. for citizens to assess health risks and increase pollution awareness. In: Proceedings of the IEEE EMBS International Conference on Biomedical & Health Informatics (BHI), pp.1–1 (2019)
7. García-Betances, R.I., Cabrera-Umpiérrez, M.F., Ottaviano, M., et al.: Parametric cognitive modeling of information and computer technology usage by people with aging- and disability-derived functional impairments. Sensors **16**(2), 266 (2016)
8. Vito, D., et al.: The PULSE project: a case of use of big data uses toward a comprehensive health vision of city well being. In: Jmaiel, M., Mokhtari, M., Abdulrazak, B., Aloulou, H., Kallel, S. (eds.) The Impact of Digital Technologies on Public Health in Developed and Developing Countries. Lecture Notes in Computer Science, vol. 12157, pp. 423–431. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-51517-1_39
9. Urošević, V., Paolini, P., Tatsiopoulos, C.: An interactive environment for managing detected data towards geriatric prevention. In: 2017 IEEE 3rd International Forum on Research and Technologies for Society and Industry (RTSI), pp. 1–5 (2017)