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TECHNICAL REPORT

Proposing an undergraduate framework for intensifying medical training on stroke diagnosis and management *via* a multimodal approach

Konstantinos Kalafatakis

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Abstract: The increasing prevalence of stroke at a global scale and the ever-growing complexity of its prompt and proper management by the healthcare personnel, involving pre-hospital, in-hospital emergency and subacute actions, as well as long-term rehabilitation and secondary preventive measures, create the need for shifting medical training on stroke to earlier stages. In this technical report, I propose an action plan for the improvement of undergraduate training on stroke by accommodating four teaching sessions dedicated to this topic into a relevant module of the medical curriculum. Modern educational technologies, such as augmented reality and multimedia, can assist the delivery of these sessions, and the structure of flipped classroom can also be followed in order to enhance the efficiency of the learning outcomes. Quality indices for assessing educational excellence of the proposed action plan, ethical remarks, as well as an indicative deployment, implementation, and dissemination timeline are also discussed. Finally, the philosophy of this action plan is placed it into the wider context of recent advances in medical education.

Keywords: action research; augmented reality in education; flipped classroom; multimedia in medical training; stroke

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Stroke is an ever-increasing health issue, without geographical or sociodemographic predominance, that constitutes a significant part of the clinical routine for multiple medical specialties; mainly for neurologists and doctors practicing internal medicine, but also for neurosurgeons, geriatricians, interventional radiologists, cardiologists, vascular surgeons, and doctors working in intensive care units (Meretoja *et al.*, 2017). Due to the ageing population, stroke is expected to cover in the future an even bigger portion of the overall clinical cases that these medical specialties have to deal with (Wafa *et al.*, 2020). Thus, the need for acquiring an effective training on promptly diagnosing and properly treating stroke at earlier stages of the medical education becomes apparent (Kato *et al.*, 2017). The skills required by healthcare professionals to become competent in properly managing stroke patients rely on good knowledge of basic and clinical neuroscience (brain / spinal cord perfusion, anoxic response of neurons and glial cells, patterns of neurological damage, neurological examination, and imaging of the central nervous system), but also extend to generic patient management within the hospital setting, a holistic diagnostic approach (monitoring various systems, such as the cardiovascular system, circulation, and metabolism), cardiovascular therapeutics (for example, treating hypertension, arrhythmias, large vessel stenoses or occlusions), and a multidisciplinary approach for long-term rehabilitation and secondary prevention.

In most European medical curricula (being either 6-year-long, with a more distinct separation between the

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first 3 years of preclinical training and the late 3 years of clinical training, or 5-year-long, with a less obvious differentiation between preclinical and clinical training), undergraduate students do not usually directly engage with the topic of stroke management before clinical exposure. In rare cases they may do, but the experience acquired is fragmented and circumstantial. Thus, there is a need for intensifying undergraduate (theoretical and practical) training around approaching the stroke patient in the acute- and long-term setting. This technical report suggests the development of an action plan (Cornish *et al.*, 2023) in order to improve the stroke education of medical students in their early curricular stages. It aims at providing academics, responsible for implementing changes to the medical curricula in their universities, with a conceptual framework for advancing stroke education and evaluating its impact on the learning efficacy of medical students in the early undergraduate stages of medical training. Moreover, this technical report attempts to set a general direction for improving undergraduate stroke education, rather than proposing a stringent institutional plan intended for imminent implementation by a medical school.

Proposed framework for undergraduate-level medical training on stroke management

The proposed action plan involves the integration of a series of four seminars (one per module week) into a relevant preclinical module (during year 3 of a 6-year-long curriculum or during year 2 of a 5-year-long curriculum). This could be a module on medical neuroscience, internal medicine, pathology, or pharmacology, depending on the availability of such modules in the corresponding medical curriculum. The seminars must combine three different techniques and educational approaches: (i) augmented reality, (ii) multimedia, and (iii) the flipped classroom concept. In particular, during the first session, students could revise functional vascular neuroanatomy by utilizing a virtual or an augmented reality environment, following recently published methodologies (Moro *et al.*, 2021; Gurses *et al.*, 2024). For the second and third sessions, custom-made videos, produced in collaboration with consultant neurologists and multimedia experts, should be used in order to capture real-life scenarios from the emergency departments. These should depict the hospital approach of ischaemic and haemorrhagic stroke patients (history taking, neurological examination, ordering paraclinical examinations, performing various interventions, diagnosing, and deciding on treatments and overall management) and must be developed for the students to watch and comment on. These sessions must be complemented by flipped classroom ones, for which students would have to read certain landmark papers in advance and engage into interactive discussions about the management and treatment of stroke (Feske, 2021; Montaño *et al.*, 2021). Finally, the last session must also have a flipped classroom structure around the long-term rehabilitation and secondary / tertiary prevention strategies (Stinear *et al.*, 2020) (Figure 1A).

The use of virtual and augmented reality technologies is being gradually introduced into education in general, and into university-level curricula in particular, over the last decade. In certain counties such as Australia and Spain (mainly), but also in Germany, the Netherlands, the United Kingdom, Canada, Brazil, and Turkey, these tools have been experimentally implemented into health science programmes, mainly for the teaching of anatomy. Various aspects of these tools, such as the use of multimedia technology, three-dimensional (3D) modelling, real-time tracking and registration of objects, as well as the intelligent interaction and detection of images, facilitate the ability of students to perceive an anatomical model in a real 3D plane without losing the user's own sense of environment. They also help optimize the acquisition of anatomical knowledge in students with lower visual and spatial skills. Moreover, the use of augmented reality strategies gives better learning outcomes evidenced by higher content retention, better academic performance in solving tasks, and a greater capacity to interact and contextualize the biological structures observed in nature, while encouraging dialogical learning through peer interaction. Furthermore, augmented reality enables the development of new skills such as the spatial ability through 3D visual stimuli, thereby combining the experiences of real-world environments with those deriving from virtual ones (Roman *et al.*, 2024). Other studies have already indicated that such tools increase self-confidence, motivation, attention, empathy, and interest (Calvert and Abadia, 2020). Of course, one needs to take into serious consideration the main obstacles identified when trying to implement such tools into university education, such as the cost, the lack of educator training and improvement, the limited number of educational experiences found, the lack of conceptual foundations, the limited educational research on the topic, and the lack of institutional support (Barroso-Osuna *et al.*, 2019). Still, accumulating evidence suggests that virtual / augmented reality approaches offer diverse advantages in neuroanatomical education, such as reducing the cognitive load of students, improving learning outcomes in cross-sectional anatomy and spatial orientation, increasing motivation for and satisfaction from learning neuroanatomy, and improving overall knowledge retention (Kockro *et al.*, 2015; Stepan *et al.*, 2017; Ekstrand *et al.*, 2018; Henssen *et al.*, 2020; Bölek *et al.*, 2022; Aridan *et al.*, 2024).

As already mentioned, one component of each seminar should have the structure of a flipped classroom so as to include an asynchronous pre-session part, in

which students would be able to engage with the plenary type activities and other study material in advance. The material should mainly involve landmark papers on the clinical approach of stroke. During the synchronous session, students should be able to spend about 90% of the in-session time engaging with interactive individual, whole-class exercises, requiring either the physical / intellectual interaction between the students or their interaction with a digital tool like Mentimeter (Ahmad, 2020). The flipped classroom model has emerged as an innovative solution for the improvement of student-centred learning. The impact of the flipped classroom in the context of a medical curriculum has been examined in the past. Over 200 junior medical students from the University of Utah participated in a 2-year-long study: half the cohort was being taught anatomy with the traditional way (*via* classical lecturing) and the other half was being taught the same topic through a flipped classroom approach. The performance of students in 28 multiple choice anatomy items (some of which required simple recruitment of knowledge, some application of that knowledge, and some critical analysis) were compared between the two classes of students (Morton and Colbert-Getz, 2017). Results showed that the flipped classroom approach may benefit retention when students are expected to analyse material; i.e., when students need to climb to higher levels of the Bloom's revised taxonomic learning pyramid (Krathwohl, 2002), which is the desired case in the proposed action research.

Quality indices for assessing educational excellence

Various sources of data can be collected in order to evaluate the action. Students will need to complete computerized questionnaires at the end of each seminar so as to allow us to assess their satisfaction and rate their experience with using the augmented reality equipment, their level of engagement in the debate surrounding the video presentation of the real-world stroke management cases, and the usefulness of discussions around the different topics on key stroke literature. Moreover, students could be asked to complete another type of computerized questionnaires (at the beginning of each seminar following the first) on the acquired knowledge they gained during the previous seminar. The questions could have the form of the single-best answer type, and could test for neuroanatomical knowledge, the capacity of students to critically analyse the multimedia material that they have watched in order to comment on stroke management in the hospital setting, and the depth of studying the key literature on stroke. Finally, a global assessment session could take place after the end of the action, between the study participants and gender- and performance-balanced control peers, simulating the final exams that students undertake; this would establish a measure of the impact of the action on the standard / current educational practices (Figure 1A).

Analysis of the results can be qualitative and quantitative. For the questionnaires measuring student satisfaction and the in-course testing of their knowledge, results / student performance can be discussed among the faculty members in order to specify whether the seminars achieve their goal, or whether significant modifications to the content or design of the seminars should be decided. The results of the global assessment session must undergo a statistical analysis so as to confirm or reject the hypothesis that this action plan can achieve significantly better learning outcomes for students about stroke, compared to current practices.

The questionnaire on student satisfaction should be designed according to general recommendations; for instance, questions should be constructed to be as clear, simple, specific, and relevant for the study's research aims as possible, should focus on current attitudes, more general questions should precede more specific questions, Likert-type responses should be considered as desirable, and scale length ranges should include from five to eight response options (Lietz, 2010). Moreover, the questionnaire should be tested for reliability and validity in a preliminary study (Taherdoost, 2016), and must be influenced by the work of Aldridge *et al.* (2012), who have developed a new learning environment questionnaire for reflection in teacher action research. Their new learning environment questionnaire contains 88 items that measure 11 dimensions of the actual and preferred classroom environments; namely student cohesiveness, teacher support, involvement, personal relevance, task orientation, cooperation, equity, differentiation, young adult ethos, formative assessment, and clarity of the assessment criteria.

Training on stroke management: placing it into the wider context of recent advances in medical education

This action research must carefully consider the wider transformations that take place in medical education over the last few years, which encompass ubiquitous and digitalized healthcare systems, exponentially expanding medical knowledge, artificial intelligence and advanced healthcare-centric technology, and globalized digitization; the latter is a generic societal feature that drives the learning style of modern students and dictates the evolution of new strategies by educators in order to facilitate the process. In this context, various initiatives of the last two decades have specified a number of competencies to be integrated into education for healthcare professionals (patient-centred care, interdisciplinary teams, evidence-based practice, quality improvement, and informatics) and have defined

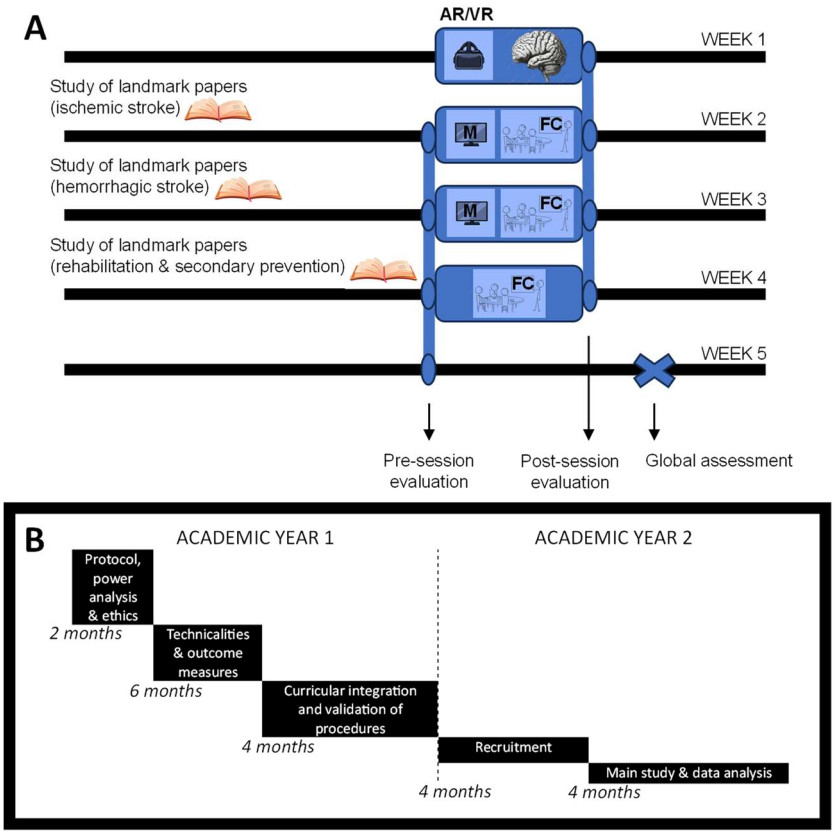

Figure 1. (A): Structure of the action plan regarding the boosting of stroke education at the early / preclinical stages of the medical curriculum. Four sessions could be integrated into an equal number of consecutive weeks. During session 1, neurovascular anatomy could be revised with the assistance of modern technologies (augmented and virtual reality; AR/VR). At the pre-session stage of sessions 2, 3, and 4, students could be given literature to study in advance. Students must be expected to engage into interactive discussions about the management and treatment of ischaemic stroke (session 2), haemorrhagic stroke (session 3), and the long-term rehabilitation and secondary prevention of stroke (session 4) in a flipped classroom (FC) design. Sessions 2 and 3 could also contain a part of video-watching of stroke cases (M), from the moment the patient enters the emergency department until admission to the neurology / internal medicine ward, aiming at provoking a debate among students and instructors around the acute management of the condition. Students could complete a computerized set of questions at the end of each session in order to assess the level of their satisfaction, as well as a computerized set of questions at the beginning of each session, from the second session onwards, in order to assess the efficiency of the learning process achieved by the previous session for the given cohort of students. A global assessment could take place at the end of the 4-week period involving the group of students engaged into the action plan and a control (gender- and performance-balanced) group of peers, so as to evaluate whether the action plan makes any difference on the level of the students' theoretical training surrounding stroke. (B): Indicative timeline for designing, setting up, deploying, and implementing the action plan into the medical curriculum, which spans across two academic years.

additional parameters related to the educational process *per se* (like the training environment, the importance of research, public reporting, leadership, accreditation, standardization, and individualization, integration, the habit of inquiry and improvement, as well as identity formation). The most recent effort, that attempted to specify themes and subthemes of medical educational trends for future physician training, has highlighted four domains: the humanistic approach to patient safety (i.e., encouraging humanistic doctors and facilitating collaboration), early experience and longitudinal integration (i.e., early exposure to patient-oriented integration and longitudinal integrated clerkships), moving away from the hospitals towards society (i.e., responding to changing community needs and respecting for diversity), and student-driven learning with advanced technology (i.e., active learning with individualization, social interaction, and resource accessibility) (Han *et al.*, 2019). On another note, various sources of evidence indicate how useful healthcare simulation and educational contexts analogous to simulation can be for medical training (Ayaz and Ismail, 2022).

Moreover, the proposed action research should se-

lectively consider the available data on the impact and methods of stroke education from the point of view of different stakeholders implicated in its management and patient support. For example, it has been reported that multi-level stroke education carried out among residents and medical staff can effectively improve the patients' awareness of stroke, as well as the acute management of patients in the emergency department (Zhang *et al.*, 2020), while educational interventions to patients and caregivers may improve the caregivers' knowledge and skills in providing daily care for post-stroke patients, reduce the associated burden and anxiety, and improve their quality of life. Educational interventions may also positively impact post-stroke patients *per se*, by improving their quality of life, their functional abilities, and their ability to undertake daily activities, as well as by reducing cognitive impairment, anxiety, and depression (Rumiati *et al.*, 2021). Finally, different educational approaches have been recruited in order to facilitate training on the topic in audiences of varying origin (either healthcare professionals or patients, or even the general population); such approaches include classical lectures, videos / televised media, comics, written manuals, cartoons, electronic games, flyers, and posters (Maniva *et al.*, 2018).

The proposed action research must consider the specific areas of currently unmet needs or ongoing study concerning the epidemiology and management of stroke. These should include: (i) multicentre observational studies in community and rural areas aiming to explore stroke outcomes and management patterns so as to allow for comparisons between patients in urban areas and those in rural ones, (ii) longitudinal studies aiming to explore temporal trends of risk factors, treatment patterns, and stroke outcomes, (iii) prospective studies and clinical trials on the natural history and management of silent cerebral infarcts and asymptomatic carotid artery plaques, (iv) studies on the causes and the management of cerebral small vessel disease (including intracerebral haemorrhage), (v) studies on the implementation of emergency services and stroke unit care according to international, national, or regional quality standards, (vi) studies on the development of widely accessible and affordable strategies for long-term secondary prevention and rehabilitation, and (vii) studies on the early identification of patients at high risk of bleeding in order to provide individualised treatment on blood flow restoration (Wu *et al.*, 2019).

Various secondary goals could be achieved through this action research project. The action could enhance graduate attributes of students, like applying expertise, being digitally fluent, and learning to collaborate and engage in a critical manner. Moreover, this action could increase the awareness of faculty members on the need to modify the medical curriculum frequently and according to the ever-evolving healthcare challenges. The proposed action also aims at increasing the coherence of multiple modules between different stages of the curriculum, further develops the early clinical exposure of medical students, exploits the capabilities of modern technologies such as augmented / virtual reality, and aligns well with the recent updates of the General Medical Council or other regulatory bodies' guidelines on the different routes (*via* geriatrics, neurology, acute internal medicine, or internal medicine) that may lead to the sub-specialty training on stroke medicine. Finally, the action aims at strengthening the student experience within the medical curriculum and clarifying various domains of discrepancy in the practice of stroke management between different healthcare systems, thereby adopting the suggestions of the World Stroke Organisation (Mead *et al.*, 2023) and the United Kingdom's National Clinical Guideline for Stroke. Finally, the action is in line with the Health and Social Care Act 2008 (Regulated Activities) Regulations 2014, which require care providers to ensure safe, person-centred care that comprehensively meets people's needs, including any that arise because of experiencing a stroke.

Ethical remarks

The consent of the healthcare practitioners and of the patients and / or their relatives must be sought for the development of the educational videos. It should be noted that the videos cannot be processed with suitable software in order to distort the discriminatory features of the people presented, since these features (like faces, voices *etc.*) are critical for the clinical evaluation of the patients and, as such, are important in the educational process. Moreover, in relation to the data collection, consent forms of students must be collected and anonymisation and data security in the processing, handling, storage, and analysis of the obtained data must be applied, following the UK General Data Protection Regulation. The study should follow the British Educational Research Association 2018 guidelines when it comes to being responsible towards the study participants, such as by obtaining consent, being transparent with the purpose of the study, the processes followed, and the data produced, giving students the right to withdraw (as their involvement will consume extracurricular time), ensuring secure and appropriate data storage, being responsible towards the community of educational researchers, and having a responsibility for the publication and the dissemination of the findings. Moreover, all types of data collected from the study should be electronic, be stored in password-protected and institutionally-owned workstations, and be backed up into institutional and cloud-supported central servers. Any data analysis output must also be produced in a computerized form, by a software accessible only to researchers and institutional staff members, and must

be similarly stored in the aforementioned entities. For study-specific databases, once the database has passed acceptability testing and is version-controlled, it is deemed active. Acceptability testing involves local user, functional, and design specifications. It is essentially tested by a study researcher for ease / simplicity of use. The electronic databases must be updated weekly with the new data acquired.

Healthcare practitioners, patients, and anyone else included in the educational videos must be asked to give their consent in written form, after being informed in detail about the purpose of the videos and how they will be processed and handled by the institution and the faculty. For patients that might not be able (due to their medical condition) to give their consent, relatives must provide the necessary permissions (Lamont *et al.*, 2019). Students must also be properly informed about the content, the purpose, and the timeline of the action research, as well as about the data to be collected and how they will be processed and analysed. Students must also be asked to give their consent before participating in the study. Finally, students must be explicitly informed that they retain the right to withdraw from the study at any stage, for any reason, without having to explain their decision.

Anonymisation must be applied to all data acquired at a pre-processing level (Godfrey-Faussett, 2022). A member of the academic staff, who must not be part of the action research team (i.e., not involved in data collection, processing, or analysis) must create, store, and back up an electronic document with unique identification codes (a combination of letters and numbers) assigned to each student participating in the study. Students must use these codes (instead of their names or their student ID numbers or any other discriminatory words or phrases) when completing questionnaires or assessments. A breaking of the anonymisation must only take place – if deemed necessary – after the publication of the data.

Practical remarks and indicative timeline for development, implementation, and dissemination

The realistic span of the action research should cover two academic years. The project must be divided into a preliminary stage (corresponding to academic year 1) and a main part (corresponding to academic year 2). During the preliminary stage, the action research protocol should be finalized and submitted for ethical approval. The necessary virtual / augmented reality equipment must be brought and installed into the teaching facility that will host the proposed action plan, while the software allowing the production of the desired optical output for the neuroanatomy lessons must be developed based on current proposed practices in academia (see, for example, Mendez-Lopez *et al.*, 2022). The necessary software validation and optimisation steps must also be performed. Subsequently, the videos showing the real-life management of stroke cases within the hospital setting must be produced, processed, and integrated into the educational material of the seminars under development, with assistance by multimedia experts. This stage of the project might take some time to cover all the topics included in the teaching plan, and thus, the collaborating hospital should be carefully chosen with the expectation of it to receive a great number of stroke cases and to possess strong expertise in the proper management of such cases. Nevertheless, even if the videos contain scenes of suboptimal clinical decisions, they still retain their educational value, given the fact that these scenes can act as the basis for group discussions during the seminars between the students and the faculty staff. The latter must also be responsible for collecting and organizing all educational material into four cohesive seminars, serving the best way possible the predefined learning outcomes. Finally, the faculty members must develop the questionnaire about the student satisfaction as well as the assessment tests, must define standard operational procedures, and must consolidate the data management plan. The questionnaire on student satisfaction should be validated before being used in the main study. A power analysis must be performed in order to establish the ideal number of participants. At the start of the next academic year, the action research must be advertised to the cohort of target students, and participants should be enrolled on a gender-balanced, "first come, first served" basis, until reaching the prespecified number of students. Data analysis must take place right after finishing with the main study (Figure 1B).

The evaluation and the dissemination of the action must commence after data analysis. The outputs of the project must be discussed internally with a panel of academics containing neurologists, neuroscientists, and experts in the wider field of medical education. The purpose of these discussions should be to establish whether these outputs are strong indicators for changes in the undergraduate medical curriculum. Moreover, participating students must be kindly asked to create short presentations reflecting on their educational experience, and to discuss with their peers about its positive and negative aspects. The findings of the study must be also contrasted against complementary efforts (proposed over the last 15 years) to increase stroke management competency in healthcare professionals (Donnellan *et al.*, 2013; Lindsay *et al.*, 2014; Reynolds *et al.*, 2016), so as to place them into the wider context of this educational domain. Aside being disseminated through relevant conferences (for instance, the conferences of the World Federation for Medical Education or of the International Association for Health Professions Education) and peer-reviewed journals (e.g., *Academic*

Medicine, *Medical Education*, *Advances in Health Sciences Education*, *Medical Teacher*, *BMC Medical Education*, *Journal of Medical Education and Curricular Development*, *International Journal of Medical Education*), the outcomes of the action research could also be communicated to professional bodies of clinicians (for instance, the General Medical Council, the European or the American Academy of Neurology, the American Neurological Association or the World Federation of Neurology), especially to those relevant to stroke experts (such as the World Stroke Organization), in order to increase awareness on the importance of intensifying stroke education from the early years of the medical curricula.

Conclusion

This technical report proposes the implementation and evaluation of a new educational framework on stroke management at the undergraduate level of medical training, after considering the ever-increasing prevalence and complexity of the multimodal management of this condition, and by introducing modern technologies and pedagogical trends into the learning process. This technical report aims at acting as a guide for medical schools towards intensifying stroke education at the earlier stages of the undergraduate curriculum.

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Conflicts of interest statement

None to declare.

Data availability statement

Not applicable.

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Affiliation(s)

Neurology Department, General Hospital of Athens "*Pammakaristos*", Athens, Greece; Human–Computer Interaction Laboratory, School of Informatics & Telecommunications, University of Ioannina, Arta, Greece *(KK)*

Correspondence

Konstantinos Kalafatakis
Neurology Department
General Hospital of Athens "*Pammakaristos*"
Athens, Greece
kgkalafatakis@gmail.com
k.kalafatakis@uoi.gr