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Article

An Integrated Support System for People with Intellectual Disability

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Abstract: People with Intellectual Disability (ID) encounter several problems in their daily living regarding their needs, activities, interrelationships, and communication. In this paper, an interactive platform is proposed, aiming to provide personalized recommendations for information and entertainment, including creative and educational activities, tailored to the special user needs of this population. Furthermore, the proposed platform integrates capabilities for the automatic recognition of health-related emergencies, such as fever, oxygen saturation decline, and tachycardia, as well as location tracking and detection of wandering behavior based on smartwatch/smartphone sensors, while providing appropriate notifications to caregivers and automated assistance to people with ID through voice instructions and interaction with a virtual assistant. A short-scale pilot study has been carried out, where a group of end-users participated in the testing of the integrated platform, verifying its effectiveness concerning the recommended services. The experimental results indicate the potential value of the proposed system in providing routine health measurements, identifying and managing emergency cases, and supporting a creative and qualitative daily life for people with disabilities.

Keywords: intellectual disability; user interface; content; information; entertainment; user profile; inference model; caregiver; health emergency; wandering alert

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1. Introduction

Intellectual Disability (ID) is one of the most common neurodevelopmental disabilities worldwide [1] and, in 2019, was estimated to affect about 2% of the global population, with significant regional inequalities (highest prevalence rates in low–middle sociodemographic index regions) [2]. Although ID may be isolated, it is frequently linked to other neurodevelopmental disorders, such as autism, sensory (hearing, vision) or motor impairments, sleep and eating disorders, as well as medical conditions such as epilepsy. It can also be associated with a wide range of psychopathological issues, such as anxiety, depression, and emotional regulation disorders [3]. The ID condition affects individuals in significant ways throughout their entire lives, in important aspects such as health, well-being, education, recreation, employment, citizenship, community participation, and financial stability [2]. According to the study in Ref. [4] people with ID encounter difficulties in expressing their feelings, and they are likely to be victims of fraud, bullying, and harassment. This makes people with ID one of the most vulnerable groups in our society that deserve great attention in order to deal with their difficulties in managing daily activities and accessing health services, but also to participate more actively in education, creative avocation, recreation, and to enhance their interaction with other people. Addressing these issues could promote their independence, self-confidence, self-sufficiency, health care, and inclusion in socio-cultural activities.

Assistive technology (AT) is identified as a vehicle for better self-functioning and independence, and for promoting the overall well-being of people with ID, but also, as highlighted by the World Health Organization (WHO), for improving population health and upholding basic human rights [5]. In Ref. [5] the factors related to the use of AT by people with ID are analyzed and they are categorized into two groups: (a) aspects of ID that may be associated with a need for AT (impairment of adaptive or cognitive functioning), comorbidities (e.g., neurological impairments, mental health problems, obesity), multimorbidity, frailty, misdiagnosis, underdiagnosis, and common impairments and (b) aspects of AT provision that may be associated with ID, including AT for ID (e.g., simplified mobile phones), AT for other disabilities often associated with ID (e.g., hearing aids), and AT for other impairments (e.g., prosthetic limbs). However, it is crucial to identify and address any barriers that may hinder their usage by people with special needs, including ID. AT has been recommended as an intervention to enhance the quality of life of patients and their caregivers in the United Kingdom's clinical practice guidelines [6]. Regarding the comorbidities of people with ID, AT has the potential to increase the safety, confidence, and independence of dementia patients, while also reducing behavioral and psychological symptoms and maintaining cognitive and social functioning [7–10]. Along the same direction, several studies have investigated the influence of AT on improving the active behavior, entertainment opportunities, and communication abilities of individuals with intellectual impairments [4], while specialized software applications, platforms, devices, and specialized equipment are increasingly used to maintain and enhance their functional capabilities. However, existing systems are limited to incorporating few or even a single service, e.g., job, product or content recommendations, games, detection of health issues, medication reminders, support of physical activities, etc. Based on and motivated by the lack of an integrated system that provides several different functionalities, a complete platform conception is proposed, covering not only the digital information, entertainment, and education aspects, but also the necessary outdoor monitoring of people with ID, related to their psychological and physical well-being, respectively.

In this paper, we present an integrated system, which consists of several components performing different functionalities, tailored to the special needs of people with ID. The proposed system is designed and developed within the framework of the QuaLiSID research project and aims to deliver an appropriate, interactive content recommendation platform for people with mild, moderate, and severe ID, while serving the detection of emergency cases. It constitutes an easy-to-use solution, serving information and entertainment, education and communication, and at the same time serving as an automated system support and delivering appropriate notifications to the caregivers so they can provide assistance, following the detection of urgent situations related to health issues, as well as disorientation and wandering [11]. Its novelty lies in combining all the above-mentioned characteristics into an integrated platform addressed to people with ID, regarding the friendly and convenient user interface, the content recommendation services for information, entertainment, and education, the automatic detection of emergency cases, the issuing of respective alerts and notifications to the carers, and the corresponding system assistance.

This paper is organized as follows. In Section 2, the research and technical works from the literature related to the individual components of our integrated platform are briefly described. In Section 3, firstly, the people with ID who participated in the initialization and testing of the proposed platform are presented, focusing on their individual characteristics. Following this, the discrete technical components of the integrated system and the deployed research methods are described in detail. Subsequently, in Section 4, indicative results associated with the testing of our platform's separate components are presented and discussed in Section 5. Finally, conclusions are drawn in Section 6 regarding the system's limitations, potential exploitation, and future works in order to further enhance and expand the functionality of the proposed platform.

2. Related Work

Several initiatives, research projects, platforms, and applications have been developed revolving around the use of digital technologies for assisting Individuals with ID (IID) and their families. Along this direction, a recent study [12] concluded that using digital devices can have positive effects on children and adolescents with ID, including improvements in executive function, basic cognitive—linguistic skills, academic skills, and social and behavioral skills; thus, they can prove highly assistive to people with disabilities. The assistive technologies are either integrated platforms serving different functionalities or mobile applications tailored to particular services. In the following subsections the related platforms, as well as mobile sensor-based and smartphone applications, are reported in detail.

2.1. Integrated Platforms

Several platforms aim at providing support to IID, as well as services in different domains, such as training, education, content recommendation, socialization, and employment. The ELPIDA e-learning platform [13] offers training to people with ID, as well as awareness raising and/or attitude changes in the areas of human rights, communication, stress management, transition to adulthood, sexual health, and aging. The ENABLE inclusive learning platform [14] offers training services to IID, their families, professionals in ID, and local community representatives, while the Stomp interactive platform [15] has been designed to support the social and physical interaction for IID through tangible user interfaces. KIDEA [16] constitutes an innovative application that provides multimedia content for learning fundamental life skills, in order to increase the autonomy and independence of children with ID, and the MAS platform [17] aims to assist and reinforce the learning capabilities of IID, offering games and processing/monitoring tools. The IDPLIVING e-training platform [18] supports the understanding of educational material and experiential training activities for IID, aiming to strengthen and facilitate their community life. Moreover, the LudoMinga games-based platform [19], has been designed to facilitate the learning process of people with ID, providing an inclusive and accessible learning environment. Healthy Mind [20] is an online Easy Read tool designed to help people with ID recognize and regulate their thoughts and feelings. Following this, the MySigns web application [21] can be used to support mental health and communication difficulties assessment of an IID. This tool is designed for collaborative use by individuals with intellectual impairments, their caregivers, and their mental health clinicians. Finally, regarding the complicated issue of employment for IID, technical efforts suchthe ERGASIAMOU job search platform for people with intellectual disabilities in Greece [22] and the Inclusion International network [23] attempt to enable individuals with disabilities to find employment and earn a—as possible—financially independent living.

Several websites have been constructed in order to support IID and their families, such as the Puzzle website [24], which aims to facilitate access to information, education, and training for young people and adults with ID in certain European countries. The epic web page [25] features the services of a non-profit disability support provider specializing in essential services such as transportation, home care, physical activities, community living support, etc., that promote independence. Other web pages, e.g., the site of the DEP project [26], are addressed to IID and their families who are in need of psychological support and rehabilitation services.

Regarding the recommendation services to IID, there is a limited number of projects dealing with the recommendation of multimedia content [4]. The delivery of personalized multimedia content in interactive Internet Protocol (IP) television environments in Ref. [27] is carried out by taking advantage of information gathered through the users' interaction with the system and generating profiles that reflect groups of similar users, while it consequently adapts profiles created for groups of users to each user's preferences. Moreover, the smartphone-based MUBS recommender system for behavioral activation [28] introduced a personalized content-based activity recommendation model using a unique list of 384 enjoyable activities from the following six categories: work/education, daily living, practical, spare time, movement, and social.

2.2. Mobile Sensor-Based Applications and Wearable Technologies

Apart from the interaction and communication difficulties, research suggests that in many cases, health problems of IID are either undetected, not communicated to the caregivers, or poorly managed by healthcare services [29]. Recent advances in Information and Communication Technologies (ICT), particularly IoT/wearable technologies [30], can contribute to improving the well-being and quality of life of IID and their caregivers [31] by offering early warning for different symptoms. For example, in Ref. [32] a smartwatch application was developed in order to help users improve their ability to focus on tasks, reduce their anxiety via mindful meditation, and improve their overall mental health via positive message priming. More recent smartwatch applications also aim to detect COVID-19 symptoms by exploiting heart rate variability (HRV) [33]. In more detail, current smartwatches in the market can support many different sensors that can be used for health monitoring (e.g., heart rate, respiration rate) [34], including specialized sensors such as ECG sensors. However, up to this day, most smartwatches encounter problems in properly measuring very common biomarkers, such as body temperature [35].

Additionally, disorientation and wandering are common behaviors of people with ID that might occur during their daily activities. This behavior is described by research on Autism Spectrum Disorder (ASD) as movement through space lacking intention or exact destination, as when a person is disoriented or not self-aware [36]. Wandering away from home or facilities is dangerous for IID and stressful for families and caregivers when those who go missing cannot be located. Frequently, wandering activity is associated with adverse events such as falling, elopement, getting lost, and emotional distress [37]. In this context, emerging technologies offer a promise of comfort and security in being able to easily locate a missing one. A lot of research has been dedicated to the detection of disorientation or wandering-like behaviors, a complex task highly influenced by the location-based technologies used and the context in which people move. Ref. [38] proposed one of the most widely accepted classifications of wandering movements, defining three differentiations: (a) pacing: moving back and forth between two points, (b) circular wandering: circular movements between at least three points, and (c) random wandering: an unpredictable and inefficient course without repeating points. In Ref. [39], the wandering movement was suggested as a spatiotemporal locomotion behavioral pattern that consists of rhythmical movements consisting of two phases: walking and non-walking, and before each non-walking phase, one of the aforementioned walking patterns is presented. Two main research objectives pertain to the wandering of populations with cognitive impairments. The first one focuses on wandering evaluation methods based on the offline analysis of trajectory data. For example, in Ref. [37] an algorithm is suggested to detect Martino–Saltzman wandering movement spatial patterns [38] by analyzing location data concerning direction alterations in trajectories. Furthermore, in Ref. [40] a framework is presented that allows the classification of GPS-based mobility indicators commonly used in the literature based on several characteristic and analytical aspects of mobility. The second one focuses on real-time wandering detection by designing assistive systems to provide IID safety assurance based on online observations. For example, in Ref. [41] an autonomous GPS system that monitors the location of patients is developed, looking for abnormal users' behaviors, e.g., when the person (a) is entering predefined dangerous zones, (b) has exceeded a certain speed, (c) has stopped moving for a specific time or, (d) is wandering. Ref. [42] focuses on real-time detection of spatial wandering patterns, i.e., pacing and lapping movements from users' GPS traces, by examining count turning points in each trajectory. However, wandering patterns may vary for different people, hence, there is no widely accepted technique to automatically detect wandering behavior.

2.3. Smartphone Applications

Mobile devices, including mobile phones, smartphones, and tablets, are highly accessible forms of AT and are more widely used than personal computers and older portable electronic devices [43–47]. Smartphones and tablets provide adults with intellectual impairments a chance to access social media platforms, enabling them to connect, communicate, and participate in activities with others, which can help alleviate the negative effects of social exclusion and stigma [48]. The smartphone revolution has transcended age barriers, extending its impact beyond just children and young adults to also include older adults. The ownership of smartphones among older adults has shown substantial growth, rising from a mere 10% in 2011 to an impressive 61% in 2021 [49].

One of the significant advantages of smartphone and tablet technology is its suitability for healthcare interventions. These devices come equipped with various features such as Internet access, mobile telecommunications, sensors, geolocation data, and notifications. Additionally, they offer the capability to install clinically focused applications [50]. With built-in sensors, smartphones and tablets can provide support similar to dedicated assistive devices without the need to carry an additional device constantly, or the potential stigma associated with more visible assistive devices [51].

Furthermore, as these technologies become increasingly integrated into everyday life, they are likely to be familiar to users. This familiarity makes them easier to adopt as assistive technologies for older adults [7,10]. Despite the widespread adoption of smartphones and tablets in modern society, rehabilitation practice has been slow in embracing these new technologies [43]. In the recent study of [52], a mobile-based augmentative and alternative communication solution is presented, designed as a tool to aid the rehabilitation process of people with ID.

Some of the smartphone applications associated with ID or its comorbidities are listed below:

- Soy Cappaz [53] is a mobile application for IID, available on Android worldwide in English and Spanish. It displays an opening screen with four main sections: (a) My Calendar, (b) Where Am I?, (c) My Tasks, and (d) I Need Help. The application helps with work tasks, answers questions, and provides guidance. It is also useful for daily activities such as using a microwave or catching a bus.
- Viamigo [54,55] is a digital travel assistant with a mobile application interface for IID. It aims to promote independent mobility, reducing the burden on informal caregivers. It teaches users specific routes they can navigate independently, while the informal caregiver monitors them.
- MindMate [56] is an application designed to support individuals living with dementia and their caregivers. It offers features such as cognitive exercises, reminders, and mood tracking. The application also provides access to articles and information related to dementia care.
- MemoryWell [57] is a digital platform that helps create life stories for individuals with dementia. Caregivers and family members can use the application to build personalized narratives and share them with healthcare professionals to improve patient-centered care.
- Alzheimer's Society's Talking Point [58] is an online community and mobile application that allows people affected by dementia to connect, share their experiences, and seek support from others in similar situations.
- Elder 411 [59] is an application designed to provide practical advice and tips for caregivers of individuals with dementia. It covers a wide range of topics, including communication strategies, safety measures, and resources for additional support.

- Timeless [60] is an application that offers reminiscence therapy to people with dementia. It allows users to access a vast library of pictures, music, and videos from the past, which can stimulate memories and encourage conversations.
- CogniCare [61] is an application designed to help caregivers manage their daily responsibilities effectively. It provides tools for medication tracking, appointment reminders, and communication with other caregivers or family members.
- GPS SmartSole [62] has been designed for caregivers to monitor the location of individuals with dementia who wear a special shoe insole with a built-in GPS tracking system. It can be particularly useful in cases where the person tends to wander.
- PainChek [63] is an application designed to help healthcare professionals assess pain levels in individuals who may have difficulty communicating, such as those with advanced dementia.
- Puzzle Me [64] allows caregivers and their loved ones with dementia to solve puzzles together virtually, fostering a sense of engagement and connection.

3. Materials and Methods

The proposed system constitutes an integrated platform that provides substantial support to people with mild, moderate, and severe ID, regarding the recommendation of appropriate information, entertainment, and educational content, and on the other hand, the detection and management of emergency situations related to health and disorientation issues. The design of this multi-functional system takes into account the issues that people with ID have in their interaction with Information Technology (IT) systems, their difficulty in expressing how they feel, as well as the need for continuous outdoor surveillance.

As far as the content recommendation features are concerned, several systems have been developed for delivering multimodal material through web applications and corresponding mobile devices [65,66]. Focusing on the group of people with ID, the characteristics that a content recommendation system should have in order to efficiently serve these individuals are reported in Ref. [4]. Based on this analysis, we have developed a content recommendation system that covers a variety of requirements. In order to generate personalized web-content recommendations to the users, the semantically relevant items are identified, based on the information stored in the individuals' user profile, reflecting their preferences, interests, and special skills.

A user-friendly interface has been designed for convenient use by people with ID who encounter difficulties in efficiently handling web platforms. The content is categorized into thematic topics, which have been formed according to the general preferences and interests of people with ID, following the responses on interviews and questionnaires of such a group (see Section 3.1) who participated in the testing and evaluation of the integrated platform. Additionally, the individual preferences in the user profile are automatically updated according to the actual user's web activity (implicit feedback), which reduces the manual involvement of the user, allowing the constant provision of suitable recommendations. The proposed platform takes into consideration the crucial issue of exchanging information in a secure way, concerning the protection of personal data, but also the safety of the content that people with ID have access to. The latter is achieved by pre-filtering the candidate recommendations in order to exclude violent or any kind of potentially harmful content.

Furthermore, emergency detection, which constitutes another substantial component of our platform, concerns the current health status of people with ID through monitoring of critical biosignals by means of a smartwatch and the disorientation and/or wandering detectors, utilizing the location monitoring features of smartphones [67]. The system provides appropriate alerts to the caregivers with respect to the detected urgent cases. In addition, the proposed platform integrates automated speech recognition and text-to-speech technologies on smartphones, which minimize the manual intervention of the user, offer information, entertainment, and offer communication services through voice interaction with a virtual assistant, using a specialized smartphone application. The latter also includes limited automated assistance, implemented as voice instructions in particular detected circumstances, such as increased body temperature. Other notifications, such as medication reminders and alerts of upcoming adverse weather conditions, towards users with ID, their carers, and close relatives have been integrated into the platform. Finally, the smartphone is equipped with an emergency (S.O.S.) button for voluntary usage, when the individual with the ID feels uncomfortable.

As opposed to other systems and applications that implement few or a single operation addressed to an IID, the architecture of the proposed platform depicted in Figure 1 incorporates different substantial functionalities of content recommendation, emergency detection, alerts and notifications, mobile virtual assistant, etc., consisting of discrete fixed (i.e., server, computers) and mobile (smartwatches, smartphones) components. Moreover, the rationale behind choosing smartwatches instead of other wearable devices, lies in the fact that the former is proved to be quite acceptable by IID, based on the carers' experiences.

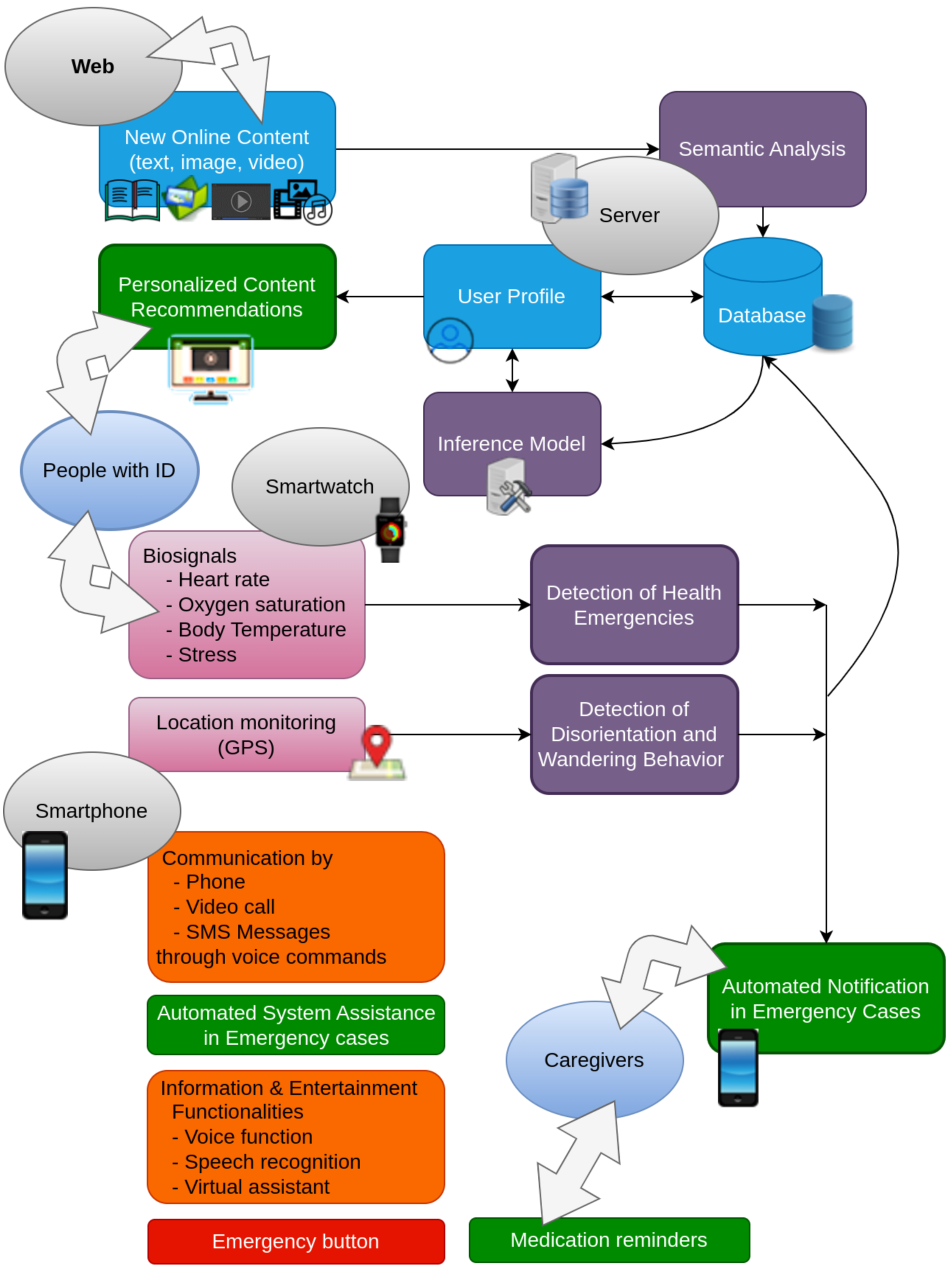


Figure 1. Integrated system architecture. The shapes with the same color express similar component types.

The evaluation plan includes a short-scale pilot study in the users' environment, during which potential problems or failures of the system or any of its parts can be identified and resolved. Furthermore, during the pilot study, the integration of the system can thoroughly be examined to ensure seamless functionality. The qualitative outcomes of the short-scale study regarding the use of the web-based user interface and the mobile modules are reported and discussed in this paper.

3.1. Participating Users

The participant selection for the study was based on specific criteria confirmed through questionnaires and interviews in a creative activities center that supports people with disabilities. Specifically, the criteria were as follows. First, adults with a primary diagnosis of intellectual disability [68]. Secondly, individuals with varying severity degrees of intellectual disability, i.e., mild, moderate, or severe ID [69]. Thirdly, individuals who had expressed their interest in using technological means such as (a) a computer or tablet that, through an online application, provides a variety of recommendations for news, entertainment, interactive games, virtual exploration, education, creative activities, as well as social networking services, (b) smartwatch that monitors specific biosignals for identifying emergency cases, and (c) a smartphone that offers information and entertainment material, as well as assistance in particularly urgent cases. Fourth, the relevance of the offered services of a residential, occupational, or creativity center (e.g., simple, functional daily activities, creative activities, care, strengthening of socialization) for people with ID within the present project. Fifth, professional caregivers/staff who had expressed their full support and assistance in designing, testing, and evaluating the proposed integrated support system.

Considering the above criteria, the study involved a sample of seventeen (17) adults based on their primary diagnosis. Specifically, the sample included (a) three participants with mild ID (males), with chronological ages ranging from 21 to 28 years, (b) three participants with moderate ID (one male, two females) with chronological ages ranging from 28 to 42 years, (c) nine participants with severe ID (five males, four females) with chronological ages ranging from 32 to 48 years, and (d) two participants (males) whose classifications and chronological ages are unknown.

All study participants receive professional support from a Creative Activities center in Greece that serves individuals with special needs. In order to protect their privacy, the center will be referred to as "AC". The center offers a wide range of programs, including educational activities (e.g., music–kinetics, gymnastics, gardening, art, painting, computer skills, cooking, and games), as well as education on daily life activities (such as eating, personal hygiene, and housework). Additionally, AC provides social interaction opportunities that can greatly improve the skills and quality of life of people with disabilities. A multidisciplinary team (psychologists, social workers, gymnasts, musicians, support staff, etc.) at AC work together to enhance the creativity and daily functioning of individuals with disabilities.

In addition to gathering demographic and disability-related information, we utilized a semi-structured questionnaire as an evaluation instrument to comprehensively understand the needs of the study population and interpret the findings qualitatively. The attainments and functioning of the participants with ID were assessed by two professional caregivers based on a questionnaire designed by adopting components from [70] and taking into account various aspects of the existing models, including the two models of human functioning and disability proposed by the American Association on Intellectual and Developmental Disabilities (AAIDD) and WHO—International Classification of Functioning, Disability, and Health (ICF), respectively, as well as quality of life and support models [71]. Regarding attainments, reading, writing, speech, self-care, and work skills were assessed. Additionally, concerning functionality, abilities such as autonomy, perception and memory, emotion, behavior, and activities were assessed. The 5-point Likert scale was used for this purpose to measure the degree, i.e., very high, above average, below average, very low, and incomplete. The participating IID possess various abilities and skills that significantly differ among them in terms of degree, as shown below, expressed in user percentages:

Attainments:

- Reading ability: 18.8% very high, 12.5% above average, 6.3% below average, 31.3% very low, 31.3% incomplete
- Writing ability: 18.8% very high, 6.3% above average, 12.5% below average, 37.5% very low, 25% incomplete
- Speech: 12.5% very high, 31.3% above average, 25% below average, 25% very low, 6.3% incomplete
- Use of everyday vocabulary: 12.5% very high, 31.3% above average, 18.8% below average, 37.5% very low
- Self-care ability: 37.5% above average, 31.3% below average, 25% very low, 6.3% incomplete
- Assisted self-care skills: 25% very high, 31.3% above average, 37.5% below average, 6.3% very low
- Semi-skilled work: 6.3% above average, 18.8% below average, 25% very low, 50% incomplete
- Unskilled work without supervision: 18.8% above average, 25% below average, 37.5% very low, 18.8% incomplete
- Unskilled work with supervision: 18.8% very high, 25% above average, 31.3% below average, 18.8% very low, 6.3% incomplete
- Household chores: 25% above average, 31.3% below average, 37.5% very low, 6.3% incomplete
- Assisted household chores: 25% very high, 31.3% above average, 31.3% below average, 6.3% very low, 6.3% incomplete

Functionality:

- Autonomy: 12.5% very high, 25% above average, 25% below average, 31.3% very low, 6.3% incomplete
- Perception: 6.3% very high, 25% above average, 31.3% below average, 37.5% very low
- Cognitive abilities: 6.3% very high, 31.3% above average, 31.3% below average, 31.3% very low
- Concentration ability: 12.5% very high, 6.3% above average, 25% below average, 50% very low, 6.3% incomplete
- Memory: 12.5% very high, 6.3% above average, 31.3% below average, 43.8% very low, 6.3% incomplete
- Emotional maturity: 12.5% above average, 18.8% below average, 56.3% very low, 12.5% incomplete
- Motility: 18.8% very high, 43.8% above average, 25% below average, 6.3% very low, 6.3% incomplete
- Stereotyped movements: 25% above average, 25% below average, 31.3% very low, 18.8% incomplete
- Self-control: 50% below average, 50% very low
- Cooperation ability: 6.3% very high, 12.5% above average, 56.3% below average, 25% very low
- Participation in individual activities: 6.3% very high, 25% above average, 37.5% below average, 31.3% very low
- Participation in group activities: 6.3% very high, 18.8% above average, 56.3% below average, 6.3% very low, 12.5% incomplete

Due to the specific characteristics of the people with ID, the ethical component, privacy, and data protection policy are ensured and considered a priority. Prior to proceeding with any research involving IID, we made sure to obtain informed (written) consent from their legal guardians, who are typically their family members or next-of-kin. This consent confirms that they agreed to allow the person under their care to participate in the study.

Approval to conduct the study was obtained from the Ethical Committee of the Technical University of Crete. In the study, ethical principles were followed in accordance with the Helsinki Declarations [72].

The IID were interviewed by experienced caregivers using a semi-structured questionnaire in order to discover their preferences in various categories such as entertainment, news and information, virtual navigation, interactive games, educational activities, as well as their creative avocation (i.e., hobbies). These interviews were necessary for gathering information in order to formulate the final categories' hierarchy in our platform, but also to create the individual user profiles. Additionally, the analysis of the gathered information aided in developing scenarios for the pilot study. The questionnaire is comprised of three parts. The first part consists of questions about personal users' information, such as their sex and age range, as well as their computer usage habits. The second part consists of questions related to the general categories and subcategories. The third and final part includes questions that measure the user's willingness to use the web application in the future, their requirement for assistance with computer handling, and their interest in a hypothetical new category that was not included in the given topics. Users were asked to rate their agreement or disagreement with positive and negative statements about the choices provided by the platform using a three-point Likert scale. In addition, five narrative interviews were carried out with individual staff members to gather data regarding their experiences with communication, daily routine, activities, and special needs of IID from their professional point of view.

As mentioned, the platform provides modules for people with ID, their families, and caregivers in occupational activity centers, learning support centers, and other residential environments. In order to ensure the platform's effectiveness, a short-scale pilot study was conducted in order to test the functionality of the subsystems and the integrated platform prior to the final evaluation and validation. This study concerns the real-time testing of the web-based recommendation services, as well as the smartwatch and smartphone application usage. The experimental testing was conducted in the AC environment with users with mild, moderate, and severe ID levels.

It is important to highlight that the research team interacted directly with the people with ID who participated in this study, along with the continuous support of center specialists (psychologist, occupational therapist, etc.) during the development, testing, and evaluation of the proposed platform. Parents were not present during interviews and the pilot study.

3.2. Content Recommendation and User Interfaces

The content-based filtering technique, which is utilized in the proposed recommendation system, analyzes the new content and calculates the similarity of items [73], aiming to recommend items similar to those that the user has selected/consumed in the past. In order to perform personalized recommendations, the user preferences are stored in the profile and are constantly updated based on implicit user feedback. In these cases, specific similarity measures, such as cosine similarity, can be used to match the new content to the user's current preferences. Following this, the most relevant material is suggested and displayed in the priority order resulting from a ranking process based on the highest similarity between each element and the user profile [74]. Therefore, our content recommendation mechanism is based on an inference model, which has been developed for the selection and ranking of personalized recommendations and the update of the user profile, based on the current implicit feedback.

Our recommendation services are provided through a user-friendly web-based interface in cooperation with the system's relational database. The latter has been developed in MySQL in order to store the users' content and the system's data, as well as facilitate the platform's functionalities. Apart from the system administrator, the users are distinguished into the following main groups:

- People with ID (adults and children), who are the key users of the recommendation system and may use it directly themselves, or with the aid of their relatives or/and caregivers;
- Their close relatives, i.e., parents and family, who have access to view their personal data registered to the system;
- The caregivers that represent the professional carers—occupational therapists who are allowed to access and modify the preferences, location, biomedical, and medication data of the people with ID that they have under their provision.

Through the proposed system, people with ID have access to the pre-analyzed online material that falls under the six main categories of News, Entertainment, Education, Creative Activities, Interactive Games, and Virtual Exploration, which contain several detailed sub-categories, depicted in Table 1. Each of these categories consists of sets of particular descriptive human-interpretable terms (keywords), namely the prototype terms that actually represent more detailed categories' aspects. For instance, the category of "Cities" contains "building", "square", "street", "monument", "transportation", etc. Moreover, each prototype term is accompanied by a degree of relevance, namely the prototype weight, corresponding to its association with the current category.

The corresponding items are published on a daily basis on secure websites and are of various modalities, including text, image, and video. Due to the limited number of websites that are especially addressed to people with ID, the recommended content is mainly selected from general-purpose web pages, such as Photodentro [75], Travel All Over Greece [76], Pixabay [77], Pexels [78], YouTube [79], Google Arts & Culture [80], Wikimedia Commons [81], Openbook [82], Airpano [83], etc. However, the suggested items are not stored in the proposed system's server, rather, the selection of a specific title directly leads to the publicly available web source of the content.

The online content that is recommended to the users is initially semantically analyzed and classified into one or more detailed thematic categories. This analysis leads to the extraction of metadata, including the most descriptive and frequent terms contained in each item, namely the metadata terms. Additionally, the weights related to the terms' frequency of occurrence of the metadata terms in the items' content, i.e., the metadata weights, are also specified.

The user profile consists of the entire set of thematic categories along with the corresponding degrees of preference, ranging between 0 and 1, and consists of three levels: Low [0–0.3], Medium (0.3–0.7), and High [0.7–1] [84]. The detailed preferences in the user profile are initialized based on explicit user feedback, namely the information that has been gathered through questionnaires and interviews of the participating users, as described in Section 3.1. Additionally, the prototype terms are also included in the user profile, along with the respective weights, which differ among users. The latter is initially calculated from the user-defined preferences inherited by the parent category, multiplied by the respective prototype weight, and expresses the intra-category and inter-user differentiation.

Table 1. Content categories and their sub-categories.

General Categories	Detailed Categories
News	Timeliness and Weather Forecast, Politics, Celebrities, Decoration and Fashion, Culture and Art, Sports, Environment, Architecture and Technology, Hygiene and Diet, World News
Entertainment	Music, Movies, Dance, Theater, Paintings, Nature and Landscapes and Archaeological Sites, Countries and Cities, Animals and Plants

Table 1. *Cont.*

General Categories	Detailed Categories
Education	History and Archaeology and Culture, Mathematics, Physics and Astronomy, People and Society and Ecology and Environment, Internet and IT, Biology, Chemistry, Vocational Guidance, Geography and Geology, Language and Writing and Reading, Foreign Languages, Literature, Theater and Art History, Music Theory
Creative Activities	Gymnastic and Dance, Pottery, Cooking and Pastry, Gardening, Knitting, Technology Usage, Painting and Crafts, Musical Instruments
Interactive Games	Assembling-Games and Puzzles, Number Games, Crossword Games, Riddles and Quizzes, Scientific-Fantasy, Adventure, Strategy, Sport Games
Virtual Exploration	Museums and Temples and Monuments, City Attractions, Natural Landscapes, Art and Technology Exhibitions

3.2.1. Content Semantic Analysis

Aiming to support content recommendation by estimating the relevance of media items to the thematic categories of the platform, we designed methods for image, video, and text semantic analysis. Concerning the image semantic analysis, we exploited three publicly available models pre-trained on the ImageNet [85], Places365 [86], and YouTube8M [87] datasets (1000, 365, 3886 semantic labels, respectively), as well as two new models that we trained on the TRECVID SIN [88] and the Kaggle Sports100 [89] datasets (300 and 100 semantic labels, respectively). These five models constitute model set I, which can annotate images with more than 5000 unique semantic labels. To semantically analyze a video, we first segment the video into shots using the method of [90]. Then, leveraging the model set I, we analyze three key-frames per shot (selected by a temporally uniform sampling of frames within the shot's duration), annotating the shot with the most confident annotations of all key-frames. Additionally, we adopted the method of [91] and modified it for the annotation of each video shot with the activity labels of the MiniKinetics [92] and ActivityNet [93] datasets (both with 200 semantic labels), with the two resulting models constituting model set V. Our modifications on [91] concern dropping the object-level processing for the sake of computational efficiency. Regarding the text semantic analysis, we encode textual items in the joint feature space of [94], where we can compute the similarity to the—encoded in the same space—thematic categories' labels.

We designed two approaches to estimate the relevance of a media item to a thematic category. In the first approach, *categories2concepts*, we initially used the Sentence-BERT text encoding method [95] to match each semantic label supported by I and V model sets to the labels of the thematic categories. Through a manual filtering procedure, we selected the most relevant from the top 100 matches. When a media item is submitted for analysis, it is first annotated with semantic labels from the appropriate model set (i.e., I for images, and I and V for videos). The relevance of a media item to a thematic category is relative to the order of the matched semantic labels in the sorted-by-confidence-score list.

In our second approach, *categories2avs*, we start by constructing a pool of text sentences by aggregating the textual part of the four video-captioning datasets i.e., the MSR-VTT [96], TGIF [97], ActivityNet [93], and Vatex [98] datasets. Utilizing the Sentence-BERT text encoding method, we measure the text similarity between the sentences of this pool and the thematic category labels. After visually inspecting the top 100 similar sentences, we select the most relevant matches. When a media item is submitted for analysis, we calculate the cosine similarity between the item's embedding and the relevant sentences' embeddings in the joint feature space of [94]. The relevance of an item to a category is expressed as the maximum similarity of all selected relevant sentences.

To evaluate the two approaches, we employed the V3C1 subset of the TRECVID AVS dataset [99] and treated each thematic category label as a query to retrieve related V3C1 videos. Then, we performed a visual inspection of the top 50 videos returned by each approach, noting whether each video was relevant to the query. We used precision as the evaluation measure (i.e., correct answers against the number of examined videos, averaged over all categories). We observed that late fusing the results of *categories2concepts* and *categories2avs* approaches (by considering the maximum score from the two approaches) yielded the best results (62.8% versus 54.4% and 58.8%, respectively), therefore this fusion of both approaches was employed for estimating the relevance of a media item to a thematic category.

Moreover, the human-interpretable stem vectors were derived through the analysis of a large number of media items found on the web. This set of prototype terms semantically describes each thematic category. The semantic analysis methods also calculate the relevance to each of these prototype terms (i.e., a similarity value in $[0, 1]$), using a technique very similar to *categories2avs*.

The semantic analysis methods were deployed as a REST service with an endpoint for each supported media item type (i.e., video, image, and text). In Figure 2, an overview of the semantic analysis process is illustrated, while in Figure 3, the input media item (left side) along with an indicative selection of the results (right side) is presented. Specifically, (a) for a video we showcase the top three inferred thematic categories, as well as the top five concepts of the "imagenet" and "YouTube8M" concept pools, (b) for an image we showcase the top three inferred thematic categories, as well as the top five concepts of the "SIN" and "Sports100" concept pools, and (c) for a short piece of text we showcase the top three inferred thematic categories.

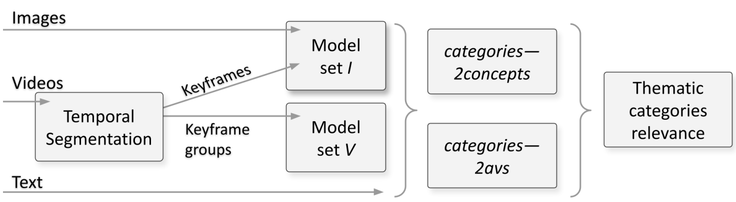


Figure 2. Overview of the content semantic analysis procedure.

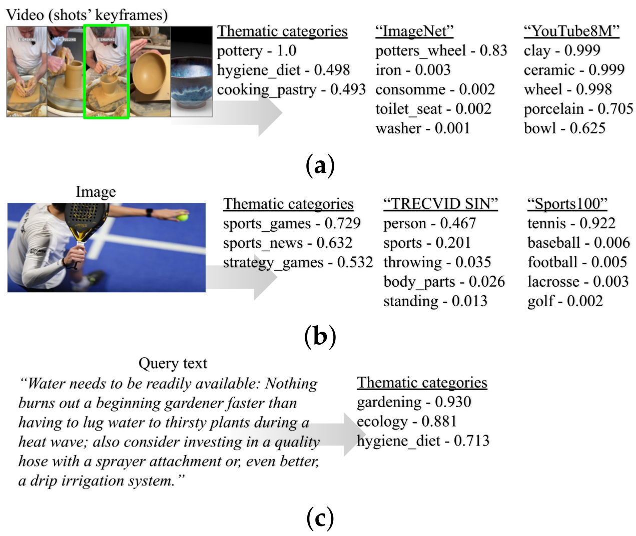


Figure 3. Examples of media items—(**a**) video, (**b**) image, and (**c**) text—used as input to the semantic analysis module and an indicative selection of the results.

3.2.2. Inference Model

The inference model is the actual learning mechanism of the recommendation system and is responsible for (a) the selection of personalized recommendations regarding each detailed category and ranking based on the user preferences and (b) the update of the preference degrees for each category included in the profile, based on the user's current implicit feedback, i.e., the web activity. The inference model has been developed using the Python 3.6 programming language and integrated with the back-end for retrieving information from the system's database.

Personalized recommendations: In order to determine the particular online content for personalized presentation to the users, firstly, the new classified content and its metadata terms and respective weights are specified. Following this, the common terms are detected between the current item (metadata terms) and the categories, where it has been classified (prototype terms), and the cosine similarity measure is calculated according to the following formula:

$$CoSim(U_P, M_W) = \frac{\overrightarrow{U_P} * \overrightarrow{M_W}}{|\overrightarrow{U_P}| \cdot |\overrightarrow{M_W}|} \quad (1)$$

where $CoSim$ is the cosine similarity measure, U_P stands for the vector of the user's prototype weight of the common terms (between the content and the classification category), and M_W represents the vector of the metadata weights extracted from the current content.

The results of the cosine similarity measure are used to rank the recommendations in an intra-category priority order. However, the user is allowed to sort the suggested content by its type (image, video, etc.). Furthermore, depending on the user's degree of preference in each category, the content is recommended according to the following rules: (a) all of the most recent items for the High preference categories, (b) up to 10 items for the Medium preference categories and (c) up to 5 items for the Low preference categories.

User profile update: In order to dynamically update the categories' degrees of preference in the user profile based on recent user online activity, all the prototype weights of the terms contained in the individual user profiles should be adapted. The prototype weights of each category in the user profile are constantly updated by means of the mathematical Formula (2), which is based on the approach [74] and has been adapted to the particular characteristics of the proposed platform. More specifically, it has been modified taking into consideration the main differences and individual features of our system, compared with the system in Ref. [74], namely:

- The approach of [74] deals with a mobile phone application, where the user is limited to a single screen, which does not constitute a web-based interface.
- The content concerns textual news items in Ref. [74], as opposed to our system, where the content is multi-modal and derived from several different sources.
- The most important difference concerns the target users, which, in our case, constitute IID that are characterized by special behaviors, e.g., they might have opened a webpage for a long time, without being concentrated on the content itself.

$$W_{new} = W_{old} \pm MW_t \cdot \ e^{-\beta \cdot U_b \cdot U_h} \quad (2)$$

where W_{new} and W_{old} are the new and the current prototype weights, respectively, in the user profile associated with the categories where the suggested content is classified. MW_t corresponds to the average of the metadata weights of the specific term in the entire set of items presented to the user. The weights of a specific term in the user-ignored items are subtracted from those contained in the selected/consumed ones. Hence, the $+$ or $-$ signs are applied where the metadata weights of the term prevail concerning the consumed or ignored items, respectively. Moreover, e^x is used to follow the personalized nonlinear change of the prototype weight with respect to the usage term's history. The changing rate of the weight is inversely proportional to the value of the parameter x, where U_h stands for the number of the selected items, where the term exists and U_b represents the indicative mean number of the daily selected items, computed every week, i.e., the more items a user consumed per day, the more slowly the prototype weights increase in the profile. Furthermore, the β constant is used to differentiate between the changing rate of the weight if the update is performed concerning an interesting or an ignored item, taking different values for positive and negative user feedback. More specifically, in the case of ignored items, the changing (decreasing) rate should be slower, since a non-selected item does not constitute an explicit indication of non-interest. For instance, it can be interpreted as already read from another source, or as possible that the user had no time to spend on it. On the contrary, in the case of consumed items the changing (increasing) rate should be faster, since a selected item demonstrates a strong indication of interest [74]. Based on the numerical values resulting from applying the formula, in Equation (2), the indicative values for the β constant have been set to $\beta = 0.01$ for selected items (positive feedback) and $\beta = 0.02$ for non-selected items (negative feedback). Note that the weight adaptation concerns only the common terms between the user profile and the currently recommended items.

Finally, each new category's degree of preference is calculated as the average value of the included term-weights, where each of them is divided with the respective initial prototype weight, i.e., the term's degree of relevance:

$$P_{new} = \frac{\sum_{n=1}^{n=k} \frac{W_n}{R_{Pn}}}{k} \tag{3}$$

where P_{new} is the new preference degree of the current detailed category, k is the number of the prototype terms associated with the category, W_n stands for the prototype weight of each term, and R_Pn corresponds to the relevance degree of the term with respect to the current category.

Subsequently, the new preferences of the general categories result from the average degree of their subcategories.

It should be noted that the categories' degrees of preference are not updated as regularly as the prototype weights (daily), but gradually, on a longer-term basis (e.g., once per week).

3.2.3. Web-Based User Interface

The web-based user interface is being constructed in the Greek and English languages. The user enters the proposed platform, which allows the different user groups to interact with the integrated system. Apart from the login (and registration of new user) page, three tabs are contained, corresponding to the page of (a) people with ID, (b) caregivers, and (c) close relatives (parents, family members, etc.), where the user is automatically led after login.

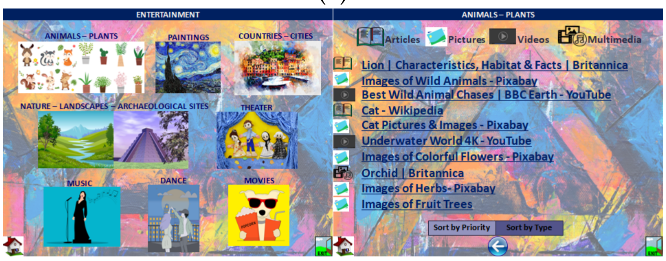
The images that illustrate each category, as well as the functionality icons, have all been downloaded from Pixabay [77] and Pexels [78], where they are freely available and are not subjected to license issues.

The development of the user interface is based on the WordPress tool version 6.2, combined with the WampServer, which is a Windows-based web development platform that enables the creation of robust web applications with the MySQL database and PHP Apache2 functionality. WordPress handles the user login and registration and displays the web pages that are visible to the users depending on their role in the system. A RESTful API using the Python library FastAPI (version 0.92.0) was developed for the interaction of the user interface with the MySQL database.

Communication of front-end and back-end modules is achieved via REST calls (GET, PUT, POST, DELETE requests) using the JSON format. All information is stored in the platform's database, on which the back-end module can connect and retrieve information for fulfilling the requests of the front-end.

People with ID are allowed to access personalized recommendation content that belongs to the general categories of Table 1. Apart from the content categories, the page provides a search option and the socialization choice through a specific Facebook group, where the users might join. Moreover, the (through-click) selection of each general category leads to the respective detailed categories (Table 1), which provide access to lists of titles corresponding to the relevant web items. The latter are presented in appropriate ranking order, based on the preferences, interests, and special characteristics reflected in the user profile. However, since some categories contain limited content (e.g., Virtual Exploration), or material that is not regularly updated (e.g., Education), the recommended content may concern the entire category corpus and not only the most recent items. The structure and functionality of the User Interface addressed to people with ID are depicted in Figure 4, along with indicative suggested content.

(**a**)



(**b**)

Figure 4. Web-based User Interface for IID—(**a**) login (**left**) and general categories (**right**) page, (**b**) detailed categories of entertainment (**left**) and content recommendation for Animals–Plants sorted by priority (**right**).

The web interface of the proposed system allows caregivers and close relatives to access the registered data of the people with ID. More specifically, the caregivers, apart from their own personal profile, have access to the personal data of the people with ID who are under their provision, and they are allowed to specify, view, and modify their supported person's platform data (Figure 5), namely:

- The detailed preferences of the supported people, which the caregivers can anytime alter, in case they believe that the system's automatic updates do not follow the actual individualized degrees of preference.
- The medical history, including reports and medical imaging modalities, which the therapists are allowed to (optionally) store in the system's database.
- The current medication of a specific benefiter with ID that the caregivers can store in the platform (Figure 6—left). In addition, through the button of 'Reminders', they can specify as well as modify when/if it is necessary and schedule the time intervals of the corresponding reminders hat are sent to the people under their provision.
- The current values of biomeasurements monitored by the smartwatch, i.e., heart rate, oxygen saturation, body temperature, and stress level, which the carers can view at any time (Figure 6—right).
- The daily and weekly statistical reports of health parameters, namely specific statistical metrics, such as mean, maximum, and minimum values, etc., which are constantly calculated by means of the received time series of the heart rate, oxygen saturation, body temperature, and stress level, along with the respective time-series graphs (Figure 7).

- The current location parameters are monitored by the smartphone's GPS, which the carers can view anytime. Additionally, the caregivers are able to specify and change—directly on the map—the polygons that represent the individual safety areas of movement and activities for people with ID, namely geofences.
- The health and disorientation-related emergency incidents that are automatically detected by the system, along with the corresponding alerts. The carer can, at any time, view the recorded alerts, fill in additional data, as well as register new emergency incidents.

Finally, the close relatives of IID can view all the above-described data concerning their familiars, yet they are not permitted to change any of these.

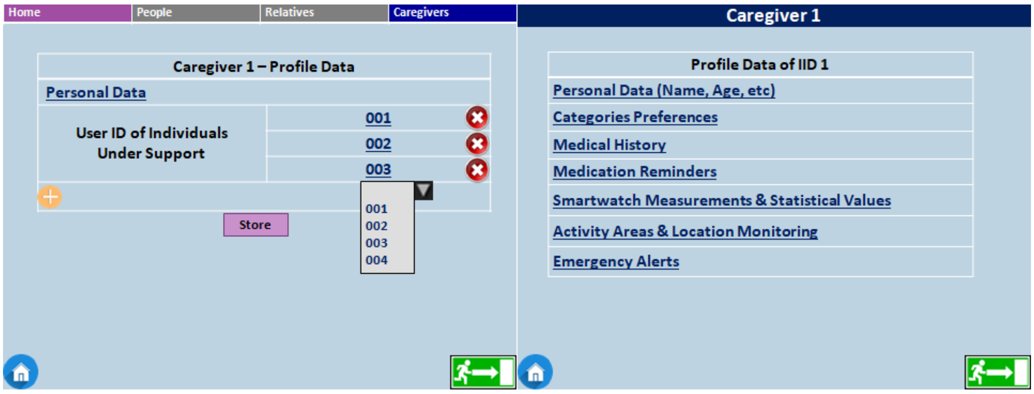


Figure 5. User interface of caregiver—page of personal data (**left**) and page of data for a specific benefiter with ID (**right**).

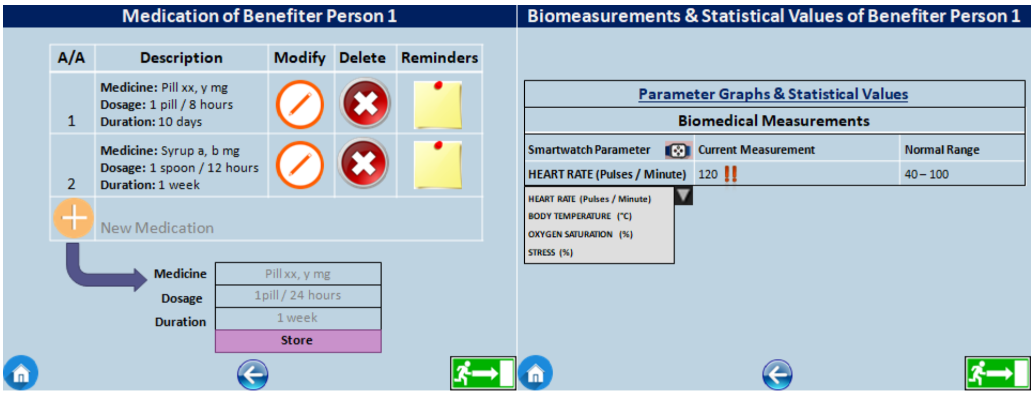


Figure 6. Medication of a specific benefiter (**left**) and visualization of smartwatch current biomeasurements along with the predefined normal ranges (**right**).

3.3. Mobile Applications

The integrated mobile applications concern the modules performing detection of health and disorientation issues, the respective alerts towards the caregivers, along with the automated system assistance, particular useful notifications, and reminders, as well as information, entertainment, and communication services through the vocal interaction with the smartphone's virtual assistant. These functionalities have been considered and proved substantial in order to minimize the manual effort of disabled users on several tasks and increase their security and the potentiality of convenient emergency management, especially in outdoor activities.

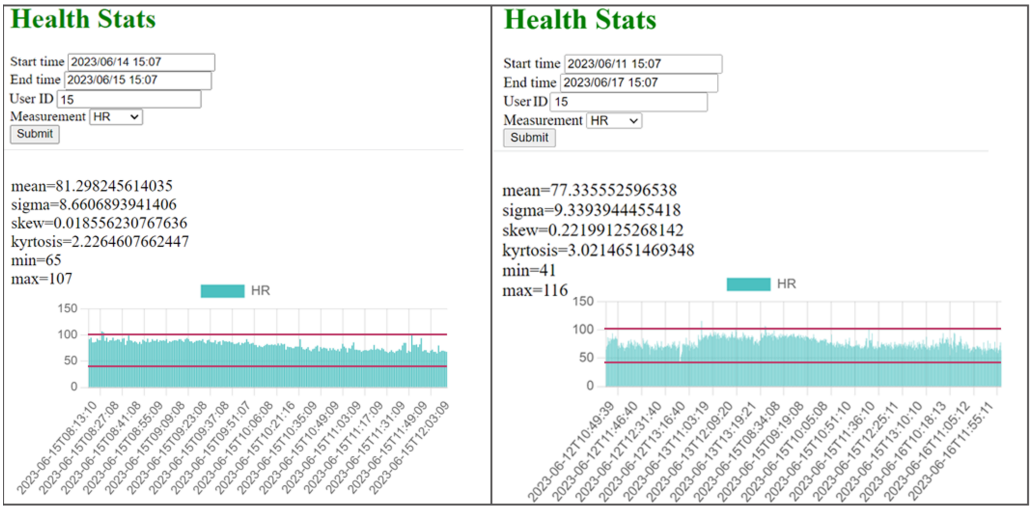


Figure 7. Report of statistical daily (**left**) and weekly (**right**) values of heart rate, where the min, max, and mean values of the defined (day or week) interval are shown along with standard deviation (sigma), skewness, and kyrtosis statistical measures. The red lines in the graphs for heart rate indicate the high and low normal limits.

3.3.1. Detection of Health Emergencies

A health monitoring service based on smartwatch data was integrated into the proposed platform in order to support the continuous measurement of specific biomedical parameters, i.e., heart rate, oxygen saturation, body temperature, and stress level. This service also issues appropriate alerts to the disabled users and their assigned carers, in case the measured values exceed the predefined normal ranges during a specific time interval, set to 5 min in our application.

At first, two smartwatch applications were developed, with respect to two popular platforms, namely Garmin and Fitbit, which were identified after the related market research, and were successfully tested with three mid-priced smartwatches, specifically the Garmin Vivoactive 4 and Venu 2 (Figure 8), as well as the Fitbit Sense device, to gather and send the physiological data to a web server, such as heart rate and oxygen saturation measurements.

Figure 8. User Interface of QualiSID Garmin application.

Regarding the body temperature parameter, although the majority of smartwatch models include a temperature sensor, it is typically used for ambient temperature measurement rather than body temperature. Moreover, since a smartwatch is usually worn on the wrist, body temperature measurement is unreliable due to the influence of perspiration, etc., Ref. [100] and environmental factors. To meet this challenge, body temperature estimation was performed, based on the Kalman filter [101,102], using successive heart rate measurements from the smartwatch devices. This model can provide quite accurate detection of body temperature fluctuations.

Furthermore, the stress level feature was selected to be continuously monitored, since IID may be at a greater risk for experiencing high stress. User's current stress level is determined on the smartwatch based on their heart-rate variability; the lower variability between beats equals higher stress levels, whereas the increase in variability indicates less to no stress. The SDKs provide a stress level between 0 (resting phase) and 100 (high stress). Finally, some additional useful user activity metrics, provided by both the Garmin and Fitbit SDK, such as calories burned and step count are also monitored.

All user data are transmitted to the server using a REST API and are stored in the MySQL database. The sampling rate of heart rate and oxygen saturation bio-signals is 1Hz, while average values are obtained and transmitted once per minute. Similarly, the estimation of body temperature and stress level value are updated every minute using the accumulated data of the past minute time window. Figure 9 presents an example of data recordings for a time duration of 12 min, additionally illustrating the calories and steps parameters.

Furthermore, a tool for offline statistical analysis was developed, offering the options for calculating statistics (e.g., mean, minimum, maximum, values, etc.) of the aforementioned parameters, per day and week. As reported in Section 3.2.3, this tool can be accessed by the caregivers and close relatives of IID through the web-based user interface to provide data graphs and highlight time periods, where measurements are beyond the predefined normal ranges.

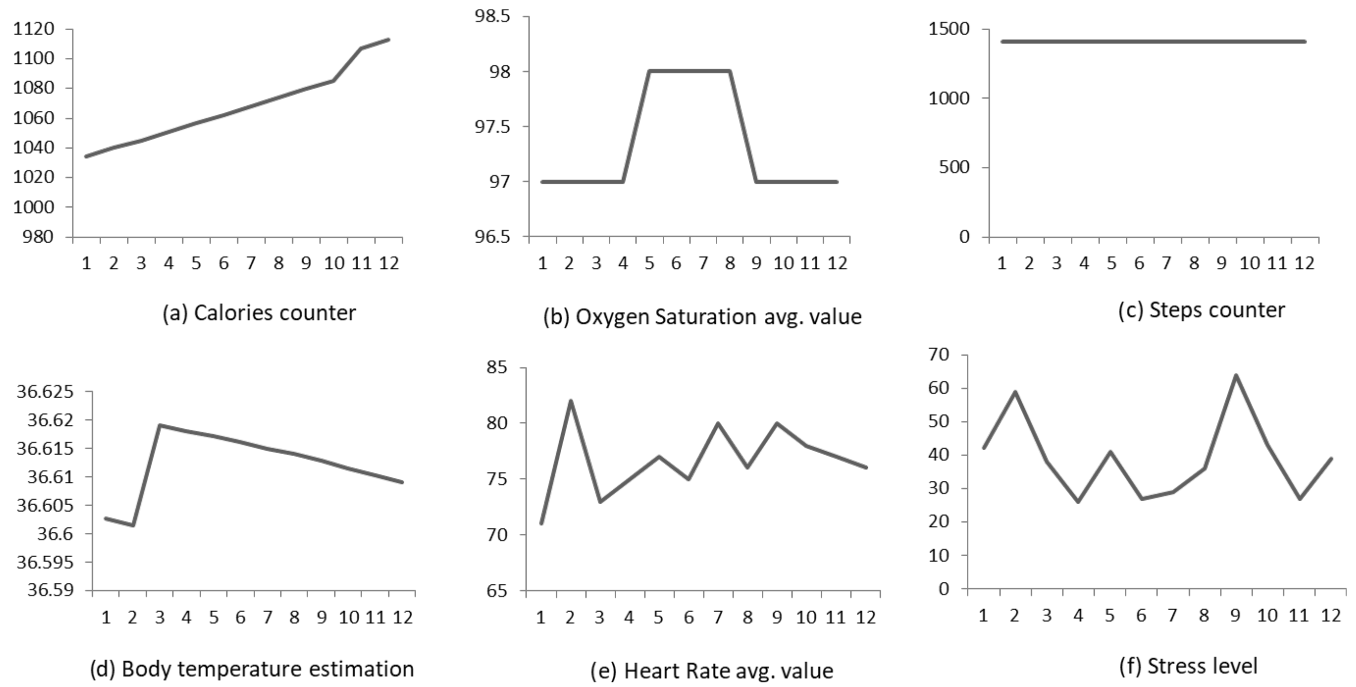


Figure 9. An example of smartwatch recordings of user data for a time duration of 12 min.

3.3.2. Detection of Disorientation and Wandering Behavior

The detection of disorientation and wandering behavior emergency cases have been integrated into the proposed platform. Initially, the caregiver specifies one or more closed polygons ("geofences"), which represent the safety zones for the IID. The definition of these areas can be performed using the interface, as reported in Section 3.2.3, illustrated in Figure 10.

Furthermore, wandering behavior is also detected, based on analysis of GPS trajectories, by using best practices from recent research. More specifically, GPS recordings are continuously analyzed to detect three wandering patterns, according to the Martino–Salzman model [38,39]. However, a drawback of this approach is that it detects and analyzes sequences of movements between specific locations that need to be defined in advance by the carer, e.g., different rooms within a house or predefined locations in the city. Moreover, specific rules need to be defined to segment long sequences into segments to be analyzed (e.g., when the person remains static for *N* seconds), so this further increases complexity. Thus, an alternative simpler algorithm for detecting loops in GPS trajectories was also implemented based on the approach proposed in Ref. [103].

When the user moves outside the predefined areas, or when a wandering pattern is detected, a notification is provided to the caregiver, containing details related to the detected issue. Following this, the carer can view the current location of the IID on a map in order to offer appropriate assistance through the automatic starting of a video call between them. Furthermore, the carers can also initiate tracking through the web-based or smartphone interface, if they suspect that the IID is lost or in a difficult situation.

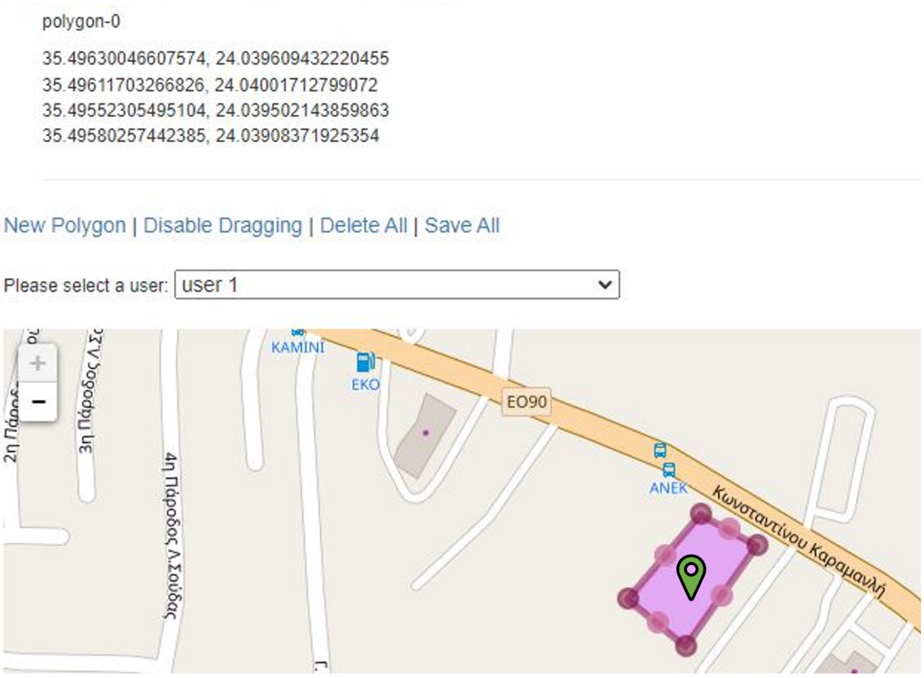


Figure 10. An example of a safety zone that was marked by a carer at an AC support center, where a user with ID is located.

3.3.3. Smartphone Application

People with intellectual disabilities often encounter challenges in acquiring reading skills. According to a comprehensive large-scale survey, reading difficulties were identified as the most common secondary condition associated with ID, with 67% of the participants reporting reading as a problem area [104,105]. Additionally, it is well-known that individuals with ID may also experience speech-related issues, such as slow pace, lack of articulation, and clarity, leading to difficulties in verbal communication.

Given the higher incidence of severe reading disabilities in this population, especially in relation to the intelligibility of natural speech, we have carefully selected natural, free speech as the primary means of interaction for our application. By leveraging Automated Speech Recognition (ASR) and Text-to-Speech (TTS) technologies, we aim to provide a more accessible and inclusive experience for users with intellectual disabilities.

Moreover, to ensure ease of use and quick access to important features, such as calling for help or responding in case of health disorientation issues, we have implemented automatic activation for these functionalities. In some cases, we have minimized the involvement of the user, allowing critical actions to be triggered with a simple press of a distinct button.

Through these thoughtful design choices, the proposed smartphone application, namely the QualiSID mobile App, aims to promote independence and enhance the overall user experience for individuals with intellectual disabilities, facilitating smoother interactions and better support in their daily lives. The QualiSID mobile App follows a modular development model, integrating and interconnecting all the individual implemented modules. The utilized infrastructures, hosted on cloud servers, include the Apache Server [106], MariaDB database server [107], and Node.js Server [108], while in terms of programming languages, PHP [109], Javascript [110], HTML [111], and CSS [112] were exploited.

The proposed smartphone application constitutes a Progressive Web App (PWA), developed using web platform technologies, yet it delivers a user experience comparable to that of a platform-specific application, such as a native Android one. Additionally, PWA is capable of functioning across various platforms and devices apps [113] and is multilingual, with Greek (full version) and English (extended version) being the first two implemented languages. It consists of four main functional units, i.e., Support and Assistance, Emergencies and Alerts, Communication, and Voice Controlled Virtual Assistant, which are presented in Figure 11. Concerning the depicted "socket channel room", a WebSocket-based messaging system was implemented that enables the exchanging of client-to-client messages between IID and their caregivers by joining the same room, right after the login in the platform. This feature has been integrated in order to enhance the proposed system's functionality.

Figure 11. Main functional units of QualiSID smartphone application.

The smartphone application provides several services to people with ID, but also to their caregivers, which are:

1. People with ID:
    - Information, such as encyclopedia subjects, points of interest, weather forecasts, answers to short questions, etc., and entertainment, i.e., videos, pictures, music, radio, etc., through oral request (voice function and speech recognition) and the response of the virtual assistant.
    - Communication with caregivers, relatives, and friends by phone calls and SMS messages through voice commands.
    - System support and assistance in emergency cases through the automatic start of video calls with the responsible carers and/or voice instructions.
    - Medication and other (such as lunchtime) reminders by the virtual assistant.
    - Weather forecast notifications and alerts for upcoming bad and extreme weather conditions.

- S.O.S. (emergency) button for pressing in urgent situations related to health issues, disorientation, or other circumstances where the individual with ID feels uncomfortable.

2. Caregivers:
    - Automated sound alerts for notification in emergency cases related to health issues that have been detected through the smartwatch monitoring of biomeasurements, i.e., heart rate, oxygen saturation, body temperature, and stress level.
    - Automated sound alerts for notification in emergency cases related to disorientation and/or wandering behavior through the location monitoring from the smartphone's GPS, when the individuals with ID have been located out of the safety zones (geofences).
    - Alerts for upcoming bad weather conditions, in order to protect the individuals under their care who might be in potential danger.
    - Automatic video call between the caregiver and the individual in an emergency situation and opening of the map where IID's current location is depicted.
    - Specification of geofences that constitute the individualized safe activities areas for the supported IID through the mobile user interface.
    - Specification of automated sending of medication reminders to the supported IID, their carers, and families through the mobile user interface.

In Table 2, the mapping of the individual modules to the main units of the QualiSID mobile application is depicted. Table 3 lists the main data required for the proper operation of the QualiSID mobile App and the achievement of its objectives. Furthermore, Figure 12 presents the voice-controlled virtual assistant architecture, while the flow chart of the health parameter monitoring, location tracking, and alerts-related processes are depicted in Figure 13.

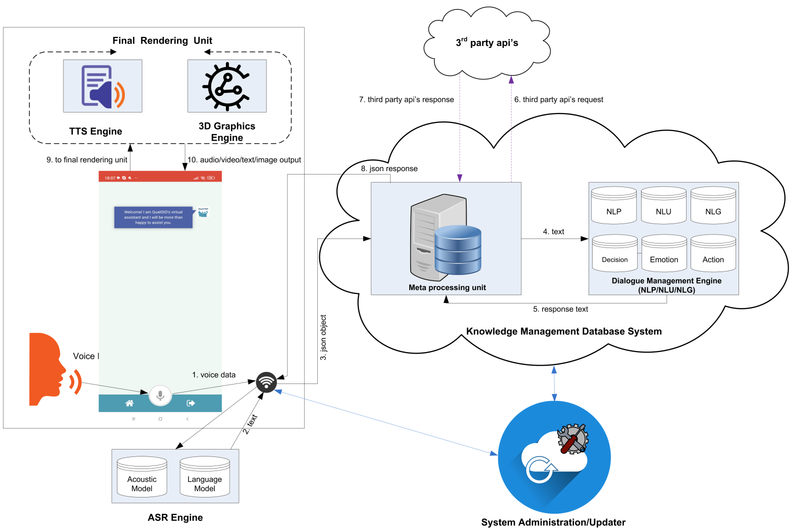


Figure 12. QualiSID voice-controlled virtual assistant architecture—NLP: Natural Language Processing, NLU: Natural Language Understanding, and NLG: Natural Language Generation.

Table 2. QualiSID smartphone application: Units—modules mapping.

Module/Unit	**Voice-Controlled Virtual Assistant**	**Emergencies & Alerts**	**Support & Assistance**	**Communication**
Weather	✓	✓		
Music	✓			
Radio	✓			
Video	✓			
Useful	✓			
Advices-ITs	✓			
Entertainment	✓			
Phone calls	✓	✓		✓
SMS	✓			✓
Points of interest	✓			
Encyclopedia	✓			
Short answers	✓			
Chat	✓			
Reminders (general)	✓		✓	
Reminders (medication)	✓		✓	
S.O.S. Button		✓		
Video calls		✓		✓
Sound Alerts		✓		
Automated Speech Recognition (ASR)	✓			
Text To Speech (TTS)	✓			
Open Street Maps		✓		
IID geo-tracking		✓	✓	
Geolocation	✓	✓		
Geocoding	✓	✓		
Geofences		✓		
IID biometric data tracker		✓	✓	

Table 3. Data required for the proper operation of the QualiSID mobile application.

Data	**Source**
User's geographic location	PWA + Smart Device GPS unit
Voice input	User
Weather	Visual Crossing Weather API [114]
Wikipedia	MediaWiki API [115]
Youtube	Youtube Data API [116]
Geolocation (direct and reverse)	Nominatim—Open-source geocoding with OpenStreetMap data [117]
Maps	OpenStreetMaps [118] and Leaflet library [119]
Biometrics	SmartWatch
Automated Speech Recognition (ASR) Text To Speech	Web Speech API [120]
Points of Interest (POIs)	Google places API [121], OSM [122]

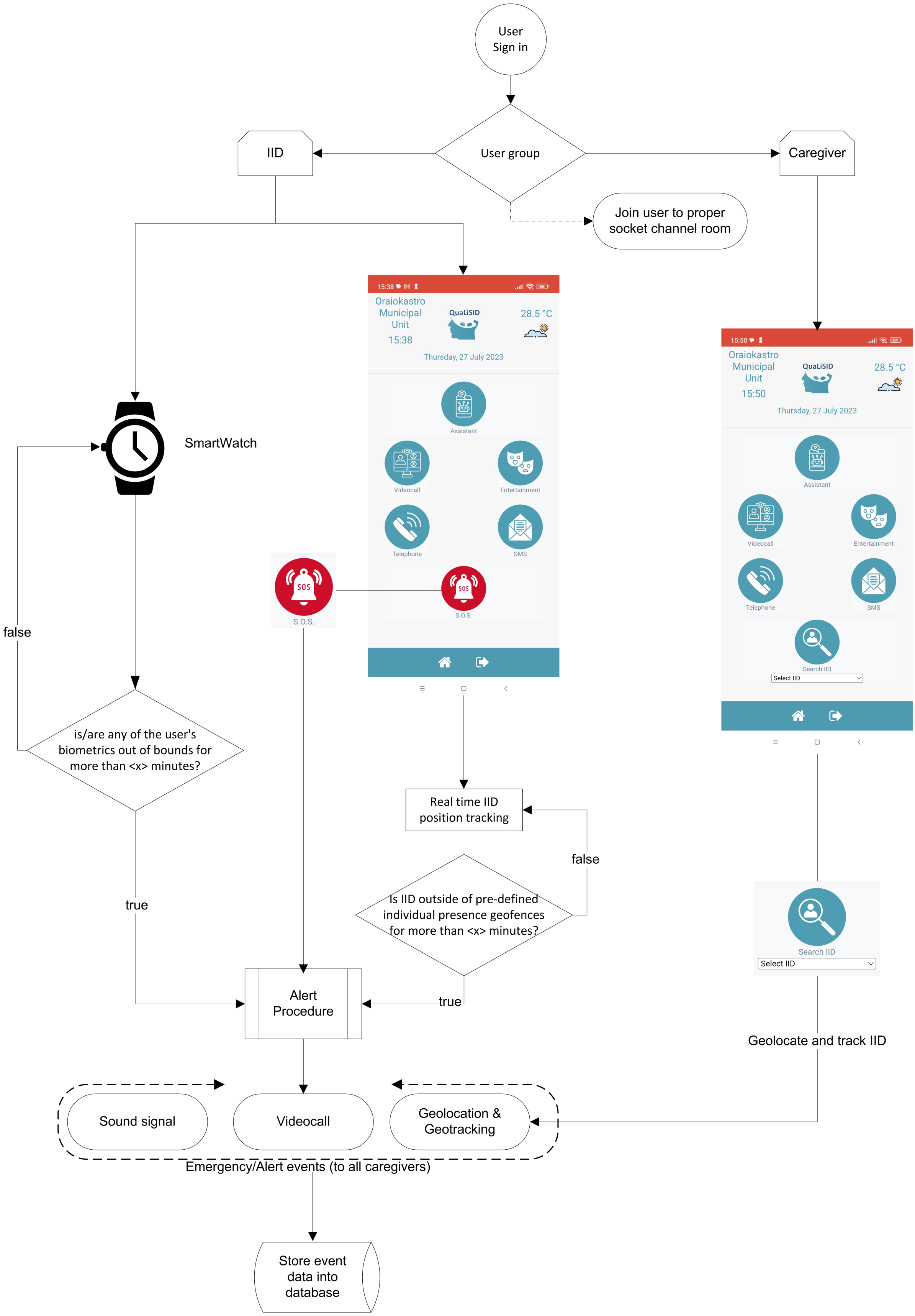


Figure 13. Emergency Detection, Location Tracking, and Alerts modules architecture of the QualiSID mobile App.

4. Experimental Results

In order to experimentally evaluate the effectiveness of the proposed system, 17 individuals with ID from the AC Creative Activities Center were involved in testing the developed components of the integrated platform.

4.1. Content Recommendation Service

The initialization of the preferences on the general and detailed categories in the participating users' profiles was performed according to the information gathered through questionnaires and interviews described in Section 3.1 (Table 1). In addition, based on the results of the completed questionnaires, the respondents identified eight detailed categories as highly preferred, which include (a) Timeliness and Weather Forecast and Sports from the News general category), (b) Animals and Plants, Music and Movies from the Entertainment general category, (c) Internet and IT from the Education general category, and (d) Cooking and Pastry, as well as Painting and Crafts from the Creative Activities general category.

In order to experimentally evaluate the effectiveness of the proposed recommendation service and the web-based user interface, a small-scale pilot study was carried out in real-time. To this end, eight content sets were constructed, each consisting of 15 web items classified to each one of the above-mentioned detailed categories; namely, 120 web items in total were selected as recommendation material.

Concerning the testing process of the recommendation service through the web-based user interface, a specific number of items were suggested to the users according to their initial preferences; particularly, 15 for the High-, 10 for the Medium-, and 5 items for the Low-preference categories (as described in Section 3.2.2). At first, the users were asked to log in and subsequently select the preferred items from each category. It should be stressed that during this pilot study, the users took their time in order to explore the content items at their own pace.

Indicative results are presented for three end-users with different severity of disability, namely, mild, moderate, and severe, as well as a brief description of the users' peculiarities and issues regarding the use of the web interface. In Table 4, the initial degrees of preference with respect to the categories are reported, while in Table 5, the number and IDs of the recommended content items (R), corresponding to the initial preferences are included for each user (first row).

1. User 1: This user has a mild ID. He understood the scope of the test and could use the web-based platform with assistance at the beginning, performing the task well while being very concentrated during the process. The user selected items according to his original preferences (e.g., paintings and crafts) and others not marked as High in the questionnaire (e.g., animals and plants). He used the system's recommended ability to increase the font size of textual elements. Based on his selected content items, the updated preferences in his profile were maintained in four categories, while changed in the other four (reduced in three and increased in one, as depicted in Table 4).
2. User 4: This user has a severe ID. He used the web-based platform with assistance, performing the task pretty well. This user mostly selected items according to his initial preferences (Table 4), and he could read to a minimal extent; he chose to look mostly at pictures and videos. In the beginning, it was difficult for him to push buttons, while he could not concentrate and tended to speak during the testing. Based on his selected content items, the updated preferences in his profile were maintained in two categories and changed in the other six (fell in six) (Table 4).
3. User 12: This user has a moderate ID. She also used the web-based platform with assistance, responding very well during the process. She mostly selected items according to her original preferences (Table 4) and also chose to look mostly at pictures and videos. She is communicative; she could concentrate but also tended to speak while performing the testing. Based on her selected content items, the updated preferences in her profile were maintained in five categories and changed in the other three (reduced in two and increased in one—see Table 4).

Table 4. Initial (I) and updated (U) user preferences in 8 detailed categories.

User-ID	Timeliness & Weather-Forecast	Sports	Animals & Plants	Music	Movies	Internet & IT	Cooking & Pastry	Painting & Crafts
1	**I:** High **U:** High	**I:** Medium **U:** Medium	**I:** Medium **U:** High	**I:** High **U:** Medium	**I:** High **U:** Medium	**I:** High **U:** High	**I:** Medium **U:** Low	**I:** High **U:** High
4	**I:** Medium **U:** Low	**I:** High **U:** Medium	**I:** High **U:** High	**I:** High **U:** Medium	**I:** High **U:** High	**I:** High **U:** Medium	**I:** High **U:** Medium	**I:** High **U:** Medium
12	**I:** Low **U:** Low	**I:** High **U:** Medium	**I:** High **U:** High	**I:** High **U:** High	**I:** Low **U:** Medium	**I:** High **U:** High	**I:** High **U:** High	**I:** High **U:** Medium

Table 5. User-ID numbers of the initially recommended (R) and selected (S) content and updated ranking order (U) of content in eight detailed categories for each user.

User-ID	Timeliness & Weather-Forecast	Sports	Animals & Plants	Music	Movies	Internet & IT	Cooking & Pastry	Painting & Crafts
1	**R (15 items):** 1–15	**R (10 items):** 16–25	**R (10 items):** 31–40	**R (15 items):** 46–60	**R (15 items):** 61–75	**R (15 items):** 76–90	**R (10 items):** 91–100	**R (15 items):** 106–120
	S: 12, 13, 14, 1, 2, 3, 5, 15	**S:** 20, 17, 22, 23, 24, 18	**S:** 32, 35, 36, 37, 38, 39, 40, 31, 33, 34	**S:** 46, 47, 48, 49, 53	**S:** 61, 62, 63, 64, 65, 66, 73	**S:** 79, 80, 76, 77, 78, 84, 85, 86, 81, 88	**S:** 97	**S:** 107, 108, 114, 109, 111, 110, 112, 113, 117
	U: 12, 13, 14, 1, 2, 3, 5, 15, 4, 7, 8, 9, 6, 10, 11	**U:** 20, 17, 22, 23, 24, 18, 19, 29, 28, 30	**U:** 32, 35, 36, 37, 38, 39, 40, 31, 33, 34, 41, 45, 42, 43, 44	**U:** 46, 47, 48, 49, 53, 51, 56, 58, 60, 59	**U:** 61, 62, 63, 64, 65, 66, 73, 67, 68, 69	**U:** 79, 80, 76, 77, 78, 84, 85, 86, 81, 88, 82, 83, 87, 89, 90	**U:** 97, 93, 100, 99, 104	**U:** 107, 108, 114, 109, 111, 110, 112, 113, 117, 115, 116, 106, 118, 119, 120
4	**R (10 items):** 1–10	**R (15 items):** 16–30	**R (15 items):** 31–45	**R (15 items):** 46–60	**R (15 items):** 61–75	**R (15 items):** 76–90	**R (15 items):** 91–105	**R (15 items):** 106–120
	S: 5, 8	**S:** 16, 22, 19, 25, 27	**S:** 38, 39, 40, 41, 42, 43, 44, 45, 32, 37	**S:** 50, 47, 52	**S:** 65, 61, 62, 64, 66, 67, 68, 70	**S:** 79, 80, 85	**S:** 98, 99, 103, 104	**S:** 115, 116, 109, 110, 118
	U: 5, 8, 4, 7, 13	**U:** 16, 22, 19, 25, 27, 17, 18, 20, 29, 30	**U:** 38, 39, 40, 41, 42, 43, 44, 45, 32, 37, 34, 35, 36, 31, 33	**U:** 50, 47, 52, 54, 56, 57, 58, 60, 46, 49	**U:** 65, 61, 62, 64, 66, 67, 68, 70, 69, 71, 72, 73, 74, 75, 63	**U:** 79, 80, 85, 82, 83, 84, 81, 78, 89, 90	**U:** 98, 99, 103, 104, 91, 92, 96, 101, 105, 102	**U:** 115, 116, 109, 110, 118, 108, 111, 112, 113, 120
12	**R (5 items):** 1–5	**R (15 items):** 16–30	**R (15 items):** 31–45	**R (15 items):** 46–60	**R (5 items):** 61–65	**R (15 items):** 76–90	**R (15 items):** 91–105	**R (15 items):** 106–120
	S: 3, 4, 5	**S:** 18, 22, 19, 20, 25	**S:** 35, 37, 32, 31, 33, 34, 38, 39, 40, 41	**S:** 60, 58, 56, 52, 53, 50, 59, 57, 49, 48, 54	**S:** 62, 64, 65, 61, 63	**S:** 76, 78, 77, 79, 80, 83, 85, 90	**S:** 91, 93, 94, 96, 98, 100, 101, 105	**S:** 119, 106, 107, 113, 118
	U: 3, 4, 5, 8, 13	**U:** 18, 22, 19, 20, 25, 17, 21, 22, 27, 30	**U:** 35, 37, 32, 31, 33, 34, 38, 39, 40, 41, 36, 42, 43, 44, 45	**U:** 60, 58, 56, 52, 53, 50, 59, 57, 49, 48, 54, 55, 51, 46, 47	**U:** 62, 64, 65, 61, 63, 66, 69, 67, 68, 72	**U:** 76, 78, 77, 79, 80, 83, 85, 70	**U:** 91, 93, 94, 96, 98, 100, 101, 105, 97, 92, 95, 99, 103, 104, 102	**U:** 119, 106, 107, 113, 118, 108, 110, 111, 112, 114

Finally, regarding the next system's recommendation, the same content sets were exploited for presentation to the users, where the number of the newly suggested items per user corresponds to the updated degrees in the category preferences. Additionally, the new priority order of the items in each category has been determined according to the users' feedback, i.e., corresponding to their previous choices. Therefore, the previously selected content is ranked first, while the most relevant items are subsequently listed.

In Table 5 the second row for each user presents the IDs of the selected (S) web items, while in the third row, the priority order of the IDs corresponding to the new item recommendations (U). The results demonstrate that the updated degrees of preference (Table 4), as well as the ranking of the new recommendations (Table 5), is performed according to the implicit users' feedback, i.e., following the previous choices during the testing process. Of note, these content items are provided in Table S1, Section Supplementary Materials, where they are numbered according to their individual ID, as shown in Table 5.

4.2. Health and Location-Related Alerts

Regarding the experimental testing of the health parameters monitoring, four smartwatches paired with four smartphones were used. These devices were assumed to belong to their respective caregivers. Each smartwatch was worn by an individual with ID for 15 min, while the measurements were continuously transmitted to the database per minute. In Figure 14 the indicative graphs of heart rate, oxygen saturation, body temperature, and stress level time series are illustrated for the group consisting of four users with mild, moderate, and severe ID. The red lines indicate the predefined normal limits, which have been defined according to the following values:

- 40 pulses/minute < Heart Rate < 100 pulses/minute.
- 95% < Oxygen Saturation < 100%.
- 35.7 °C < Body Temperature < 37.2 °C.
- 0% < Stress Level < 75%.

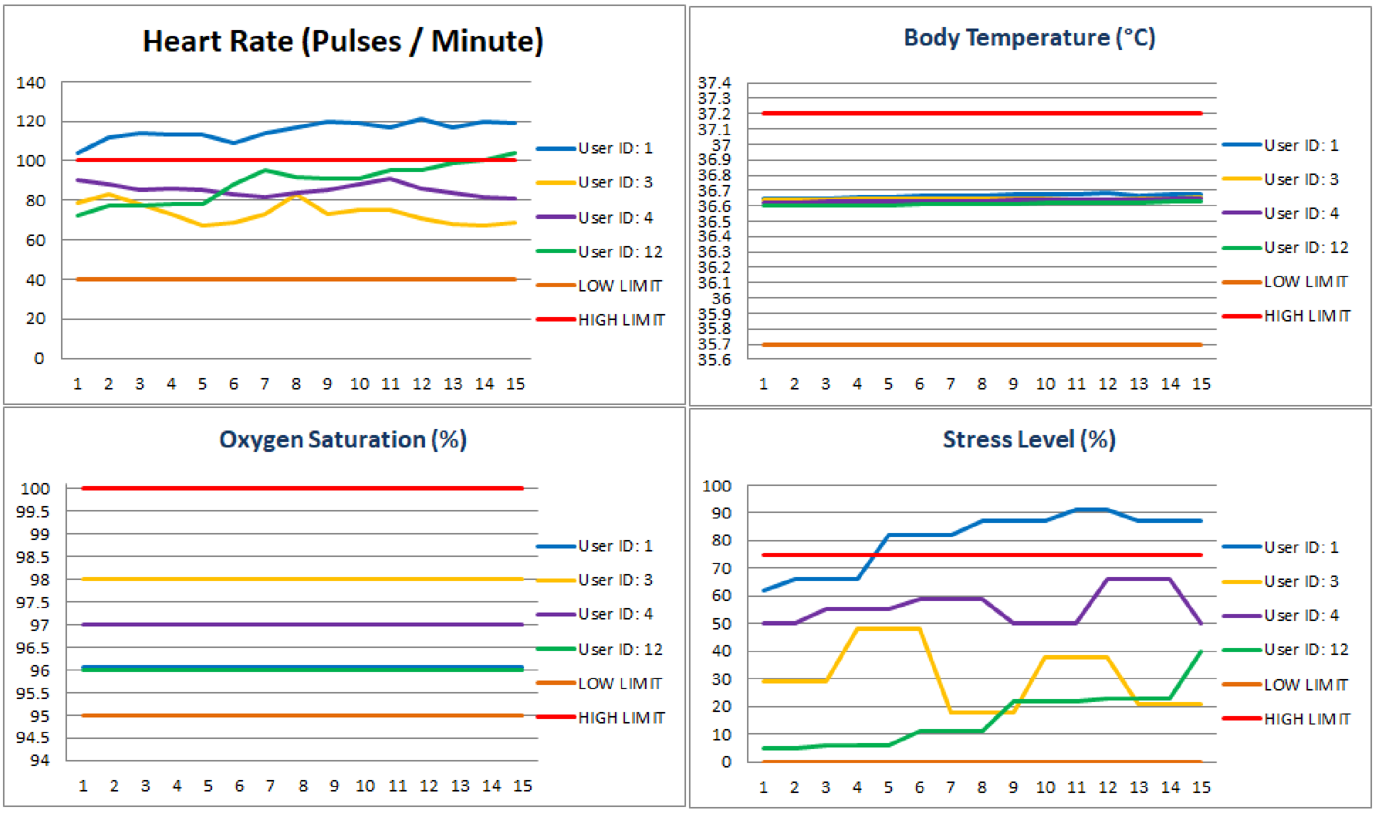


Figure 14. Smartwatch measurements of four users with ID—heart rate (**top left**), body temperature (**top right**), oxygen saturation (**bottom left**), and body temperature (**bottom right**). The predefined normal limits are illustrated in red (high) and orange (low) lines.

As clearly observed in the depicted measurements, all the parameter values lie in the predefined normal ranges, apart from the heart rate and the stress level of User 1, which have exceeded the normal limits for over 5 min. In this case, corresponding notifications (alerts) were sent to the related carer's mobile phone.

As far as the location tracking is concerned, a safety zone was defined, covering the entire region of the AC center, i.e., the interior of the building along with the front and the back yards, as depicted in Figure 10. Since none of the participating IID walked out of the boundaries of the geofence area, no disorientation alert was sent to the caregivers. However, this feature has been extensively tested in hypothetical scenarios in order to verify its reliable functionality.

4.3. Smartphone Application

The mobile application was evaluated based on its usability, user familiarity, and voice recognition accuracy. All but one user with a mild, moderate, or severe ID were initially uncomfortable, especially with the virtual assistant, yet they eventually responded well to the test, after assistance from their carer. Three users with a severe ID needed help to form some questions and ask for answers, whereas three others with a mild and moderate ID were more concrete and specific with their questions. The user who responded very well during the testing posed many questions and had a very creative dialogue with the virtual assistant named Clio. The outcomes of the creative dialogues between the test users and the virtual assistant Clio were successful, with 70.45% positive answers to the users' questions. It is noteworthy to mention that a large number of the "negative" answers, such as "I don't understand you", "I didn't catch it", or "Rephrase, if you want", and including three non-answers and two false positive answers, resulted from incomplete and missing questions, or due to the poor voice recognition with respect to the specific users with a severe ID, whose utterance was not clear. In addition, some users seem not ready to dialogue with Clio. These results highlight the high usability of the proposed smartphone applications, a good level of voice recognition accuracy, and the need to train the users to be more familiar with and have a creative dialogue with Clio.

5. Discussion

People with ID encounter several issues in communication with other people, interaction with their environment, and the activities of daily living, since they have certain limitations in cognitive functioning and skills, as well as in social, mental, and self-care abilities. To this end, technological advances can provide convenient interactive systems and services that address their special needs in entertainment, education, and creative activities, but also automatically detect issues that they are not able to sufficiently express. In this context, the Global Cooperation on Assistive Technology (GATE) program, initiated by the WHO, aims to enhance accessibility to affordable and high-quality assistive products for individuals with different illnesses, age-related conditions, and disabilities, including intellectual disabilities, which is a neglected area of research and practice [5]. Particularly, according to a study in Ref. [123], using MESE (Multimedia in Education for Special Education)—an assistive multimedia application involving different senses and media—improved reading skills and memory in children with ID.

In order to evaluate the proposed platform's functionality, a short-scale pilot study was conducted, including experimental tests of the individual components in real-time conditions. Seventeen users supported by the AC Center of Creative Activities participated, starting by declaring their preferences concerning the detailed categories of our application through dedicated questionnaires and interviews. Following this, the detailed preferences were registered to the individual user profiles. Considering the limited availability of content that caters to the unique requirements of IID, we have carefully chosen easily accessible content items that can be viewed, searched, navigated, read, and interacted with. The content primarily consists of text, images, videos, and multimedia material, in order to engage users and cover their preferences and needs. Our goal is also to motivate users to explore topics beyond their usual interests and provide them with appropriate stimuli. In practice, based on a closed question (giving the respondent a limited amount of options to choose from) of interviews, we can report that ten participating users expressed their initial interest in using the platform only for Entertainment, two users for News, two users for Creative Activities and one user for Interactive Games, while the Education and Virtual Exploration were not part of their interests. On the other hand, based on the indicative results of the experimental testing but also the interaction with the participants in the AC center—a pleasant environment that greatly matched the design, implementation, and scope of our research—we can claim that the users could explore, select, and also enjoy the alternative topics. According to the experimental results of the recommendation service, our system had a high response, since the follow-up content recommendations conformed to the previous user feedback, concerning (a) the number of suggested items with respect to the updated degree of preference for each category and (b) the ranking order of the items in each category, corresponding to the detailed subjects of the user's previous selections. The results demonstrate that the updated degrees of preference, as well as the ranking order of the new recommendations, correspond to the implicit users' feedback, i.e., the previous choices during the testing process, verifying the high performance and reliability of the inference model and the content semantic analysis.

The measurements of the health parameters demonstrate that the detected values lie in the predefined normal ranges, which indicates their correct estimation by the selected smartwatch and/or improvement by means of the developed methods described in Section 3.3.1. Concerning one case where heart rate and stress level exceeded the normal limits for over 5 min, respective alerts were automatically sent to the carer's mobile phone.

Concerning the mobile application, the experimental testing demonstrates the high quality of the related services when providing information and entertainment content, as well as the feature of providing answers to simple questions. This is due to the high speech recognition accuracy, even in the case of the users with increased levels of ID, i.e., mild and severe. Apart from effective speech recognition, the smartphone application of our system provided moderate user familiarity and high usability. According to our study, one IID could use the smartphone virtual assistant independently, while six others could use it with prompts. Our findings support the notion that IID could use computers (73.3% Google) and social media (46.7%, Facebook, 13.3% Instagram), but only more recently, and this is consistent with other studies [124]. Special attention should be given to individuals who require training before using the proposed application. Additionally, alternatives should be provided for those who may not want to interact with Clio.

Moreover, as part of the final evaluation that will be further conducted, the System Usability Scale (SUS) will be used in order to assess the usability of the proposed web-based recommendation service. SUS is a widely-used questionnaire consisting of 10 questions that evaluate a product or system's overall usability, incorporating both positive and negative statements. It is known for its simplicity and reliability, even when applied to small samples. In our final evaluation process, the participating users will be asked to answer by scoring the SUS questions with one of five responses ranging from Strongly Agree to Strongly Disagree using a 5-point Likert scale, and supported by specialists who can interpret their feelings or opinions when necessary. The global score ranges from 0 to 100, while, based on related research, a SUS score above 68 indicates acceptable usability of the system or product [52].

In order to account for related existing platforms and applications, in Table 6, we include a comparison of the features offered by several systems designed to aid individuals with a wide range of disabilities. The listed systems include smartphone/smartwatch applications [28,32,41,53,55,56,60,62,64]), software and computer applications [42,56,62], websites and web applications [20,21,24], learning/training, games and content recommendation platforms [13–19,27,57], and platforms for employment/jobs information [22,23]. The features that we take into consideration concern functionalities that are visible to (and directly concern) the user with ID. Therefore, systems that deal with helping caregivers, or raising the awareness of the general population, despite their critical purpose, are excluded from this comparison. Finally, we should highlight that the list of systems (i.e., Table 6 rows) is complete to our knowledge. Yet, the list of features (i.e., Table 6 columns) is not exhaustive—there may be further features offered by a particular system, which is tailored to a specific goal, that do not fit the categories of functionalities defined here for the sake of comparison. Even so, we can observe that QuaLiSID is a comprehensive system comprising interfaces for web/desktop/smartphone/smartwatch, offering a complete solution (with respect to the features listed here) for supporting individuals with ID.

Table 6. QualiSID platform comparison to similar systems in the literature.

Support System for People with Intellectual Disability	Information-News Features	Education-Training Features	Socialization Features	Entertainment Features	Games	Content Recommendations	Disorientation-Wandering Detection	Health Monitoring & Emergencies Detection	Medication Reminders	Weather & Other Notifications	S.O.S. Button	Virtual Assistant
MUBS [28]		✓		✓	✓	✓						
FOQUS [32]		✓						✓				
m-Carer [41]							✓					
Soy Cappaz [53]	✓						✓		✓	✓	✓	
Viamigo [55]	✓						✓					
MindMate [56]	✓	✓		✓	✓				✓			
Timeless [60]			✓	✓					✓	✓		
GPS SmartSole [62]							✓					
Puzzle Me [64]					✓							
OAED [42]								✓	✓			
Healthy Mind [20]		✓										
MySigns [21]		✓	✓									
Puzzle [24]	✓	✓										
ELPIDA [13]	✓	✓										
ENABLE [14]		✓	✓			✓						
Stomp [15]		✓	✓	✓								
KIDEA [16]		✓			✓							
MAS [17]	✓	✓			✓							
IDPLIVING [18]		✓	✓									
LudoMinga [19]		✓			✓							
IPTV [27]	✓			✓		✓						
MemoryWell [57]		✓	✓									
ERGASIAMOU [22]	✓											
Inclusion [23]	✓			✓								
QuaLiSID	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Considering the mobile applications reported in Table 6, the MUBS [28] smartphone-based system constitutes a personalized content-based recommender that adopts machine learning methods for updating the depressive individuals' profile and analyzing the registered data. MUBS was validated under a clinical study, however, it does not provide usability and functionalities to other user categories (e.g., clinicians, carers, family). Following this, the FOQUS smartwatch application [32] appears as an effective assisting tool for people with mental health issues, exploiting the benefits of wearable devices for status monitoring. However, this solution does not take into consideration personalized information, user experience, and feedback to update and "filter" system output. Mindmate [56] is a widely-tested smartphone (and computer) application, addressed to people with dementia and Alzheimer's disease as well as their families, providing interactive daily workouts and mental activities for the maintenance of health and wellness. Although it combines multiple tasks and interesting stimulation sources, it seems that the platform is not dynamically adjustable to user experience, since it provides customized content. Based on a similar concept, the multilingual tool Timeless [60] facilitates people with Alzheimer's in their daily activities, incorporating artificial intelligence algorithms for data analysis; however, it is restricted to face recognition and telecommunication solutions, rather than content recommendation and status monitoring services. Concerning gaming smartphone applications, Puzzle Me [64] allows people with dementia to solve puzzles accompanied by their caregivers. Moreover, although the Soy Cappaz smartphone application [53] incorporates multiple functionalities and treats personalized information on the daily activities of people with ID, it rather serves as a guidance system and lacks the intelligence of self-learning from data, as well as monitoring of user's biometric information. Similarly, the real-time smartphone "travel coach" Viamigo [55], is limited to user route monitoring. Subsequently, the m-Carer mobile application [41] privately monitors the movements of Alzheimer's patients in order to detect potential events or dangers, such as disorientation, approaching of risky areas, and fall. With regard to the wandering detection, the smartphone (and computer) application GPS SmartSole [62] is based on a special shoe insole equipped with a GPS tracking system, in order to monitor the location of people with dementia. In this concept, a real-time method has been developed within the OAED [42] system serving detection of disorientation, fall, and inactivity, as well as wandering behavior, by analyzing the individuals' GPS traces. On the other hand, concerning the reported websites, Healthy mind [20] is an online tool designed to gain a deeper understanding of how people with ID interact with websites through interviews and semistructured schedules, where particular user groups participated, including support workers and allied health professionals. Moreover, MySigns web-application [21] supports mental health assessment of IID and interactive functionality to other users, such as carers and clinicians; however, it is rather a mood monitoring and communication system than a personalized and intelligent content recommendation application. The Puzzle project [24] aims to assist the access to information, education, and training for IID in European countries through its website, where the "easy to read" method is applied, facilitating the conversion of text into a format that is easily understood by people with limited reading ability.

Apart from the mobile, software, and web-applications, several platforms have been developed aiming to provide training, games, and content recommendations to people with cognitive and mental disabilities. ELPIDA [13] is mostly focusing on providing family members with the necessary skills to better support the needs of children with ID of all ages, based on stand-alone training modules in different thematic areas, without taking into account the individuals' personalized data. Moreover, the inclusive learning platform of the ENABLE project [14] offers services for independent living, lifelong learning, and social inclusion of people with intellectual disabilities involving their families, clinicians, and local community representatives. The platform provides generalized guidelines and suggests activities and tasks to stimulate user interest and active participation, yet personalized recommendations, user feedback, and health monitoring are not supported. Along the same direction, the Stomp tangible user interface [15] is developed to support IID's social and physical interaction, based on predefined scenarios and materials, while the system does not integrate capabilities for learning from user history data and interaction. Furthermore, KIDEA computer-based platform [16] introduces an interactive learning tool for IID, enabling gesture and voice recognition along with face tracking to analyze user behavior. The system is designed exclusively for children and, as opposed to the proposed platform, it does not account for personalized information and history data. Furthermore, the MAS learning platform [17] is introduced to serve as an assisting tool for students with severe ID within their educational procedures, combining games and data processing approaches for delivering adaptive teaching/learning services, while the IDPLIVING framework [18] learning program aims to facilitate community living of IID through lectures, questionnaires, and discussion forums, available online to address their issues and experiences. However, both systems lack dynamic content recommendation, monitoring of user health status and location, as well as emergency detection and management, which are integrated into the proposed platform. In addition, the LudoMinga multi-device system [19] combines educational content and video games and provides profile management for organizations and specialists, while it additionally offers functionality for generating reports on user performance; however, it does not consider biomedical nor location-based user information. The interactive, personalized, multimedia content delivery framework of [27] focuses on filtering and recommending specific Internet TV programs corresponding to user preferences, yet it is limited to TV sources and does not provide a registered user interface where personalized data are stored. Moreover, the MemoryWell platform [57] focuses on increasing satisfaction and retention by serving the recording of life stories; however, it constitutes a purely commercial digital framework for utilization by health care providers rather than individual users. Finally, the employment platforms ERGASIAMOU [22] and Inclusion [23] provide information related to work, as well as assist people with ID in finding particular appropriate jobs that fit with their individual skills.

The recently developed platforms and applications reported in Table 6 highlight the importance of assistive technology in cases of ID and/or comorbidities (e.g., dementia). Following the preceding comparative analysis, the proposed platform seems to outperform the others, since it combines multiple sources of information recovered from web-based services and wearable and mobile phone devices for personalized content recommendation, emergency detection, and multiple assistance functionalities. According to the Web Content Accessibility Guidelines (WCAG) [125] and Mobile Web Best Practices (MWBP) [126] standards, our work drew on the previous experience of developing smartphone solutions, as well as identifying suitable web development tools and wearable technologies that are further discussed below.

In order to select smartwatches that include appropriate sensors and support the development of smartwatch applications (at least for Android mobile phones), market research was conducted. Two popular platforms were identified, namely Garmin and Fitbit, which (a) support a wide range of smartwatch models with different prices and capabilities, catering to various user needs, and (b) provide adequate SDKs for supporting smartwatch application development. Our proposed smartwatch application (App) extends previous work described in Ref. [127], i.e., an open-source smartwatch application that was used to detect epileptic seizures and raise an alarm to warn the assigned carer that the user may need assistance. Moreover, the implementation of our health monitoring and emergency detection system offers several advantages with respect to previous approaches, such as (a) by deploying the popular Garmin and Fitbit SDKs, we support a large number of smartwatches, (b) the system is modular and easily extensible, (c) temperature detection via Kalman model is internally implemented using the smartwatch SDKs, and (d) constant and unobtrusive monitoring, as all data are periodically provided via a REST API to the server for further processing.

Concerning the smartwatch biomeasurements, although stress is not designed to be a diagnostic marker, its detection can help users and their carers manage stress levels throughout the day and identify activities that cause tension; since research suggests that anxiety is a pertinent issue for adults with autism (that often coexists with ID), i.e., the more anxious the individuals, the less likely they are able to successfully cope with tasks [128].

Regarding an additional biomedical measurement, namely blood pressure, which was considered for inclusion in our application, this is mainly supported by inexpensive smartwatches. However, usually (a) no support is provided for application development, (b) details about the measurement process are not provided, and (c) the reliability of measurements is unknown and possibly problematic. Greater reliability in blood pressure measurement is only reported for a few specialized but expensive watches [129], which still require a special measurement process by the user. Due to the aforementioned reasons, it was decided to exclude blood pressure measurement devices from the current application and consider them only as future platform expansions.

6. Conclusions

In this paper, the design of an integrated content recommendation and emergency detection platform for people with ID is presented. The proposed system is being constructed on a web interface that constitutes a user-friendly environment, which, based on its experimental evaluation, is easy to handle and assists users with mild, moderate, and severe ID. It provides information and entertainment content, while suggesting educative and creative activities, according to the personalized preferences, interests, and skills reflected in the user profile. The latter is explicitly initialized, yet is dynamically updated through the inference model, taking into consideration the user's online activity, which is recorded through the content's selection. The recommended content constitutes freely available web items of various formats, such as text, image, video, and multimedia, for which the links to the source, rather than the files, are preserved on the platform's server. In order to match the new available content with the current user preferences, the inference model exploits certain metadata, extracted using advanced AI-based multi-modal semantic analysis. The rationale behind building such a recommendation system lies in the inability of people with ID to efficiently handle and make use of IT systems. Hence, the automatic adaptation of the profile-stored preferences, according to the web interaction of those people, allows them to constantly receive suitable recommendations, while it relieves them from the manual intervention in their individual preferences.

The proposed platform integrates additional functionalities, which serve the detection of emergency cases related to the health status of IID and the current area of movement and action. The health status recognition is performed through the monitoring of specific biomedical parameters, i.e., heart rate, body temperature, oxygen, and stress level, carried out by a smartwatch. On the other hand, the location-related emergency concerns a potential disorientation or wandering detected based on the location monitoring by the GPS sensor of a smartphone, with respect to the defined user-specific area of physical activities. Furthermore, in emergency situations, the system provides automated notifications to the caregivers, in order to rush for help.

Moreover, a specialized smartphone application has been implemented in order to provide information, entertainment, and communication services to the IID upon vocal requests and the response of a virtual assistant through speech recognition and text-to-speech technologies. Automated system assistance in some health-related emergency cases is provided through the smartphone, which is additionally equipped with an S.O.S. button for voluntary usage by the IID. Finally, medication reminders towards IID, their carers, and family, as well as other useful notifications related to the users' daily routine are also supported.

However, the proposed platform lacks some features that may further assist people with ID in additional activities, such as their independent moving, transportation, traveling, and physical activities, for which specialized applications should be developed, tailored to their particular needs. Furthermore, among the limitations of our system is the absence of a job-matching environment taking into consideration the individual skills of the users with ID in order to support employment opportunities. Additionally, our system does not include the option of direct psychological support for IID and their families by bringing them into contact with professional psychologists and psychiatrists, since people with intellectual disabilities are highly emotionally vulnerable.

Concerning the evaluation process of our platform, the limitations mainly concern the small number of participants, but also the fact that they come from a single organization. Thus, the proposed system should be also tested at home or in other institutional environments. Of note, the number of user participants, although small, can defined as sufficient according to several related studies [130,131] that focus on application testing, qualitative observations, and interviews, rather than quantitative surveys [48]. Obstacles in using our system for many IID are introduced by the ongoing assistance that they need from their family members or caregivers (40% of the study participants) and the high cost of devices such as computers, tablets, smartwatches, and smartphones.

Regarding future work in smartwatch-based monitoring, accelerometer measurements might be added for implementing additional desired features such as fall or seizure detection, however, such applications require a high sampling rate that might result in draining the smartwatch battery quickly. On the other hand, research suggests that impairments specific to autism, as well as general environmental factors, could result in an imbalance between the intake and expenditure of energy, leading to obesity [132]. Thus, monitoring of users' total number of daily steps counted and calories burned can be exploited in the future for providing activity recommendations when a long inactivity period is detected. Furthermore, concerning the smartphone application, a future addition concerns the real-time specification of a safe pathway for the IID in order to reach a familiar activity area, when they have been disoriented outside the defined geofences. Since people with ID have certain difficulties in efficiently using the map, the system could guide them through voice instructions on the route, which safely connects the user's current location with the pre-defined zone. Additionally, this route will automatically appear on the map in the carer's interface. Moreover, specialized virtual-assistant-based dialog scripts will be developed for particular emergency cases that have been detected by the system and concern health, disorientation, and wandering issues. Additional dialog scripts will include mood and other potentially inconvenient occasions and will be activated after the pressing of the S.O.S button.

As a conclusion, based on the questionnaire outcomes about participants' attainments and functionality, the narrative staff interviews, and the experimental results of the conducted pilot study, IID can interact effectively with the integrated platform either independently, mainly in cases with mild severity, or getting some assistance from caregivers or family members, in cases with moderate or severe disability. Hence, the proposed platform can contribute to successful involvement of IID in leisure and creative activities, enabling their inclusion in educational and socio-cultural events, and enhancing their self-confidence and self-sufficiency. Additionally, it also provides a supportive tool for close relatives and occupational carers in support centers, but also in other residential environments. Finally, the QuaLiSID system constitutes an expandable platform, which, upon further validation in larger user groups, is expected to support the quality of everyday life and well-being of people with mild, moderate, and severe ID.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/electronics12183803/s1, Table S1: Web items that were used as recommendation material to people with ID who participated in the experimental evaluation of the proposed platform.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the guardians or next-of-kin persons of IID to publish this paper.

Data Availability Statement: Individual data are not published online or available due to the participants' privacy protection agreements.

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