A persuasive system to improve physical activities of older adults

Houssem Aloulou [1], Hamdi Aloulou [1], Bessam Abdulrazak[2], Ahmed Hadj Kacem [1]

[1] *University of Sfax, ReDCAD Research Laboratory, Sfax, Tunisia*
[2] *University of Sherbrooke, Québec, Canada*

Abstract

Being physically active is enjoyable and safe for all age groups including for the older adults. In fact, regular physical activity improves fitness, strength and feeling better. Each person will inevitably experience the deterioration of his functional abilities as he gets older, and the sedentary behavior represents the greatest risk having a great effect on their health. In fact, older adults are the most likely to adopt a sedentary lifestyle and convincing them to change this behavior is not generally a simple mission. In this work, we propose a persuasive system to improve physical activities among older adults. Our approach is based on persuasive and motivation theories. Also, it takes account of physical and mental capacities of the older adult, his actual location, thanks to location awareness tools, and current weather conditions using an open weather awareness data API. To be able to determine the best moment to request an activity for an older adult, we use semantic modeling and reasoning.

Keywords [1]

Older adult, Physical activity, Motivation, Persuasion, Location awareness, Weather awareness, Semantic modeling, Semantic reasoning.

1. Introduction

The development in health care around the world is keeping people alive for longer. Therefore, the ratio of older adults in the global population is increasing rapidly according to the World Health Organization (WHO) [1].

Physical activity is any bodily movement produced by skeletal muscles that increases heart rate and breathing and requires energy expenditure. Since the dawn of time, humans have recognized the importance of physical activity to stay in shape and prevent morbidity. Nevertheless, with the technological advancement and the widespread use of machines in recent decades, more and more efforts are needed to promote physical activity among all age groups and especially among older adults. These latter are the most likely to adopt a sedentary lifestyle, which accelerates their transition to the age of dependency. Sedentary lifestyle also increases sociological problems and the risk of getting several chronic diseases such as high blood pressure, obesity, diabetes, lipid disorders, cardiovascular diseases, depression, and anxiety. These chronic diseases are now the leading causes of death in all regions of the world [1]. The WHO recommends exercising regularly to maintain optimal health.

Because more physical activity provides greater health benefits, many efforts around the world aim to raise awareness of older adults about the importance of doing regular physical activity. According to the Canadian Physical Activity Guidelines for older adults, to achieve health benefits, and improve functional abilities, adults aged 65 years and older should accumulate at least 150 minutes of moderate to vigorous intensity aerobic physical activity per week, in bouts of 10 minutes or more [2].

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EMAIL: houssem.aloulou@gmail.com (H. Aloulou); hamdi.aloulou@redcad.tn (H. Aloulou); bessam.abdulrazak@usherbrooke.ca (B. Abdulrazak) ; ahmed.hadjkacem@fsegs.usf.tn (A. Hadj Kacem)

In the present work, our goal is to prevent sedentary lifestyles among older adults and to promote their physical activities without coercion or deception. Older adults must be well motivated to change their behavior and move more. Motivation serves as the guiding force behind all human behaviors. It is a state-of-mind, filled with enthusiasm and energy. It is a force inside or outside the body that energizes, directs, and maintains goal-oriented behaviors [3]. Hence, motivation could encourage older adults to change behavior and to engage in health-oriented behaviors. In fact, there exist many behavioral change methodologies which use persuasive methods to change subjects' behaviors. These methodologies are stimulated by cognitive and social psychology.

Our proposed approach applies these methodologies to promote physical activities among older adults. To ensure the success of our persuasion technique, we take into consideration the older adult's health profile and his preferred activities. To have a contextualized persuasion, our proposed methodology takes also account of the current location of the person and the current weather conditions. This intelligence is guaranteed thanks to the use of semantic modeling and reasoning, which from different types of information, it would be able to decide the best moment to trigger the desired behavior.

Following, section 2 presents a detailed state of the art of existing behavior change techniques. In section 3, we expound our methodology to promote physical activities of older adults. Then, in section 4, we present the validation of the methodology. Finally, we end this article with a conclusion.

2. State of the art

Aging of people is caused by different types of factors: biological factors, environmental factors, and behavioral factors [4]. Several scientific research have shown that being active is useful for everyone, regardless of age [5] and regardless of its intensity. In fact, it has shown more recently that daily living activities have a positive effect on health outcomes [6].

In this work, our objective is to stimulate older adults to change behavior and promote physical activities. Change is the synonym of modification and alteration. It is defined as the progress from one condition to another. A change in a person's behavior is a change in his habits or in his way of behaving [7]. To have a successful behavior change, the older adult must be aware of the importance of physical activities and must be well motivated to do it.

In [8], motivation is defined as "the set of forces encouraging an individual to engage in a given particular behavior to achieve a goal or perform an activity. It is the combination of several concepts that relates to both cognitive (internal) and environmental (external) factors". Motivation is frequently described as being either "Extrinsic" or "Intrinsic" [9]:

- Intrinsic motivation: it arises from within the individual. It is the motivation to do an activity for its own sake. For example, solving a complicated crossword puzzle purely for personal gratification. The highest level of intrinsic motivation is labeled "Optimal experience" [10].
- Extrinsic motivation: it arises from outside of the individual. It is the motivation to do an activity to attain some external goal and often involve social-environmental factors including rewards, trophies, money, social recognition, praise, competition, and surveillance. Over time, some of these goals can be internalized and the person no longer feels that they come from outside and tends to become an Intrinsic motivation.

Various behavior change theories used motivation as an essential element. Our methodology takes advantage of several existing behavior change theories to have a successful persuasion which triggers the desired behavior at the right time and place and when the person is well motivated to do it. In [11], Fogg demonstrated in his behavior change model FBM that 3 conditions must converge at the same time for a behavior to be realized: sufficient "Motivation" and "Capacity" to do the requested behavior and a well-chosen moment to "Trigger" the behavior (physical location, emotions, availability, proximity, etc.) when the person is most open to persuasion (Kairos factor) and thanks to the availability and portability of mobile devices (convenience factor).

Bandura proposed the "Social Cognitive Theory" [12]. He argues that people are motivated by external forces. This theory is formed by a triad of three interacting factors: personal factor, behavioral factor, and environmental factor [13]. These factors are controlled by behavior change variables like:

- Self-efficacy: Person's confidence in his ability to perform the behavior requested of him.

- Outcome expectations: Person must be aware of the expected consequences of a behavior.
- Self-monitoring: Empower the person by self-controlling in carrying out the requested behaviors.
- Reinforcement: any event that strengthens or increase the likelihood of a behavior.

The relation between the attitude and the behavior of a person was explained in the "Theory of Reasoned Action [14]. According to this theory, a person's belief is made from several background factors: individual factors (personality, emotions, values, etc.), social factors (age, level of education, culture, etc.), and factors information (knowledge, experience, etc.). These beliefs form the person's perception and then his intention to perform voluntary requested behavior.

The "Theory of Planned Behavior" [15] is an improvement of the theory of reasoned action. It stipulates that the behavior is determined by the intention, formed by the values/beliefs of the person and social norms, and the sense of ability and self-efficacy to adopt a requested behavior. This theory is used in a very wide range of situations like smoking, road safety, sharing content on social media and the approval of the use of new technologies. In fact, the acceptance of technology can be defined as "The approval, favorable reception and continued use of newly introduced devices and systems." [16].

In our research work, we have the mandate to propose the use of a non-intrusive mobile application which must be acceptable and appreciated by participating older adults. The "Technology Acceptance Model" [17] [18] [19] is an adaptation of the Theory of Planned Behavior for the system information domain. It models how to convince users to accept a new technology. According to this theory, two elements make it possible to determine the intention of a person to use or not a technology: Perceived Utility and Perceived Ease-of-use. Perceived Utility is directly affected by Perceived Ease-of-use.

Among the research studies that have applied the Technology Acceptance Model, we can cite [20], it was applied to examine the behavior and degree of acceptance of e-commerce by older adults in the United States. Questionnaires were distributed to people aged between 52 and 87 years. The Technology Acceptance Model was used and adapted to examine the impact of Ease-of-use, Utility, and Trust on the acceptance of e-commerce. Ease of use has a significant impact on utility and trust has an impact on ease of use and utility.

Senior Technology Acceptance and Adoption Model [21] was developed to predict factors influencing the adoption of mobile phones by older adult users. Three phases to guarantee a successful application of this model:

- Objectification phase: The user establishes his "intention" to use the mobile phone from a "User context" point of view influenced by "Social factors", "Perceived usefulness", and "Ease of learning and use".
- Incorporation phase: Characterized by a process of "Testing" and "Exploration". At the end of this phase, the "Utility" is confirmed or infirmed. If the "Utility" is confirmed for the user, that means that the motivation was successful and that it leads to a real "Intention to use" of this technology.
- Acceptance and adoption phase: The adoption and full use of mobile phones by the older adult. Acceptance is a prerequisite for adoption, but adoption involves behavior change, giving technology use a place in someone's life.

The Senior Technology Acceptance and Adoption Model was used in various research works. For example, in [22] and [23], authors tested the model, empirically using a questionnaire survey, to understand the acceptance of Gerontechnology by the oldest Chinese in Hong Kong . In fact, the Gerontechnology is an interdisciplinary field that combines "Gerontology", which is a field of study that focuses on aging, its consequences and its implication, and "Technology", which creates ergonomic technological environments to assist older adults in activities of daily life, housing, mobility and transport, communication and autonomy, health and self-esteem, work, and leisure.

3. Methodology

Engaging in more physical activity results in more health benefits. To promote health and improve functional ability, older adults aged 65 years and older should do at least 150 minutes of moderate to vigorous physical activities per week in sessions of at least 10 minutes.

Transition from a sedentary lifestyle to an active lifestyle requires targeting an optimal motivation of older adults.

In a previous work [24], we proposed a personalized and customized persuasion strategy to promote older adults' physical activity. Defined persuasion theory was based on some behavior change theories especially on Fogg's behavior model (FBM) [11]. In addition, our persuasion strategies are adapted for each participant. In fact, it uses the health and personal profile of each older adult to be sure of the ability of the older adult to do the requested behavior even before asking it. This keeps the motivation of the participant who will find the requested tasks easy and within his capabilities.

In the present work, we broaden our approach by relying on additional methods of behavior change and by being aware of the current context of the older adult. It is certain that the context-awareness of physical and psychological state of the older adult are essential to have successful persuasion strategies. But taking in consideration its surrounding state is also crucial to ensure more relevant notifications to trigger a desired behavior.

To succeed in defining an effective and sustainable persuasion strategy, able to be maintained and improved, our persuasive approach to promote physical activity of older adults has three principal stages: The pre-persuasion, the persuasion, and the post-persuasion.

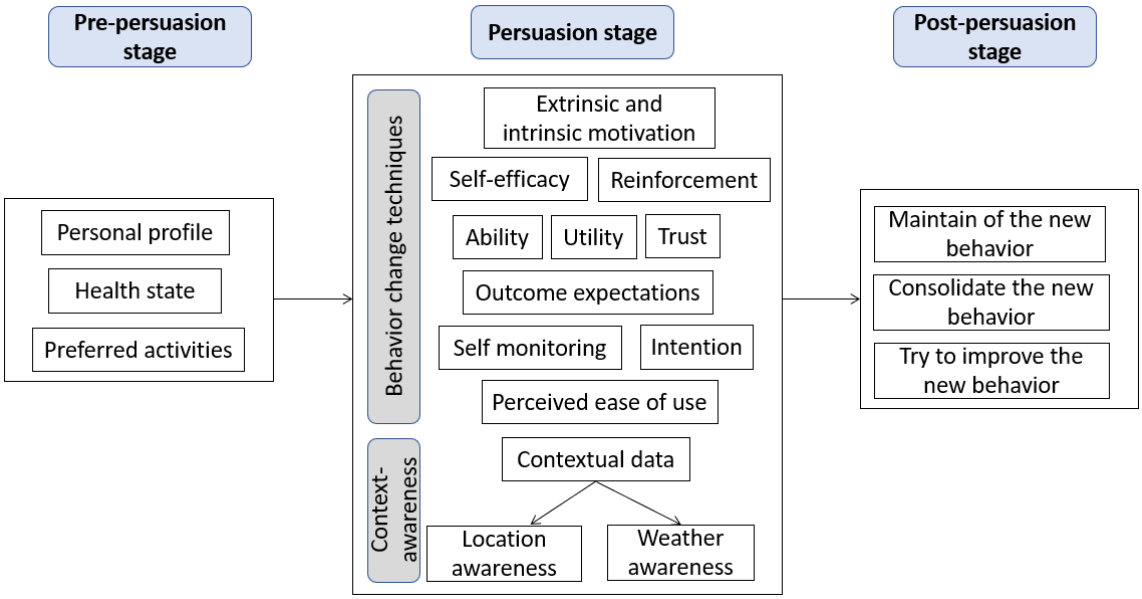


Figure 1: Persuasion stages

3.1. Pre-persuasion stage: Form older adult's profile

Each new participant willingly provides some information by answering questions when registering on our platform. The collected data concerns:

- Personal profile: Name, Family name, e-mail, gender, address, marital status, level of study, current job, etc.
- Health state: To take into consideration the older adult's past and current health history, strengths, and vulnerabilities before suggesting an activity. To draw an overall overview of the health state of a participating older adult, we mainly used the HUI-3 index (Health Utility Index – Mark 3) [25] which is a generic health profile and preference-based system for measuring health status, for reporting health-related quality of life, and producing utility scores, to model the health profile. The HUI-3 classification system comprises 8 attributes: Vision, Hearing, Speech, Ambulation, Dexterity, Emotion, Cognition, and Pain. Each with 5 or 6 levels of ability/disability. The value "1" means that the person does not have any health problems for the attribute. The more the value tends towards the greatest value of the attribute (5 or 6), the more the state of health of the elderly person for this attribute is deteriorated.

- Preferred activities: The proposed activities for every participating older adult can belong to one of the following types. Some activities are daily living. For example: personal hygiene, dressing room, feeding, ambulation, preparing meals, washing the dishes and clothes, etc. Some other activities relate to physical exercises whether individually or with other colleagues to break isolation and have a kind of friendly competition.

This helps our persuasive theory to draw relatively clearly the profile of the participant, his physical and mental capabilities, and his preferred activities.

3.2. Persuasion stage: Motivate older adult to change behavior

There is no doubt that regular physical activity is very useful for all age groups including older adults. For this reason, it is recommended to stay active even when getting older. Even though many older people have physical limitations, that doesn't mean they won't be able to be active, sure as far as possible!

Indeed, there are always ways to adapt physical activity, for example: Doing exercises sitting on a chair, doing exercises in the swimming pool for those at risk of falling, creating a safer environment for a person who has suffered from a stroke, etc. What is important is to keep moving while being careful.

Our goal is to keep the motivation of participating older adults at its highest level based on the different behavioral theories cited in our state of the art. The table below contain some of behavior change elements used in our approach. For each, we cite some examples and how it is implemented in our persuasive system.

Table 1
Some of adopted behavior change techniques

Element of persuasion	Example	Implementation
Intrinsic motivation	Cooperation: Several older adults with similar profiles and preferences can cooperate in carrying out collective group activities.	Offering activities that are done in group such as: walking outdoor with friends.
Intrinsic motivation	Acknowledgement: to make older adult feel good about his effort in promoting his physical activity.	Periodically, congratulate the participant who achieves good performance.
Reinforcement	Training to be able to well accomplish the requested behavior.	To finally be able to take long walks, the older adult can start by taking short walks in the neighboring streets.
Ability	Only suggest activities that are possible to do	Semantic reasoning to suggest activities based on the health profile.
Utility	Show the benefits of doing the requested physical activity and possible drawbacks if not.	Well-formulated notifications to explain the importance of physical activity on mental and physical health.
Trust	Having credibility and expertise will give increased power of persuasion	Notifications contain quotes taken from official sources and with scientific merit.
Perceive ease of use	Simplifying the mobile App to be easy to use by older adults	A mobile App is always available, responsive, and easy to access, has greater opportunity to persuade.

Outcome expectations	Make it possible to be aware of the expected consequences of a behavior	Demonstrate the benefits that will be derived from performing this behavior.

3.2.1. Contextual data

A very good motivation leads to a successful influence of attitudes and behaviors change only if timing and context are well chosen. In [26], Fogg has demonstrated that new computing capabilities, especially network and mobile technologies, offer additional potential to persuade people by offering suggestions:

- At the opportune moment (the Kairos factor): thanks to the mobility and connectivity of new IT systems, and
- Easily (the Convenience factor): since a computing device is always available and close to the user and its use is fast and easy without requiring a delay.

Contextual data based on "location awareness"

The location awareness refers to the capability of a device, like a smartphone, to determine its location in terms of coordinates [27]. This allows to identify the user's location through mobile devices with location technology and provide the required application services based on the location. In recent years, many portable devices have been equipped with built-in GPS location services.

To be able to geolocate the older adult, we have used the "android.location[2]" API which uses Android location based services and its related services to determine the location of the older adult's smartphone.

This API is so accurate to the point of being able to have the full address of the current position: geographic coordinates (latitude and longitude), building number, street name, city, country, and the postal code. Our Android app receives regular updates on the person's current location from "android.location" API. For example, knowing the name of the city or the name of the borough where the older adult is currently located will allow to suggest activities sensitive to the current location.

Contextual data based on "weather awareness"

To access weather's data of the older adult's current location, our mobile app uses an Open Weather Map API[3] allowing to access current weather data worldwide. Data provided by this API comes from various sources such as global and local weather models, satellites, radars, and a large network of weather stations.

Knowing the name of the city where the older adult is currently located will allow the possibility of offering activities that consider the current weather conditions in addition to the physical and mental state of the older adult.

3.3. Post-persuasion

To be considered as successful persuasion strategy, a new behavior must be preserved for a long time as several older adults may adopt the new proposed behavior for a limited period and they give up after a certain time. This can be explained by the fact that preserving a behavior or attitude requires a lot of effort, energy, and time, etc. For this reason, the older adult will continue receiving notifications on their smartphone to encourage them to maintain their new behavior and to consolidate it.

4. Validation

The availability and portability of smartphones make it possible to reach participating older adults at any place and time. We developed a full persuasion system called "ActiveSenior", a first version of

[2] https://developer.android.com/reference/android/location/package-summary
[3] https://openweathermap.org/

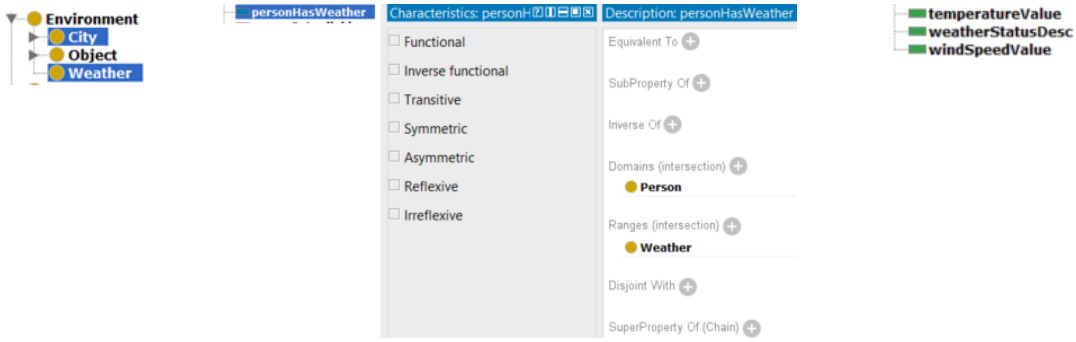
it was presented in a previous work [24]. “ActiveSenior” is made on the one hand of a front-end part which contains mobile App activities and on the other hand of a back-end part used to define the server App holding services in relation to the initial user.

Participating older adults interact directly with the front-end application, while the server App is connected to a database, containing data of each participant (his personal profile, his health state, his preferred activities, and his current context) and an ontology for decision making with semantic reasoning of defined rules.

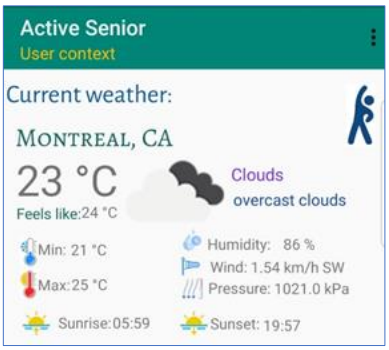
Interaction between the front-end application and the back-end application is done through php requests and with automated notifications sent via the Firebase[4] service.

Before triggering a behavior change or a physical activity, our back-end application will try to ensure the success of the persuasion technique. We have therefore extended our ontology so that it will be able to take into account the current contexts of location and weather of the older adult.

Hence, we added two sub-classes of the class “Environment”: “City” and “Weather”, an Object Property: “personHasWeather”, and several Data Properties to handle location and weather data such as: “temperatureValue”, “weatherStatusDesc”, “windSpeedValue”.



All gathered information about the older adult’s current city weather conditions is presented in our mobile App. The information presented in the activity of the mobile App are: the name of the country and the city (obtained thanks to the use of “android.location” API), the current temperature and the temperature felt, minimum temperature and maximum temperature of the day, weather condition and its description, humidity percentage, wind speed and its direction, air pressure, the sunrise time and the sunset time.



We have defined inference rules to be used by our ontology in the server side of our persuasive system. Inference rules allow to the reasoner to generate new intelligent knowledge. This latter enable to decide the best time and location to trigger a notification suggesting a suitable activity to the older adult taking into consideration his health and mental profile.

So, we have defined several rules to be used by the reasoner to decide to most suitable strategy. Below 2 examples of defined rules:

Rule 1:

```
[RuleForWalkingOutdoor: (?u pre:personHasPreferredTopic pre:walking)
(pre:walking pre:topicRequestAbility ?a) (?u pre:personHasAbilityLevel ?cl)
(?cl pre:levelHasCorrespondingAbility ?a) (?cl pre:levelValue ?v) lessThan(?v,
3) (pre:walking pre:topicRequestLocation ?loc) (?u pre:personDetectedIn ?h) (?h
pre:placeRepresentLocation ?loc) (?u pre:personHasWeather ?w) (?w
pre:temperatureValue ?temp1) moreThan(?temp1, 20) (?w pre:weatherStatusDesc
```

[4] https://firebase.google.com/

```
?d1) equal(?d1, "Clear") (pre:walking pre:topicHasPersuasionStrategy ?s) ->
Debug(?u, ?s) (?u pre:personMotivatedByPersuasionStrategy ?s)]
```

This rule asks an older adult to take a walk outside (activity WalkingOutDoor) only if all the following conditions are validated: the older adult has good health profile (the Health Utilities Index is <3) allowing him to go out to walk, the weather is clear (weatherStatus = "Clear") and the temperature is more than 20°C (temperatureValue >20).

Rule 2:

```
[RuleForHousework: (?u pre:personHasPreferredTopic pre:housework)
(pre:housework pre:topicRequestAbility ?a) (?u pre:personHasAbilityLevel ?cl)
(?cl pre:levelHasCorrespondingAbility ?a) (?cl pre:levelValue ?v) lessThan(?v,
4) (pre:housework pre:topicRequestLocation ?loc) (?u pre:personDetectedIn ?h)
(?h pre:placeRepresentLocation ?loc) (pre:housework
pre:topicHasPersuasionStrategy ?s) (?u pre:personHasWeather ?w) (?w
pre:temperatureValue ?temp1) lessThan(?temp1, 20) (?w pre:weatherStatusDesc
?d1) equal(?d1, "Rain") (pre:housework pre:topicHasPersuasionStrategy ?s) ->
Debug(?u, ?s) (?u pre:personMotivatedByPersuasionStrategy ?s)]
```

This rule asks an older adult to housework if it is raining (weatherStatus = "Rain"), the temperature is less than 20°C (temperatureValue <20), and health profile (the Health Utilities Index is <4).

To assess “ActiveSenior” App, we carried out an experiment with 8 older adults (4 females and 4 males), all aged more than 60 years. We installed “ActiveSenior” App in the smartphone of each participant and helped him to create his own profile with all required information. The following table shows some of information of personal and health profiles of participating older adults. Rows present data of each older adult. We have chosen to hide the names of participating older adults and replace them with OA_n, with n between 1 and 8, to ensure data confidentiality. Columns contain the age, the gender, and attributes of Health Utilities Index 2 and 3 (HUI-2 and HUI-3).

Table 2

Some information of personal and health profiles of participating older adults

ID	Age	Gender	Cognition	Dexterity	Emotion	Hearing	Pain	Speech	Vision	Walking
OA1	62	F	1	1	1	1	2	1	1	1
OA2	83	M	3	2	2	1	4	1	2	5
OA3	60	F	1	1	2	1	2	1	1	2
OA4	70	M	1	1	2	1	2	1	1	2
OA5	68	M	1	1	2	1	2	1	2	2
OA6	67	M	3	4	3	1	5	1	3	3
OA7	73	F	1	1	1	3	2	1	2	2
OA8	61	F	1	1	1	1	2	1	1	2

The back-end framework of our persuasive system considers the health profile of each participant. For example, the value 5 of the walking attribute of older adult OA2 shows that he suffers from walking problems. OA6 has dexterity problem with severe pain that prevent most activities. OA1, OA3, and OA8 have relatively a good physical shape according to their ages.

To choose the most suitable activity for an older adult, the reasoning engine verify the ability of the older adult to do the desired physical activity while being aware of the actual location and the actual weather conditions. The table below gives some of received notifications following the use of the semantic reasoning engine and based on health state, weather current description and temperature:

Table 3

Examples of context-aware received notifications

Older Adult	Health profile	Weather description	Temperature	Proposed activity	Received notification
OA1	Good shape	Clear	26 °C (> 20 °C)	Walking	"Walking may be the best form of physical exercise for seniors. Packed with health benefits, walking is the friendliest physical exercise. It has a low risk of injury, and it's easy to get started with."
OA8	Good shape	Clouds	28 °C (> 20 °C)	Walking	"It's time to take action. Walk and enjoy life!"
OA3	Good shape	Raining	15 °C	Housework	"A clean and organized home is a beautiful home. It eliminates the risk of developing allergies and asthma; it also reduces stress, and it is extremely vital to your mental health."
OA2	Walking problems	Clear	24 °C (> 20 °C)	Water the plants	"Water is vital for the survival of all yours plants"
OA6	Dexterity and Pain	Clear	25 °C (> 20 °C)	Sit in the balcony	"You are lucky to have a balcony in your apartment, you can breathe fresh air without leaving your home."
OA1	Good shape	Raining	14 °C	Housework	"Regular upkeep of a home in terms of cleanliness and tidiness reduces stress and it is extremely vital to your physical and mental health."

The notifications faithfully translate the rules defined for the semantic engine of the server-side application of our persuasion system. Indeed, according to the obtained results, we can notice that our system proposed the physical activity "Walking" for participant older adults OA1 and OA8. Both have a relatively good profile health and are in good shape whether it is actually "Clear" or "Cloudy" and it feels more than 20 °C.

Older adults OA1 and OA3 have the ability to go out and take a walk. But given the bad weather outside, they received notifications requesting them to stay at home and to do housework.

Participant OA2 suffers from walking problems. He can't walk for a long time and distance. Considering his state of health, we ask him to water the plants to enjoy the beautiful day and to breathe fresh air, without going too far from his home.

Finally, even if the current weather is fine and the temperature is mild enough to go out and enjoy the beautiful weather, older adult OA6, who have dexterity and pain problems, received a notification inviting him to sit in the balcony. In fact, asking him to go out could present a danger for his safety.

5. Conclusion

In this paper we detailed our approach to improve older adults' physical activities. Our work is based on several existing behavioral change methodologies and persuasion strategies which were detailed in the state of the arts. Through this work, we have improved persuasion strategies' usefulness and efficiency. This was accomplished by incorporating end-users' profiles and contextual location and weather data in our reasoning engine. We have validated our method through several defined scenarios showing the impact of the user profile and the contextual information on the persuasion strategy's decision system.

Acknowledgments

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