A Concept Model of mHealth Sensorics for Digital Assistance of Human Cognitive Resilience

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***Abstract*—The Quality of Life (QoL), especially of frail and older people, depends on the ability of a person to tolerate stresses and its negative consequences. The toleration is related to the human resilience, reflecting the three basic human functions: cognitive (the thinking process), motor (the movement activity), and autonomous (the internal body processes). The cognitive resilience is acknowledged as one of the main components of human resilience. The cognitive resilience is tightly coupled with the motor resilience. Various motor-cognitive tests are known to assess the reactivity in a custom way and with specialized medical equipment. In this paper, we introduce our concept model of the mobile Health (mHealth) sensorics for digital assistance of the human resilience during person's daily activity. In reactivity testing, a smartphone becomes a core element, replacing specialized medical equipment and transforming to a daily automatic instrument of human motor-cognitive sensorics. The collected measurements provide the base to monitor person's mental condition.**

I. INTRODUCTION

The Quality-of-Life (QoL) is an important area of consideration in modern society and human life [1]. The aim is at supporting and improving QoL. Physiologists are interested in personalized approaches when the QoL parameters are measured and analyzed for a given person. The progress in digital technologies and, especially in smart human sensorics allows regular measurement of QoL parameters for a person. Importantly that the person can become an active participant of the process as a consumer of the derived knowledge from the measurements. More knowledge on person's cognitive function provides additional ability to improve QoL.

Our special focus is on frail and older people as well as people under stressful conditions, e.g., see [2-8]. The frailty has several distinct symptoms, such as: 1) weakness, 2) slow walking speed and general slowness, 3) low physical activity, 4) unintentional weight loss, and 5) fatigue (exhaustion). In this case, the QoL level depends essentially on the human resilience as the ability to tolerate stresses and other negative impacts from the environment and society [9]. A related term is the human vitality to show the level of "life force". For frail people, the cognitive resilience is substantially decreased.

The human resilience and human vitality are related to the three basic human functions: cognitive (the thinking process), motor (the movement activity), and autonomous (the internal body processes). The cognitive resilience is acknowledged as one of the main components of human resilience. In this paper, we assume measuring the cognitive function via motor function. Our assumption is that almost all cognitive reactivity tests are motor-cognitive in nature, since human ideas, decisions, and reasoning are ultimately realized in the form of motor activity.

We introduce a concept model of mobile Heath (mHealth) sensorics for digital assistance of the human resilience during person's daily activity. The assistance is implemented when the person performs motor-cognitive reactivity tests. Our solution is smartphone-based. The smartphone replaces the specialized medical equipment in custom human reactivity testing. Such daily activities are used as tests: a telephone (for choice reaction time testing) and alarm clock (for simple reaction time testing). In addition, clicking (touch-pad) mode supports evaluation of finger tapping characteristics. In sum, the concept leads to a smartphone-based mHealth system that digitally supports the cognitive activity of a person in daily life. The assistance of cognitive resilience uses the collected measurements, which provide the base to "make insight" to person's cognitive function and mental health.

The rest of the paper is organized as follows. Section II provides a literature review to discuss the concepts of QoL, cognitive resilience, human vitality, and frailty. Section III shows our approach of motor-cognitive testing to assess human cognitive function based on motor reactions. Section IV introduces our concept of smartphone-based mHealth system for daily life use by a person him/herself. Section V summarizes the key findings of this concept study.

II. THE QUALITY-OF-LIFE PROBLEM: HUMAN RESILIENCE, VITALITY, AND FRAILTY

It is globally recognized that the QoL problem appears as critical in modern society [1]. Methods to support and improve QoL are developed all the time, and digital technologies play ever growing role in this. The improvement of QoL largely depends on the possibility and ability to adequately measure and further digitalize its characteristics. As once Peter Drucker said, *"[only] what get measured, gets managed"* [2]. Therefore, accurate, permanent and user-friendly measurement of QoL attracts more and more attention from physiologists and mHealth technology specialists.

To date, vast literature exits on how to define and measure QoL. Typically, QoL is measured with help of either generic (e.g., SF-36, EQ-5D, and many others) or disease-specific (e.g., EORTC QLQ C-30) questionnaires based on self-reports [1]. Thus, most of the existing questionnaires are clinically predisposed, although younger and many older subjects were practically not ill at the time of measurement. On the other hand, many people, including younger ones, still experience *stress* caused by the high rhythm of everyday life, especially in a metropolis. In addition, dozens of existing widely used questionnaires are not instrumented and for this reason seem to be highly subjective. Thus, there is an urgent need to objectively measure and further manage the QoL in today's society, especially in people suffering from stress.

The concept of QoL is closely related to such emerging concepts as the human *resilience* to stresses and other negative impacts from the environment and society [3], and *vitality*. *Vitality*, that is a kind of "internal capacity" or "life force" is a rather novel, widely used phenotypic concept. It is becoming popular among healthcare professionals and doctors. Recently, the World Health Organization defined resilience as “the totality of all physical and mental abilities of a person, including five areas: motor, cognitive, psychological and sensory” [4]. Vitality is associated with self-estimation of "liveliness" and feeling "full of energy", physical performance, vigor, or strength [4]. So far, viability has an unclear physiological nature, which refers it to the category of "phenotypic", or externally measured concepts. On the other hand, such a close relationship with the phenotype allows collecting objective data on physical, cognitive and vegetative performance using non-specific integrative indicators e.g. hand grip, various running tests, and tests for coordination. In other words, such "phenotypic" approach allows evaluating physical and mental "abilities", "capability", and "potential" without comprehension of physiological mechanisms of this concept. In this regard, the "external" or "phenotypic" approach is advantageous for practical applications, especially in the field of mHealth technologies.

The concepts of *resilience* and *vitality* are close to each other However, resilience has a certain meaning. It is understood as the ability of a person to resist (adapt) to life stresses (misfortunes, troubles, failures, etc.), or the ability to “bounce back” from stressors [3]. Failure to withstand stressors would lead to health problems and, finally, to medical conditions, e.g. stroke, cardiac infarction, depression, anxiety, apathy, etc. Therefore, the primary purpose of resilience is to cope with stressors and to prevent negative consequences of this. To better understand the idea of resilience it would be useful to use the concept of *frailty*.

Frailty usually refers to a state of *functional multisystem failure* characterized by several distinct symptoms, primarily 1) weakness, 2) slow walking speed and general slowness, 3) low physical activity, 4) unintentional weight loss, and 5) fatigue (exhaustion) [5-8]. Thus, frailty also means increased vulnerability and reduced ability to tolerate physiological stress, including recovering from a stressor. In that sense, the state of *frailty* looks generally opposite to the state of *resilience*.

The introduction of the notion of *frailty* helps to invent measuring facilities and instruments because all the aforementioned characteristics of frailty are physical and, therefore, subject to measurement. For example, weakness (hand grip) is measured as force (N), slowness (when walking) - as speed (m/s, km/h), weight - as mass (kg), and physical activity - as metabolism (kcal/h) or number (rate) of movements.

It looks that the motor aspects, e.g. mobility (the ability to change location in the environment that is to move between two locations) or motility (the ability to move) are best suited to measure and evaluate frailty. Indeed, in our previous paper in this area, we presented a list of motor tests and tasks that are widely used in movement physiology and neuroscience to characterize the motor system and potentially measure weakness [9]. Among these, are Walking Speed test, TUG-test, Trail-Walking test, 2, 6 and 10 minute Walking test, backward walking, tandem stepping, maximal step length, miniBEST, sit-to stand test, socks task, and many more [9]. The analysis of these tests and tasks allowed extracting some values that could allow distinguishing between normal and frail motor activity. For example, a study by Chen et al. (2014) [10] recommend 7.0 kg of muscle mass per m^2 for men (5.7 kg/m^2 for women) as measured by bioimpedance analysis, handgrip strength <26 kg for men (<18 kg for women), and gait speed at <0.8 m/s as normal ones. Kim et al. [11] recommend speed 1.24 m/s as a cutoff point for gait speed in the elderly. Normally, healthy older old people (over 80) walk at a speed 0.96 m/s [12]. In general, the average walking speed for the elderly is around 1.0 m/s. Within 2 minutes older people walk 134–184 m [13], and within 6 minutes - - 392-572 m [14]. We have shown that these tests and tasks can be combined with mHealth methods and used for frailty/resilience evaluation [9].

However, the motor aspect of frailty is not the only one. In the elderly, *cognitive frailty* is also present, which contributes general frailty [15-17]. For example, such a typical symptom of frailty as slowness refers not only to physical, but also to mental slowness. Accordingly, mental slowness can lead to slower than necessary responses to stimuli, slower consideration, slower decision making, and slower discrimination of stimuli. In neurology, for example in people with Parkinson's disease, such condition is often referred to *bradyphrenia* [18]. Like the motor one, mental slowness can be measured and assessed using various tests based on the measurement of physical metrics (speed of mental processes).

Therefore, in this particular study, we sought to expand the implementation of digitally based mHealth systems and methods towards measuring, monitoring and managing cognitive frailty, and, accordingly, resilience in people. To proceed, we sought for cognitive and motor-cognitive tests, which can be easily combined with the environment based on Artificial (AI) or ambient intelligence (AmI) via a custom smartphone.

Such approach would be meaningful in some hostile environments, for example, in the Arctic, where cold and winter darkness (light deprivation) can seriously worsen the frailty phenotype, including the cognition frailty. For example, cold can seriously deteriorate finger/hand dexterity (the ability to perform precision movements). Winter darkness (light deprivation) often provokes so-called "winter depression", which is presented as decreased ability to reasoning due to affective disorder [19]. In addition, motor frailty (asthenia), far distances in the North limits access to medical services. Thus, a*utomatic assessment* of human cognition state looks like the best solution to monitor older people as many of them have no enough motivation and mental capacities to visit a doctor or initiate self-testing.

We assume that automatic assessment can be based on a personalized device that is always with the person and can be used. In modern life, such a device exists. Almost everyone has a smartphone.

III. MOTOR-COGNITIVE REACTIVITY TESTING

Human cognitive function can be assessed in different ways. Surprisingly, it can be most readily done with assessment of motor reactions. Indeed, practically all cognitive tests are *motor-cognitive* in nature, since almost all human ideas, decisions and reasoning are ultimately realized in varied forms of motor activity. The best illustration of such approach to cognitive activity is the famous work of Ivan Sechenov “Reflexes of the Brain” [20, 41]:

> *"The infinite diversity of external manifestations of cerebral activity can be reduced to a single phenomenon - muscular movement. Whether it’s the child laughing at the sight of a toy, or Garibaldi smiling when persecuted for excessive love for his native land, or a girl trembling at the first thought of love, or Newton creating universal laws and inscribing them on paper—the ultimate fact in all cases is muscular movement".*

Motor-cognitive tests can be categorized into several groups:

1. *The "Reaction Time" (RT)* tests which lie in the frame of "Stimulus-Reaction" paradigm. In short, RT tests measure time (usually in milliseconds) between the presentation of a stimulus and the motor reaction on it. RT tests are not technically complex, commercially available, and feasible and have thoroughly investigated neurophysiologic background behind them [21-23]. Physically, in RT tests, subjects must *press a button* with their hand or finger (a button-press approach) in response to a physical stimulus (usually, visual, auditory, or tactile). However, advanced technologies allow producing even faster motor reaction, such as blinking in response to a visual stimulus [24].

There are three widely used RT tests:

a. *Simple reaction time* (SRT) refers to minimum reaction time to a single type of visual or auditory stimulus (flash or sound). If the time of muscle contraction ("motor time", MT) is subtracted from SRT, then the so-called "stimulus detection time" (SDT) can be calculated [25-28]. In general, SRT measures the ability to detect signal, organize muscle activity and to perform muscle contraction. Thus, SRT is the simplest motor-cognitive task, it requires only minimum of neural circuits to execute it.

b. *Disjunctive, or discriminative, reaction time* (DRT) is a more complex version of the RT task, in which one need to *respond to one* given and *not respond to other,* also given, stimuli in the framework of the so-called *“go/no-go”* paradigm [28]. The DRT test allows assessing such cognitive functions as *attention* and *vigilance*. Subtracting SRT from DRT represents "central functional processing time" which corresponds with time to keep attention in focus. This test helps assessing the function of the supplementary motor cortex involved in the *inhibition of unwanted movement* and the activation of desired movement [29].

c. *Choice reaction time* (CRT) tests evaluate the minimum time required to *choose* between two, three, or more stimuli by pressing a corresponding button. Thus, CRT allows to evaluate such complex cognitive processes as *recognition, categorization, sorting* and *decision making*. Accordingly, CRT tests activate neural structures specific for these processes [31]. Younger elderly healthy individuals have approximately 100 ms longer CRT than younger individuals [25–28,31-32]. By subtracting the SRT from the CRT, one obtains the so-called "central processing time" (CPT), which roughly corresponds to the "decision time"[31].

In general, RT tests are very informative because they are associated with specific, well-known neural circuits in the human brain. They also have practical implications, as often older people or people with Parkinson's disease have to choose between (or among) colored light stimuli, such as green, yellow, and red traffic lights on streets, in order to start moving, to start or, instead, not to start crossing the street.

2. *Digitomotor tests.* Among these tests, the finger tapping test (FTT) is the most commonly used. To perform FTT, subjects tap their wrist on a PC-based contact board with a contact pencil as quickly as possible [33]. Also, this test can be performed using a finger equipped with a contact sensor. The FTT task evaluates the total number and rhythm of pencil and contact mat touches. In addition, this test can be used to evaluate motor time [24]. In general, the FFT allows assessing the ability to produce quick stereotyped movements. Such a task is important, for example, in neurology (tapping with the index finger on the tip of the thumb). Alternatively, finger tapping can also be performed using accelerometry [34] or PC-based technologies [35].

3. Tasks for *Manual Target Interception (MTI).* In these tasks, the subject must respond by pressing a button exactly when a moving object on the PC screen coincides (overlaps) with a stationary (motionless) object. This task enables evaluating *spatiotemporal integration*, since in order to continue, subjects must track both the location and the speed of movement of two objects [36-38]. The most interesting parameter to measure in this test is Time-to-Contact (TTC) which characterizes minimal time needed to evaluate exact time for making a decision (pressing the button).

There is an even more challenging variant of MTI, known as *Predictive Motion Task* (PMT). In PMT, it is necessary to press the button when two objects are supposed to coincide on the PC screen in the *blindfold zone*, that is, in the absence of visual control over the place of collision of two objects [39,40]. These tasks are important for assessing the ability to intercept objects, i.e. in sports (a ball) or, instead, to avoid collision with moving or falling objects (cars in motion, pedestrians on the streets, birds, etc.).

4. *Pardue Pegboard Test (PPD),* a psychomotor test to assess manual dexterity and coordination. In this test, the subject needs to place pins (cylinders) into the holes on the board (from 9 to 25 holes) as fast as possible [41].

The above mentioned RT tasks can be categorized as *"button-press measurements"* or *"discrete stationary"* measurements because they collect information in a *discrete* manner exactly during button pressing. For this reason, these tests provide only limited insight into the *dynamics* of reasoning and decision-making [42]. To overcome this limitation, *"continuous measures"* based on so-called *"continuous flow model"* were elaborated [42]. Among them, *Eriksen Flancker Task* attracts [43] more and more attention. This test based on hand tracking between two targets in response to congruent and incongruent stimuli (flankers, or arrows directed in congruent or incongruent direction). In this test the reaction lasts a few seconds, which allows to measure adaptation of tracking to changing conditions.

In addition, there are tests to assess various psychomotor skills and abilities (aiming, eye-hand coordination, hand-foot coordination, etc.) [44], tracking, memory, vigilance, attention, vernal and spatial processing [45].

As mentioned above in the text, most cognitive tasks appear as the *"button-press"* ones. Basically, they are performed in standard laboratory conditions using custom instruments. However, pressing a button requires time and neural resources to organize it. Alternatively, a motor-cognitive reaction can be performed using a *"pad-touch"* [42], which can be used in a tablet or smartphone, what significantly expands the possibilities of their "instrumentalization".

Touching the pad is mechanically more efficient, fast and simple than *pressing* a button. In addition, the software of tablets and smartphones is much more adaptable/flexible in presenting different stimuli in terms of their color, number, shape, size, etc.

In addition, in most custom available PC-based psychotesters the screen, where stimuli are presented and the control panel, where buttons are located, are designed as *two separate* devices of the same tool. In tablets and smartphones, touching sites (virtual buttons, control panel) are *located on the same screen, where stimuli are presented* in Fig. 1. Thus, our touch-pad-focused approach has reduced our search to motor-cognitive tests that can be performed using smartphones or tablets.

In many ways, smartphones seem to be the most valuable home device, because it is directly connected to the transmission and receipt of information, as well as the Internet. In addition, it may come with numerous applications available for download from online stores. Nowadays, almost everyone has a smartphone.

Thus, we can presume that a smartphone (or a tablet) is well-suited for motor-cognitive testing, and is promising for integration with the digital environment, e.g., mHealth technologies. In this study, we explore some pre-requisite capacity of a smartphone to assess cognitive status and frailty in humans, and possible ways to integrate with the digital environment.

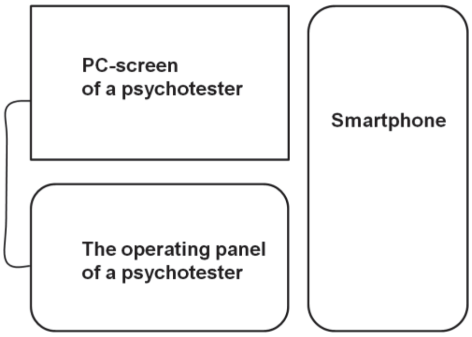

Fig. 1. Schematized appearance of a custom psychotester and a smartphone.

IV. CONCEPT OF SMARTPHONE-BASED MHEALTH SYSTEM - "INSTRUMENTALIZATION" OF A SMARTPHONE

Various digital assistants become actively used in human daily life, moving healthcare from specialized medical laboratories to smart home environments [9]. One of the latest exciting examples is chatbot interventions designed to improve physical activity, diet, and sleep [66]. Our proposed concept supports development of a smartphone-based mHealth system for assisting the cognitive activity of a person in daily life. The assistance uses the collected measurements, which provide the base to "make insight" to person's cognitive function and mental health.

A. *Specialized Device vs. Smartphone*

On the topic of the search, several studies are present in the existing literature. The most recent study by Hallgren and Rogers [46] describes an iPad-based instrument supplied with proprietary software for assessing reaction time in the SRT test and number of finger presses in the FTT test. This allowed to quantify both SRT and SDT (labeled in this study as "cognitive latency") and motor time (labeled as "neuromuscular latency"). The use of these two psychomotor tests (SRT and FTT), performed using conventional laboratory equipment, has been previously discussed in other studies and has shown high reliability for assessing both SDT and MT [25,47]. In addition, in the study [46], the user was asked to calculate a simple mathematical equation in their head, for example, subtract 3 from 5, and then select the correct answer among several alternative options by clicking on its section on the screen. The latency of this task has been quantified. Thus, the whole psychomotor task was performed entirely with the help of the iPad.

The iPad model was not specified in this study, but its dimensions seem to be quite large, since the shift between serial tasks in FTT across the screen was at least 24 cm. The results of this study look promising for the development of other psychomotor tests, i.e. CRT, MTI and PMT. Modern smartphones often have large screen, so some of them are comparable in size to mini-tablets. For example, many smartphone models are 15 cm long and 8-9 cm wide. Thus, tests such as SRT and FFT can well be performed on smartphones.

In the study by Zhan et al. [48] a smartphone app was used to assess PD with help of 5 metrics - voice features, *finger tapping*, gait, balance, and *reaction time*. Gait characteristics (step length) appeared to be the best predictor of PD severity. Nonetheless, this study showed that all types of signals studied can be sensed and are meaningful. Gait in PD subjects is often explicitly disordered, which can be detected even with the naked eye. In frail people, reaction time and finger tapping may be as informative as gait parameters. Several other studies present similar result that gait characteristics in subjects with neurological conditions (PD, multiply sclerosis, and stroke) collected and analyzed with smartphone applications are diagnostically valuable [49-52]. In neurologically healthy individuals, applications have been reported to be sensitive to trace modification in a two-choice reaction time test [53].

In general, it is likely that mobile phone applications for cognitive testing are currently designed mainly to detect certain diseases, functional deficiencies and disorders. As for frail, and especially, pre-frail people, these applications are still rarely used. However, such applications may also be useful for healthy people who are under stress, or being frail. Self-administration of cognitive tasks looks a possibility to monitor cognitive state of a frail or pre-frail person. Such a possibility, for example, for motor tasks, is discussed in the existing literature [54].

However, cognitive testing using a smartphone is a kind of experiment that requires certain commitment, adherence and motivation from the user to initiate and complete it. So, it is necessary to consider the possibility of further "instrumentalization" of a smartphone to test cognition in the direction of "daily life activity" environment, or "experiment' without "experiment".

B. *Scenario - "Experiment without experiment"*

Smartphones are already “pre-equipped” with pre-installed motion detection sensors such as accelerometers, gyroscopes, magnetometers, and location and tracking apps. These sensors and apps collect information during daily life activity, what fits well to the concept of "experiment without experiment". However, that is not the case for motor-cognitive testing. As mentioned afore head in the text, a smartphone can be downloaded with software for RT testing [46]. To complete the test, a subjects need to use touch-screen technique, what is much more comfortable than "button-push" one. Still, such approach requires strong commitment and motivation to initiate the test and complete it in the self-administration mode.

In this regard, an *alternative* approach to testing cognitive functions using a smartphone can be figured out. This approach requires only minimal commitment (compliance) from the subject, since the smartphone is actually used as an instrument for mental tasks in the conditions of "daily life activity".

More specifically, *most adults actually deal with a touchpad based motor-cognitive tasks technology, in daily-life style,* because many times a day they have to make a decision - *to answer the caller* or *decline (reject) the phone call?*

On a smartphone screen, this situation is very similar to setting the choice reaction time, because there are two round color stimuli - red (decline, reject) and green (allow access, answer the caller). In addition, a visual stimulus is supplemented with an auditory (buzzing) and/or tactile (vibration) stimulus and also some text information (the name of a familiar person or a number of a stranger), and numbers.

In general, one incoming phone call gives the user enough information (visual, auditory, tactile, and textual) to make a decision (see Fig. 2). In the same way, the beep of an alarm clock is like a signal for a simple reaction time task, as it requires only reacting, without choosing or discriminating.

As for the digitomotor tasking, in the study [35], FTT is presents in the form of "distal finger tapping" (DFT). In DFT, the PC keyboard is used to perform taps (keystrokes) and the PC comes with special FTT software. Thus, DFT looks promising, as it demonstrates the possibility of "instrumentalization" of a PC, which can be further expanded to a tablet or smartphone. Correspondingly, the button-press mode will be substituted to the touch-pad one (clicking).

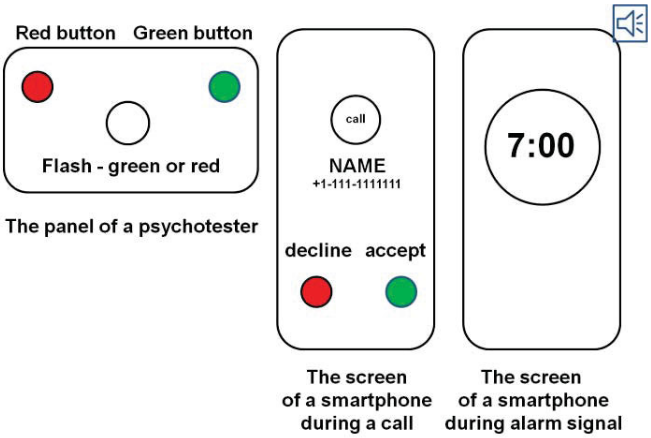

Fig. 2. The appearance of the psychotester panel (left) and the smartphone screen during a telephone call have a lot in common (middle). The alarm clock emits a sound signal, like in a simple reaction time task (right).

In addition, FTT can be further modified with some neurological finger tests. For example, in the UPDRS-III (Part III, Motor Examination), which is a widely used neurological clinimetric scale, one of the most sensitive tests for assessing the severity of PD is *finger tapping* [55]. To continue, one needs to quickly tap the index finger on the thumb, 10 times in a row. The examiner evaluates this task by the rhythm (regularity), episodes of slowing, arrest, amplitude decrement, interruptions in tapping, etc. Such a test can well be performed with a smartphone screen.

These examples show that tablet or smartphone are in advance well suited for motor-cognitive tasking.

The aforementioned examples fit well into the concept of *"instrumentalization"* that is, the expansion of the functionality of some regular household appliances (home units) into an "instrument". The treadmill appears as one of the best examples of an "instrumented" household appliance [56-59]. The treadmill was originally invented to allow exercising at home conditions and for diagnostic purposes, for example in cardiology and sports. In addition to that, treadmill allows producing standard uniform acceleration (perturbation), velocity and inclination of the running belt. Thus, a conventional treadmill equipped with force sensors, motion video capture or wearable accelerometers becomes a valuable tool for scientific research.

Altogether, we can speculate that some daily life motor-cognitive practices of a modern smartphone user are strickingly similar to certain conventional motor-cognitive tasks (Table I).

The following plan can be figured out to test the potential of a smartphone for "instrumentalization" within the "experiment without experiment" concept.

First, a data set on SRT, CRT and FTT must be collected with help of conventional tests and custom laboratory instruments. A data set on SRT, CRT and FTT must be also collected with help of smartphone apps (e.g., DFT) in laboratory, and compared for reliability with those, obtained with custom instruments.

TABLE I. CORRESPONDENCE BETWEEN MOTOR-COGNITIVE TASKS AND SMARTPHONE-USING PRACTICES

A kind of motor-cognitive task	Corresponding task in the smartphone-based practices
Simple reaction time (SRT)	Reaction to alarm signal
Choice reaction time (CRT)	Reaction on incoming call (to decline or to grant)
Finger tapping test (FTT)	Clicking during text typing

After that, a series of simulation of "daily life activities" with smartphone can be suggested:

a. To simulate SRT, alarm clock of a smartphome emits sudden sound signal, and a subject must react on it as fast as possible. Reaction time is measured.

b. To produce CRT, an examiner places telephone call to a subject. The task is to react - to choose, for example "accept" or "reject". Reaction time is measured.

c. To simulate FTT, the rate of clicking on a screen (typing a text/message) is measured.

Finally, real field conditions ("daily life activities") can be used for testing. It could be organized as automatic evaluation of reaction time to telephone calls during the whole day, reaction on alarm clock and evaluation of text typing in message service. In a way, this looks like automatic count of stepping (tracking), accelerometric or gyroscope signal. Such analysis can be carried out automatically during the day.

All three sensory modalities provided by smartphones can be used as stimuli: visual (red and green flashes on the screen of smartphones), auditory (ringtone) and tactile (vibration). In addition, some textual information (phone number, "familiar caller name" or "unknown caller") can be added to the stimulus.

C. Screening tests and cutoff values for motor-cognitive tests

As well as for motor tests, the existing literature presents studies that provide numerical normal values for finger tapping, reaction times in simple, selective, or discriminative motor cognitive tasks.

Typically, CRT lasts 190-220 ms in young healthy people and 230-250 ms in older healthy people [25,27]. In neurological diseases, such as Parkinson's disease, SRT is extended to 300-350 ms, which reflects both bradyphrenia and bradykinesia [26,31,32]. CRT lasts slightly longer in healthy people (300-400ms) and in older people (500-600ms) because some extra time (central processing time) is required to properly recognize and respond to one of the two (or more) what means to "make a decision". The auditory reaction time in CRT tasks is even faster - less than 100 ms in high-class athletes [60].

During FTT, healthy controls are able to produce tapping at a rhythm of 6–7 Hz [61]. It is noteworthy that tapping differs depending on age, gender and finger (the fastest tapping is with the index finger, the slowest is with the ring finger) [62-63]. Thus, FTT can be produced in several ways - one-finger, double-finger, individual-finger. FTT is reliable even for test durations as short as 20 s, which avoids the fatigue effect [61]. In addition, the DFT version of FTT allows collecting information about the intervals between taps, which can be used for further quantitative analysis of the nature of tapping (a measure of stereotype).

D. Enabler Technologes (smartphone-based)

Assessment of reaction time, either simple or choice, in the laboratory conditions can be regarded as "gold standard" methods. Field conditions are preferential, but

"...simply being in the field - no matter how physically challenging the task being performed - does influence physiology [64].

Therefore, the best approach to evaluating motor-cognitive reactions is to conduct them within the framework of daily life activities, with only minimal awareness of the subject (user) that tasking is actually going on. In a way, tasking, according to this approach, will be rather "embedded" into the real daily motor-cognitive activities. As for self-administered and self-conducted testing, the major problem with them is that subjects involuntarily would try to perform *as good as possible* [64].

Previously, we discussed this possibility of testing the engine using a smartphone [9]. We believe that some traditional motor-cognitive tests, such as motor tests, can be integrated into the smartphone environment and, further, combined with mHealth technologies. For example, individual data can be analyzed using machine learning (ML) algorithms [64]. On the other hand, the values of the proposed measures (SRT, CRT, finger tapping measures) usually differ significantly among the subjects. This suggests that machine learning algorithms should be applied to each subject individually, depending on his/her unique input data [64].

E. Candidate functional tests and tasks to assess the motor performance

Thus, at least three methodologically simple (easy to perform, safe, self-measured and reliable) motor-cognitive tests are used in the field of psychometric research: 1) simple reaction as a marker of slowness and ability to detect a signal, 2) choice reaction time as the ability to make a decision based on categorization and sorting, 3) the finger-tapping test as a measure of slowness and coordination, together could form a reliable battery for assessing mobility and frailty in seniors.

V. CONCLUSION

This paper introduced a concept model of the mHealth sensorics for digital assistance of the human cognitive resilience. The concept leads to a smartphone-based mHealth system for automatic assessment of cognitive resilience. The system measures and evaluates cognition-related daily life activities. The derived knowledge (for decision) is delivered to people - frail, pre-frail, or non-frail. Smartphone seems a very promising personal device for "turning" into a daily automatic instrument which can unobtrusively monitor and inform the the person on the cognitive status and mental health. As a result, human frailty syndrome is decreased, so increasing the human resilience through the motor-cognitive activity. The assistance provides motivation to the person to start more physical activity, to monitor the status and the progress.

Notably that the proposed concept model can be very effective in difficult-for-life environments, e.g., the Arctic and Nordic territories (in wide sense). Cold conditions and winter darkness (light deprivation) seriously deteriorate both finger/hand dexterity and the ability to reasoning due to affective disorder. Automatic assessment of operation with smartphone could have informed on the condition of the human motor and cognitive functions.

ACKNOWLEDGEMENT

The research is implemented with financial support by Russian Science Foundation, project no. 22-11-20040 (https://rscf.ru/en/project/22-11-20040/) jointly with Republic of Karelia and funding from Venture Investment Fund of Republic of Karelia (VIF RK).

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