Assessment of the doctoral dissertation of Assaf Ben Shoshan, MSc, entitled „Home Use Medical Devices: the User Acceptance"

The basis for the review is the letter I received from Chancellor of the College of Health Sciences of Medical University in Poznań (signed KKN/451/2021) and the doctoral dissertation prepared by Mr. Assaf Ben Shoshan, MSc, who applies for a doctor's degree in the field of medical sciences and health sciences in the discipline of health sciences.

The present PhD thesis was prepared in a form of monograph written in English language and supplied with abstracts in both English and Polish. The manuscript contains a total of 130 pages, and the text is referred to 85 bibliography items (ranging from 1979 to 2020 year) which are quoted in the order of appearance. The helpful appendices are also the lists of fugures and tables. Fortunately, the list of abbreviations is placed at the very beginning of the manuscript, which seems absolutely necessary, because the text is full of the specialized, technical abbreviations, which makes reading with understanding a quite great challenge.

Starting this review, it should be mentioned that due to the fact that people's life span is continuously increasing, there is a rapid rise of the elderly population all over the globe. These are the persons who must struggle with multumorbidity, mobility problems, mental and emotional impairments,   including, finally, disablility. Especially during the COVID-19 pandemic, accessibility of public health services occured to be extremely constricted; it was bitterly shown how difficult and sometimes completely impossible became a direct contact between patient and doctor. What makes a situation even more hopeless, most of elderly and severely ill older patients cannot afford to use the private healthcare services.

On the other hand, the permanent and very rapid development of more and more sophisticated technologies in various field of our life is a real fact. This seems to be also an unavoidable process in healthcare sector. That is why, the future of medical care will be undoubtedely closely related with routine application of different testing and monitoring medical devices at home. Real enormous budgets and giant efforts are devoted nowadays to create something like, we can say, 'home medical diagnostic and treatment center'. Also, in Poland, there are some concepts as well practical trials in the domain of so called 'telemedicine'. For instance, usage of special T-shirts supplied with electronic sensors detecting and alarming (if needed) about the basic life signs or the recorders informing the distant medical centers about dangerous cardiac events.

In the light of awareness that healthcare sooner or later will enter patients' homes, the author posed the very important questions regarding the attitudes of the users of the home medical devices. These questions are: 1. How should then users' acceptance of new technologies be evaluated and predicted? 2. Which users' charactertics nad attributes will determine whether the users will even try using an advanced medical monitoring ot treatment tool at home, let all alone purchase it and keep on using it? 3. Is there a way to better understand the process of decision making regarding the acceptance of these new home-use technologies?

Searching the answers to these questions, Author undertook considerations about the Technology Acceptance Model (abbrevated as TAM) which is thought to be the most influential model to explain the users' attitudes towards acceptance of any innovative technologies. TAM contains both cognitive and affective determinants of attitudes, like, among others, age, socioeconomic background, education level, as well the actual behaviour of the users of the new devices.

The structure of the work is a little bit diffrent from this commonly used in case of Polish doctoral dissertations. The short 'Introduction' is followed by the chapter no. 2 named 'Literature Review', through which the author described concisely some main aspects of Home Use Medical Devices (HUMD) defined as 'devices used in any setting outside of professional healthcare facilities'. The author informs that his special interest was focused on Smartphones-Based HUMD (SB-HUMD) that include smartphones apps and additional smartphone abilities, like its processing power, camera, and many others. According to the author's declaration, for the purpose of his research, the term HUMD has been identified with the term SB-HUMD.

In the discussed chapter, the reader can learn about the present and prognosed size of the global healthcare market, increasing rapidly in the medical devices sector. Based on American FDA list of devices approved between years 2018 and 2020, the HUMD innovations mostly concern usage of smartphones and non-invasive, remote detection, including wearable medical fitness devices and big data-oriented devices, as well multiscreening (here one device is designed for detection more than one illness or vital sign).

What is quite understandable, a decision about recommending any new medical devices to the patient depends first on the positive attitude and trust of the medical professionals. Their acceptance, in turn, is certainly influenced by various variables and considerations. Thus, recognizing and understanding this background seems to be crucial for wider introducing any HUMD among patients. On the other hand, obviously, given the heterogeneity of the nonprofessional population of potential home-use medical devices users (differing in age, mental abilities, physical fitness and so on), the designers and engineers of HUMD should always apply universal design principles and validated acceptance models while preparing any novel devices. Of importance is also how the particular new device is perceived by the potential user just prior the decision of usage or purchase. This aspect is just taken into consideration in almost all extensions of Technology Acceptance Model (TAM).

The original concept of Technology Acceptance Model was presented for the first time in 1985 by Fred Davis in his PhD thesis. And just the essence of the model created by Davis was that so called Perceived Usefulness (PU) of the new technology and its Perceived Ease Of Use (PEOU) determine personal attitude towards technology using (ATT), which then determine one's actual usage of the new device. The most meaningful change in the original model was introduced in 1989 also by Davies and his co-workers. It was the addition of Behavioral Intention component (BI) as a mediator between attitude towards using (ATT) and actual use of the new technology. This classic approach became then the base attracting many researchers to modify and improve TAM model mainly by adding the external factors that allegedly can influence over the person's Perceived Usefulness (PU), including, e.g., one's voluntariness.

As declared by the author, in the present study, the Technology Acceptance Model originally published by Davis and co-workers in 1989, was used as the base. In the adopted by

the author model, the Perceived Usefulness (PU) component means the degree to which a person believes that the use of Smartphone-based home-use medical devices (SB-HUMD) will improve his/ her health or health care. Then, Perceived Ease Of Use (PEOU) is defined by the author as easy or effortless SB-HUMD use in the perception of the client. Next component, Attitude Towards using (ATT) in the author's approach means the degree to which a person's attitude is favorably or unfavorably disposed towards using SB-HUMD. ATT, in turn, is assumed to positively influence on Behavioral Intention (BI) that is defined in this study as an individual's intention to real use the given Smartphone-based home-use medical device (SB-HUMD). In the author's opinion, regardless some limitations, weakness, and 35-year existence, Technology Acceptance Model (TAM), owing to its simplicity and generality, should be still considered as the very useful tool in many scientific field. Besides, TAM can be easily extended by adding external, contextual, social, and any other factors.

A novelty proposed by the author is a concept to combine TAM with another model, which is able to unite the external factors that influence TAM in the optimal manner and is integrated with TAM, in order to create a compelling prediction tool. The author' suggestion of such additional model was 'Sense of Coherence' (SOC) developed on the base of 'solutogenic model' introduced in the late 70's by Aaron Antonovsky, an American-Israeli medical sociologists. Antonovsky perceived health as changes on continuum between pathogenesis ('dis-ease') and salutogenesis (total health, 'ease'). The crucial elements in the salutogenic model are: the orientation towards problem-solving and the capacity to use the resource available. The further concepts developed by Antonovsky based on the 'solutogenic model' were: the General Resistance Resources (GRRs) and the Sense of Coherence (SOC).

GRRs are material, biological, and psychological resources, like economic status, intelligence, knowledge, healthy behavior, self-esteem, or social support. When a person is able to use these resources properly, it makes easier to cope with life challenges and relieve tension and stress caused by multifactorial stressors, which is fundamental for maintaining total health.

In turn, 'Sense of Coherence' (SOC) means the global orientation that expresses the extent, to which a person has a dynamic feeling of confidence that: 1) stimuli, deriving from one's internal and external environments in the course of living, are structured, predictable and explicable; 2) the resources are available to meet the demands posed by these stimuli; 3) these demands are challenges worthy of investment and engagement. In another approach, three content domain of 'Sense of Coherence' (SOC) were conceptualized: Comprehensibility (cognitive component); Manageability (instrumental component), and Meaningfulness (motivational component).

Therefore, SOC is considered as a major life orientation focusing on problem-solving, developing mainly up to the age of 30. People with stronger SOC probably have better abilities to deal with stressful event with the help of available resources. SOC appeared to be a good predictor of health and quality of life. It was proved that strong SOC is associated with lower depression, anxiety and physical symptoms as well with better psychological and physical well-being and functional abilities, including elderly persons.

Antonowsky also developed a self-report measure of SOC using the questionnaire composed of 29 items concerning the above-mentioned three SOC domains, and later he

elaborated the shorter version with 13 items, named SOC-13. The latter questionnaire was used in the study performed by the author of the present thesis.

Assessing the first, introductory and quite large part of the present doctoral thesis, it should be remarked that some preliminary knowledge given by the author was really neccessary to understand better the main core of his research.

Neverthless, it seems to me that the author devoted too much place for very detailed information concerning the clues which should be rather inserted in the chapters Methodology and Discussion. The minor comment regards Figures 1, 2, and 3 that are illegible, at least for the rewiever's eyes. Some statements placed in the introductory text, concerning the study aim and methodology of the doctor's own study, should be shifted to the further chapters. The present layout gives sometimes the impression of redundancy and is a bit confusing.

Going on, in the subchapter 3.2 entitled 'Aim of the study' the reader can learn that in the present study, the author intended to 'contribute to the global efforts to better understand and to model the user acceptance of new technologies, specifically home use medical devices'. The general aim of the study was followed in the manuscript by the four more detailed questions. In addition, the author formed four hypotheses, of which the 4th is the most interesting from the practical point of wiew. It concerned a possibility of creating the integrated prediction model that fits the data, in which the SOC content domains would predict the TAM content domains.

My remark – it would be beneficial to combine the subchapters 3.2 ('Aim of the study') and 3.3 ('Hypotheses') with the fragment named 'Objective' into one part entitled „Aim(s) of the study' for better clearness of the author's message.

To obtain the study aim assumed, the author was going to collect empirical evidence to answer the question whether 'Sense of Coherence' (SOC) may be used to unify the external factors and predict 'Attitude Toward Using' and 'Behavioral Intention to use' of the Technology Acceptance Model. A scheme of this new planned prediction model is nicely depicted in Figure 7.

The chapter 4., named 'Methodology', yields a description of the research sample examined. Hebrew speaking participants were recruited by means of emails and social media during January-March 2020. Finally, a group of 305 persons at age from 18 to 85 years (male 44.5%), declaring a possible usage of home devices, answered to the online questionnaires available through the link leading to the easy to use survey site. The study sample consisted of mostly well-educated and well-earning healthy individuals without any mobility problems who neeed neither to care for other persons nor check health measures often – but knows other persons who need. *Here, I would like to recommend moving the above-mentioned findings, as well Tables 3 and 4, presenting the socio-demographic and health-related characteristics of the study sample, respectively, to the chapter 'Results'.*

In the unusual manner, the information about the study method used, that is three-part self-report questionnaire disseminated among the study sample, was presented partially in the subchapter 3.1 entitled 'The Research Strategy' and partially in the subchapter 4.3 of Methodology entitled 'Tools – how was it done'. I would kindly suggest to merge these two subchapters and insert them in the chapter 4. that should be entitled 'Material and Methods'. The present arrangement makes the text a bit inconsistent.

Thus, in order to increase the usability of TAM for better recognizing the users' acceptance of SB-HUMD, the author applied 3-part survey. The first part included an explanation about SB-HUMD as well basic demographic and health data of the study sample, which correspond with GRRs ('General Resistance Resources') in SOC ('Sense of Coherence'). The second one included 19 questions testing four main content domains of TAM. The last part of the survey was the SOC-13 questionnaire assessing the level of 'Sense of Coherence' of the respondents, which is considered a link between the personal parameters (GRRs) and the TAM.

In the author's assumptions, examination of the interrelations among the GRRs, SOC, and TAM was to be useful in creating a new model that should enhance the understanding and even predict the users' acceptance of Smartphone-based home-use medical device (SBHUMD).

The selection of various statistical methods used for data analysis seem to have been proper to provide the reliable results.

Proceeding to the 'Results' of the discussed study – the first task was an evaluation of 'Sense of Coherence' (SOC) in the study group of 305 participants using the Hebrew version of the SOC-13 questionnaire. SOC, as it was mentioned earlier, unites a wide spectrum of external factors into three main SOC content domains, i.e., C – Comprehensibility (4 Qs); MA – Manageability (4 Qs), and ME – Meaningfulness (5 Qs). General SOC scores were found to be normally distributed in the study group, with the mean value of 4.94 (the higher scores, the more positve attitudes), which is presented in Figure 12. *Remark – in the right top of this Figure, there is probably a mistyped number of participants; 304 instead of 305; the same concerns Figure 14.* The individual content domains of SOC gained the following mean scores: Comprehensibility – 4,69; Manageability – 4.73, and Meaningfulness – 5.32.

Thus, it was shown that the Meaningfulness content domain scores were significantly higher as compared with the two remaining domains. It was also found, using Pearson's correlation, that there were moderate significant positive correlations between general SOC scores and the particular content domains. *The manuscript's page 48 in my copy is blank.* The Figure 13 on page 49 comprehensively presents the overall mean values of the 13 SOC items obtained, with the marked three content domains.

Then, the correlations of SOC and demographic variables and health-realted variables were examined. The study participants' age was found to be correlated positively with the general SOC scores. The statistical analyses revealed that the older group (above 46 years of age) had higher SOC scores than the younger group (under 46 years of age) in two domains, Comprehensibility and Manageability, while no differences existed in the Meaningfulness domain. Also, the author noted that the higher education level, the higher both general SOC scores and the scores of all three content domains. Similarly, the study participants with satisfying financial status had the significantly higher all SOC domains. As to gender, it was revealed that the participants' all SOC scores did not differ depending on gender. Interestingly, the general SOC scores were higher in persons living with a partner as compared with those living alone.

In the next step, the association among health-related variables and SOC were statistically analyzed. During completing the online questionnaire, examined respndents assessed their worrying about health issues using a 5-point Likert scale, ranging form 1 'not

worried' to 5 'very woried'. The Pearson's test revealed negative corelations with weak significance among the SOC scores (both general and for 3 domains) and the level of sad thinking about examined persons' health. It means, that higher SOC score are related to to lower levels of general health worries. Only 67 of the examined group declared a chronic disease; however this fact had no impact on SOC scores. No differences in SOC scores were also noted between the respondents not caring for another person versus those who had to take care of somebody else. Out of 305 participants only 43 reported the need to take health measures often; this variable did not have statistically anything to do with SOC scores. Also, no impact on SOC scores was noted in case of familiarity with another person who needs to take health measure often. This part can be summarized that SOC scores obtained by the study sample were influenced by age, education level, perceived financial status, living with/without another person and level of health-related worries.

The next questionnaire used in the study was the 19-item Technology Acceptance Model (TAM). It was found, using confirmatory factor analysis, that PEOU (Perceived Ease Of Use; items 1-6) and PU (Perceived Usefulness; items 7-12) together with ATT (Attitude Towards Technology using; items 13-16) and BI (Behavioral Intention; items 17-19) explained 67.31% of variance. General TAM scores ranged from 1.00 to 5.00 (the mean: 3.92) with negative skew (-1.11) in the examined group. *Question – what is a practical meanning of this skewness?. On page 61 – repetition of one text paragraph.*

The individual content domains of TAM gained the following mean scores: PEOU – 4.14; PU – 3.87; BI – 3.76, and ATT – 3.84. It was found that all TAM content domains were strongly and significantly related to the general TAM scores, and there were positive significant correlations among the indvidual above-listed TAM domains. It was shown that the scores of PEOU ('Perceived Ease Of Use') content domain were significantly higher than all other TAM domains' scores.

There was an interesting observation that only 11 persons out of the sample obtained extremely low TAM scores (2 and more SD below the mean value). These were older subjects (43-78 years of age) with little health worries, living with a spouse at satisfying financial level, manifesting no chronic disease and mobility limitations and who who needn't have taken a care of other persons. It can be even understood that having such an excellent life these persons were not interested in home-use health devices.

Demographic variables in relation to the TAM scores were as follows: - the older participants (above 46 years of age) had lower TAM scores exclusively in the PEOU (Perceived Ease Of Use) content domain as compared with the younger ones; - persons with better financial status showed both the higher general TAM scores and scores in PEOU content domain; - no TAM scores were correlated with gender, education level and living circumstances. *Remark: there is a typing mistake in the heading of Table 17; it should be: 'Differences in TAM (not SOC) score by age'.*

As concerns the Technology Acceptance Model (TAM) and the health-related variables, no correlations were found for health worries and TAM scores. Also no statisticaly significant differences between the study sample's subgroups were observed regarding occurrence of chronic disease, a need of taking health measures often as well familarity with persons who need do that. Interestingly, the subgroup of 22 participants who had to care for another person regularly showed the significantly lower scores in the general TAM and its two content

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domains: Behavioral Intention (BI) and Attitude Towards Technology using (ATT) that have considerable effect on the final decision of the actual use of new devices.

In the further stage of the study, the author was examining the correlations between SOC and TAM scores. Pearson's correlation coefficients turned out to be statistically significant only for the SOC's 'Meaningfulness' content domain which is a motivational component. Scores of 'Meaningfulness' correlated with the general TAM scores and all TAM's content domains except BI (Behavioral Intention). This outcome means that the higher level of meaningfulness, the higher technology acceptance presented by the study participants.

After the preliminary findings concerning the external variables associated with the SOC and the TAM scores as well the correlations between the SOC and TAM scores, finally, the author could start to construct a desired model predicting TAM (Technology Acceptance Model) with the help of SOC (Sense of Coherence). From the external variables included in SOC, 'Meaningfulness' appeared to be the most strongly related with TAM factors except BI (Behavioral Intention). However, according to the original TAM model, the PU (Perceived Usefulness) and PEOU (Perceived Ease Of Use) content domains are predictors of the BI content domain. A hypothesis that there can be a multicollinearity among PU, PEOU and ATT (Attitude Toward Technology using) as predictors and BI as the outcome variable was not supported by the linear regression analysis.

On the other hand, the TAM model suggests that external variables are antecedents of TAM's PU (Perceived Usefulness) and PEOU (Perceived Ease Of Use), and, as it was proved by the author, the SOC's 'Meaningfulness' could play a role of the strong external variable. Furthermore, according to the solutogenic theory, 'Sense of Coherence' (SOC) depends on general resilience resources (GRRs), and some of them (age, health worries, education, perceived financial status) turned out to be significantly related to SOC's 'Meaningfulness' content domain in the present study. Therefore, it seemed reasonable to include these particular variables, as covariates, to the theoretical prediction model. Taking into consideration that the author formerly found no correlation between the SOC's 'Meaningfulness' and the Behavioral Intention (BI), the designed model was to be examined including the mediation effect of PU (Perceived Usefulness) and PEOU (Perceived Ease Of Use) on the correlation between 'Meaningfulness' and Attitude Toward Technology using (ATT) content domain. These assumptions underlied the theoretical mediation model construction.

The proposed prediction model was then tested statistically using the hierarchical regression analysis. Besides the Meaningfulness and classic components of the TAM model, age, education level and financial status of the study sample were taken into consideration. *Question to the author: why in this analysis, health worries was not included although ithis factor was also significantly correlated with SOC's 'Meaningfulness' (Table 12)?*

Finally, step by step, it was proved that the theoretical prediction model proposed by the author includes the indirect relationship between SOC's 'Meaningfulness' and Attitude Toward Technology using (ATT), and Behavioral Intention (BI) as mediated by PU (Perceived Usefulness) and PEOU (Perceived Ease Of Use). The both latter TAM content domains predict the Attitude Toward Technology using (ATT), which, in turn, predicts the Behavioral Intention (BI) to actually use the new technology at home. *Remark: in Figure 18, a place of Behavior Intention is not denoted in the prediction model. What was the author's intention?*

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In the chapter 6. Discussion, the author emphasizes that the main purpose of his study was to integrate, for the first time, the classic TAM (Technology Acceptance Model) with SOC ('Sense of Coherence'), derived from the salutogenic model, as the contribution representing the influence of external variables. In the result, the simple theoretical model which is able to improve the ability to explain and predict users' acceptance of new technology has been created by the author.

Interestingly, such variables like suffering from chronic diseases and neccessity of taking health measures were not found to be significantly related to the level of 'Sense of Coherence'. This result supports the Antonovsky's view that more important than the presence of real stressful life events is a person's own perception of these circumstances as manageable challenges that can be resolved.

The other intriguing finding was that 'Sense of Coherence' is positvely correlated to age, especially as to 'Manageability' and 'Comprehensibility', however not to 'Meaningfullness'. The latter content domain, the motivational component related to perceiving life problems as challenges worth investing, turned out to be stable along the life span. Contrary to this, the perception of ability to use available life resources and the ability to understand the life demands improved with age, which can be elucidated by life experience gained with time.

In the present study, it was shown that there is a significant correlation between TAM and SOC, especially its 'Meaningfullness' content domain. 'Meaningfullness' – a motivational component that refers to the extent to which life makes sense emotionally – was found to be positively related to the perception of usefulness of the new technology and ease of its use. Then, this component positvely influences the attitudes towards using the smartphone-based home-use medical devices (SB-HUMD). This finding suggests that higher levels of the SOC's motivational component, which is 'Meaningfullness', are related significantly to better acceptance of new technology. Suprsingly enough, the SOC's cognitive and instrumental aspects, that is 'Manageability and Comprehensibility', turned out to be not related to the SB-HUMD acceptance. This phenomenon can be interpreted that the emotional- behavioral factor, as a predictors of new technology acceptance by users, overcomes the cognitive and instrumental factors.

The author summarized the study results that the examined personal General Resistance Resources (GRRs) like age, level of education, financial status and living with another person, are related to the 'Sense of Coherence' level. Then, the person's SOC level, especially 'Meaningfullness', was found to predict PU (Perceived Usefulness) and PEOU (Perceived Ease Of Use) as the domains of tehnology acceptance. In turn, these two content domains predict Attitude Toward Technology using (ATT), which then predicts the Behavioral Intention (BI) to use the technology, in this case smartphone-based home-use medical devices (SB-HUMD).

The presented chapter seems to be rather a forum for the author's discussions about the resulats obtained but not a wide polemic with reports of other researchers. However, this can be easily understandable because of the unique nature of the author's project. The author claims that the proposed by him new predictive model from the practical poin of view can open a real possibility for other researchers to consider and integrate appriopriate psychological models together with technological models, which could result in producing objective and efficient tools to predict the users' acceptance of various new devices, including useful home medical aids.

It is worth mentioning that the author widely consider the limitations of the current study, among other, that completion of the online survey requires some technical skills which are not common in the elderly population, and that there was a lack of possibility to examine causality, which is planned by him to be carried out in the future study. The most important, also in the reviewer's opinion, limitation was the fact that the study sample consisted mostly of healthy people with high financial status and easily available free health service. The above socioeconomic factors could affect the final results. I fully agree with the author that the created by him prediction model must be necessarily examined on the less fortunate population, like the older adults, who especially should need the SB-HUMD.

The chapter 7. ('Final Remarks') seems to be a redundant element containing the previously presented data and opinions. Finally, it must be emphasized that the Conclusions are generally consistent with the assumed objectives of the doctoral thesis. However, the conclusion no# 4 is too long and concerns rather detailed study results instead of being the statement of more general nature, so I would suggest to rearrange these point. Besides, it seems reasonable to use the conclusions the complete terms instead of the abbreviations, which would make them more understandable and informative even without reading the full text of the dissertation.

Summing the review up, it should be strongly noted that the present doctoral dissertation regards a very important aspect because the health care will be with time undoubtedely predominated by various technological devices used at home, which will enable to introduce for a wider scale the telemedicine solutions. The author conceived a novelty idea and then constructed the interesting prediction model combaining psychological and social factors with the commonly accepted Technology Acceptance Model.

Beside the cognitive aspect of this work, even more precious is a posssibility of practical application of the results of the present research, which can enable better understanding the determinants of new technologies acceptance by the potential users and more accurate prediction of the final decision as to the actual usage of medical devices at home. Such future perspectives seems to provide the diseased people the explicit bonus with regards to more comfortable and effective health care provision.

Final conclusion: Taking all together, I am absolutely convinced that, despite the minor, mostly editing remarks, the present doctoral dissertation fully meets the conditions set out in Article 13.1 of the Act of March 14, 2003 on academic degrees and academic title as well as degrees and title in the field of art, as later amended.

In the opinion of the reviewer, Mr. Assaf Ben Shoshan, Master of Science, presented a very good mastery of the conceptual and experimental work, scienitifc maturity, independence and inventiveness, as well the ability of effective presentation of the results of his own research.

Therefore, I am turning to the Council of the College of Health Sciences at the Medical University of Poznań to accept the work entitled „Home Use of Medical Devices: the User Acceptance" as a doctoral dissertation, as well to admit its author, Mr. Assaf Ben Shoshan, to further stages of the process of obtaining a doctor's degree in the field of medical sciences and health sciences, in the discipline of health sciences.