GLOBAL HEALTH 2019

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GLOBAL HEALTH 2019 Editors

Hassan Khachfe, Lebanese International University, Lebanon

GLOBAL HEALTH 2019

Forward

The Eighth International Conference on Global Health Challenges (GLOBAL HEALTH 2019), held between September 22-26, 2019 in Porto, Portugal, took a global perspective on population health, from national to cross-country approaches, multiplatform technologies, from drug design to medicine accessibility, everything under mobile, ubiquitous, and personalized characteristics of new age population.

Recent advances in technology and computational science influenced a large spectrum of branches in approaching population health. Despite significant progresses, many challenges exist, including health informatics, cross-country platforms interoperability, system and laws harmonization, protection of health data, practical solutions, accessibility to health services, and many others. Along with technological progress, personalized medicine, ambient assistance and pervasive health complement patient needs. A combination of classical and information-driven approach is developing now, where diagnosis systems, data protection mechanisms, remote assistance and hospital-processes are converging.

The conference had the following tracks:

- Health and Wellness Informatics
- Challenges
- Alternative
- Global

We take here the opportunity to warmly thank all the members of the GLOBAL HEALTH 2019 technical program committee, as well as all the reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors that dedicated much of their time and effort to contribute to GLOBAL HEALTH 2019. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

We also gratefully thank the members of the GLOBAL HEALTH 2019 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope that GLOBAL HEALTH 2019 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the domain of global health. We also hope that Porto provided a pleasant environment during the conference and everyone saved some time to enjoy the historic charm of the city.

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Effects of Perigestational Exposure to Chlorpyrifos and/or High Fat Diet on Sleep Apnea in Young Adult Rats

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***Abstract*-Chlorpyrifos (CPF) is an organophosphorus pesticide widely used in the world, which acts by inhibiting acetylcholinesterase (AChE). Exposure to this compound is harmful to the respiratory system during *in utero* and postnatal period. Such perturbations during prenatal and intrauterine life are associated with further diseases at adulthood through fetal programming. Some of these disturbances are linked to food composition and environmental pollutants. The aim of this study is to examine the effects of perigestational exposure to CPF and to a High-Fat Diet (HFD) on the occurrence of sleep apnea in young adult rats. Female rats were exposed for four months before and later during gestation and lactation periods to CPF (1mg/kg/day *vs* vehicle) with or without HFD. *In vivo* measurements of sleep apnea were performed by whole-body plethysmography for male pups at post-natal day (PND) 60. Then diaphragm, an essential respiratory muscle, were dissected and used for *in vitro* measurements of AChE activity assessment. The perigestational exposure to low dose of CPF and/or HFD induced an increase in the sleep apnea index in males at early adulthood, which was associated with a significant decrease in the AchE activity compared to controls. In conclusion, the chronic perigestational exposure to CPF combined with HFD feeding is associated with increased sleep apnea occurrence and reduced AchE activity at early adulthood in rats. Other studies are required to investigate the mechanisms underlying respiratory perturbations during development due to early life perturbations.**

Keywords- Chlorpyrifos; high-fat diet; sleep apnea; diaphragm.

I. INTRODUCTION

The perinatal period is characterized by high plasticity of the physiological systems, exposing the individual to higher vulnerability to his environmental factors. Then, any disruption in these physiological processes is described in the concept of Developmental Origin of Health and Diseases (DOHaD) **[**1**]**.

Maternal obesity constitutes an environmental risk favoring the occurrence of obesity or type 2 diabetes at adulthood [2][3].

Organophosphate (OP) insecticides are compounds commonly used for a variety of agricultural, industrial, and household applications [4] and are detected in food and drinking water [5]. They are potent AChE inhibitors resulting in the accumulation of acetylcholine at cholinergic synapses and consequent overstimulation of the central nervous system and neuromuscular junctions [6]. Recently, it has been shown that exposure to Carbofuran, an AChE inhibator, is positively associated with sleep apnea in US Farmers [7]. Central respiratory failure associated with apnea is considered to be the major cause of death following OP poisonings [8]-[10]. CPF, an OP pesticide, is suspected to affect the metabolic programming from the fetal period until adulthood [11]. Pre- and postnatal exposure to CPF has been shown to increase sleep apnea index during development [12]. However, continuous perigestational exposure for four months, before gestation till the end of lactation, without exposing the rats directly to CPF during early adulthood has not been examined.

It has been shown that sleep apnea is associated with moderate to severe levels of obesity [13]. Studies in obese populations have reported an association between metabolic dysfunctions and sleep apnea [14]. Furthermore, the increase in the incidence of apnea during sleep has been shown to be dependent on the metabolic disturbances such as insulin resistance induced by High-Fat Diet (HFD) feeding in rats despite the absence of obesity as reported by Ramadan et al. 2006 [15].

In this context, the present study aimed at determining the effects of long term perigestational exposure to CPF and/or HFD, 4 months before gestation and throughout gestational and lactational periods, on the occurrence of sleep apnea in young adult rats who were not exposed directly to CPF or HFD. Also, we measured the AChE

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activity in the diaphragm, an essential respiratory skeletal muscle. The paper procedes as follow: Section II describes the exparimental design, data are analysed in Section III, and, finally, Section IV presents the discusion and draws the conclusions.

II. MATERIALS AND METHODS

This section describes the methodology and the experimental tools used.

A. Experimental Design

Female Wistar rats (age on arrival: 7 weeks) receiving a standard diet or HFD (60% kcal from fat) were force-fed with CPF (1 mg/kg/day) *vs* vehicle (rapeseed oil) for four consecutive months. Then, the females were mated with the male rats. During gestation, the females were subjected to the same treatment as before gestation until the end of the lactation period. At weaning; postnatal day (PND) 21, pups were separated from their mothers and four groups of male rats (n=7 per group) were identified according to their maternal exposure into: Control group (standard diet and vehicle), HFD group (HFD and vehicle), CPF group (standard diet and CPF), and HFD+CPF group (HFD and CPF). After weaning, the pups received only a standard diet without CPF until the PND60. Whole-body plethysmography was used to score apnea index during sleep for all male pups. Only male rats were selected for this study since female rats were used in another study.

B. Protocol for sleep apnea assessment

Each animal was familiarized for 60 min to the plethysmograph chamber during two consecutive days before the onset of measurements. On the second day, during the 60 min of measurement, behavioral observations were performed. We continuously noted whether the rat was awake (i.e., lying or standing with opened eyes) or was asleep (i.e., lying down without movements with closed eyes). Sleep apneas were scored using a previously described procedure, i.e., defined as two missed breaths [16]. Sleep apnea indexes were calculated as the number of apneas/h of behavioral sleep.

C. Acetylcholinesterase activity measurement

The Acetylcholinesterase activity in the diaphragm dissected from the midcostal region was measured according to the modified Ellman method [17]. The diaphragm samples were homogenized in lysis buffer (Abcam) and then centrifuged. 1 µl of protease inhibitor (Abcam) was added to the supernatant. The supernatant (diluted 1:2) was incubated with 100 µm of the butyryl cholinesterase inhibitor, tetra isopropyl pyrophosphoramide (Sigma-Aldrich) for 15 minutes before measuring AchE activity using the AChE colorimetric assay kit (ab138871; Abcam) according to the manufacturer's instructions. The AchE activity is expressed in µmol/min/mg protein.

D. Statistical Analysis

A two-way analysis of variance (ANOVA) was used to study the main effects of diet (standard diet/HFD) or exposure (Control/CPF) and the interaction between diet and CPF exposure. If a significant interaction was found, a non-parametric Mann-Whitney U test was then performed. Statistical significance was set to $p<0.05$ and indicative results ($p<0.1$) were shown when needed.

III. RESULTS

The main results obtained are presented in this section.

A. Sleep apnea index

A significant increase in sleep apnea index with either maternal CPF exposure ($p<0.05$) or HFD feeding ($p<0.05$) was observed. Indeed, there was a significant increase in the sleep apnea index by 96% in each of CPF group ($p<0.01$) and HFD group ($p<0.01$) and by 88% in CPF+HFD group ($p<0.05$) compared to the control group (Figure 1).

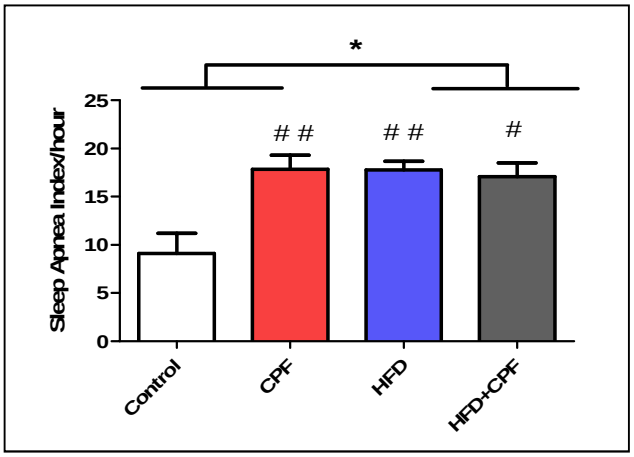

Figure 1. Effects of perigestational exposure to CPF and HFD on the sleep apnea index. Data are quoted as means ± SEM. Effect of diet *: $p<0.05$. CPF x diet interaction: #: $p<0.05$; # #: $p<0.01$ vs. control.

B. Acetylcholinesterase Activity

AchE activity levels were significantly reduced in CPF group ($p<0.05$) and HFD group ($p<0.05$) by 53% and by 29% respectively compared to controls. A significant decrease was also reported in CPF+HFD group by 40% ($p<0.05$ vs control) (Figure 2).

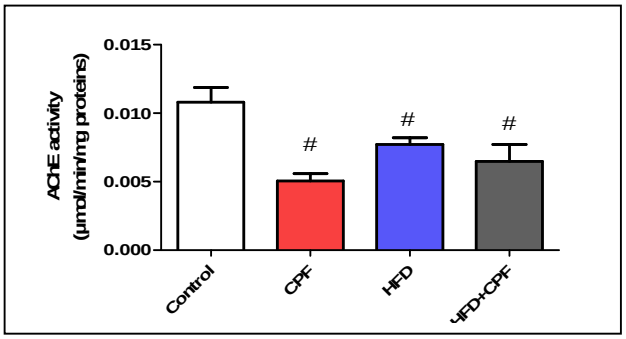

Figure 2. Effects of perigestational exposure to CPF and HFD on AchE activity. Data are presented as means ± SEM (n=7-10/group). CPF x diet interaction: #: $p<0.05$ vs. control.

IV. DISCUSSION AND CONCLUSION

This study is in line with the DOHaD concept. Since fetal development depends mainly on the maternal nutritional supply, then any disruption in the intrauterine milieu could predispose offspring to further diseases in later life. The present study was designed to evaluate, for the first time, the impacts of long term maternal exposure to two major alimentary risk factors; junk food and OP pesticide residues on the respiratory performance during early adulthood. The perigestational effects were studied through continuous exposure of female rats to CPF (1 mg/kg/day) and HFD (60% kcal from fat) four months before gestation till the end of lactation period at the PND21 and without exposing the pups after PND21 to neither CPF nor HFD.

The present study showed that perigestational exposure to CPF and/or HFD is associated with increased sleep apnea index. An increase of 67% in the sleep apnea index was reported in developing rats that are pre and postnatally exposed to CPF [12]. In our study, the increase in the sleep apnea was higher (around 100%) in CPF and/or HFD exposed rats. This incremental increase can approve the concept of DOHaD where maternal exposure to environmental toxicants can affect the life of the offspring even if they are not exposed to the same toxicants as shown in our study. The apnea episodes observed following OPs exposure can be attributed to either central effects caused by the AChE inhibition in the respiratory centers [18][19] or to peripheral effect resulting from airway obstruction [20]. On the other hand, HFD has been shown to increase apnea incidence in sleeping rats as a result of the induced metabolic disruptions [15].

The increase in the sleep apnea index could be linked to the reduced AchE activity in the diaphragm resulting in the overstimulation of the motor end plates. Obesity can affect the muscle force production by altering fiber type composition of the muscle and by disrupting calcium cycling mediated by the major calcium channels, ryanodine receptor and SERCA pump [21][22].

In conclusion, the maternal exposure of rats to CPF and/or HFD during the perigestational period alters the respiratory performance in their offspring at early adulthood despite they are not in direct contact to either CPF and/or HFD. Further studies are needed to determine the mechanisms underlying respiratory perturbations during development due to early life disturbances. The integration of this study can help in the prevention of chronic respiratory diseases in adults.

REFERENCES

[1] M. Kappil, R. O. Wright, and A. P. Sanders, "Developmental Origins of Common Disease: Epigenetic Contributions to Obesity," Annul Rev. Genomics Hum. Genet., 17, pp. 177–92, 2016.

[2] M. Z. Alfaradhi, et al., "Maternal Obesity in Pregnancy Developmentally Programs Adipose Tissue Inflammation in Young, Lean Male Mice Offspring," Endocrinology, 157(11), pp. 4246–56, 2016.

[3] S. Lecoutre, et al., "Depot- and sex-specific effects of maternal obesity in offspring's adipose tissue," J Endocrinol., 230(1), pp. 39–53, 2016.

[4] M. Maroni, C. Colosio, A. Ferioli, and A. Fait, "Biological Monitoring of Pesticide Exposure: a review. Introduction," Toxicology, 143(1), pp. 1–118, 2000.

[5] H. G. Bolles, et al., "U.S. market basket study to determine residues of the insecticide chlorpyrifos," J. Agric. Food Chem., 47(5), pp. 1817–22, 1999.

[6] B. Ballantyne, Clinical and Experimental Toxicology of Organophosphates and Carbamates [retrieved: July, 2019]. Available from: https://books.google.com/books/about/Clinical_and_Experimental_Toxicology_of.html?id=zgslBQAAQBAJ

[7] B. O. Baumert, et al., "Sleep apnea and pesticide exposure in a study of US farmers," Sleep Health, 4(1), pp. 20-26, 2018.

[8] Y. Lerman and H. Gutman, "The use of respiratory stimulants in organophosphates' intoxication," Med. Hypotheses, 26(4), pp. 267–9, 1998.

[9] M. Yamashita, M. Yamashita, J. Tanaka, and Y. Ando, "Human mortality in organophosphate poisonings," Vet. Hum. Toxicol., 39(2), pp. 84–5, 1997.

[10] P. M. Bartholomew, G. Gianutsos, and S. D. Cohen, "Differential cholinesterase inhibition and muscarinic receptor changes in CD-1 mice made tolerant to malathion," Toxicol. Appl. Pharmacol., 81(1), pp. 147–55, 1985.

[11] T. A. Slotkin TA, "Does early-life exposure to organophosphate insecticides lead to prediabetes and obesity?," Reprod. Toxicol., 31(3), pp. 297–301, 2011.

[12] W. Darwiche, et al., Impact of chronic exposure to the pesticide chlorpyrifos on respiratory parameters and sleep apnea in juvenile and adult rats," PLOS ONE, 13(1): e0191237, 2018.

[13] A. N. Vgontzas, E. O. Bixler, and G. P. Chrousos, "Sleep apnea is a manifestation of the metabolic syndrome," Sleep Med. Rev. 9(3), pp. 211–24, 2005.

[14] K. P. Strohl KP, et al., "Insulin levels, blood pressure and sleep apnea," Sleep, 17(7), pp. 614–8, 1994.

[15] W. Ramadan, et al., "Sleep apnea is induced by a high-fat diet and reversed and prevented by metformin in non-obese rats," Obes. Silver Spring Md., 15(6), pp. 1409–18, 2007.

[16] D. W. Carley and M. Radulovacki, "Mirtazapine, a mixed-profile serotonin agonist/antagonist, suppresses sleep apnea in the rat," Am. J. Respir. Crit. Care Med., 160(6), pp. 1824–9, 1999.

[17] G. L. Ellman, K. D. Courtney, V. Andres, and R. M. Feather-Stone, "A new and rapid colorimetric determination of acetylcholinesterase activity," Biochem. Pharmacol., 7, pp. 88–95, 1961

[18] J. L. Carey, C. Dunn, and R. J. Gaspar, "Central respiratory failure during acute organophosphate poisoning," Respir. Physiol. Neurobiol., 1;189(2), pp. 403–10, 2013.

[19] R. J. Gaspari RJ and D. Paydarfar, "Dichlorvos-induced central apnea: effects of selective brainstem exposure in the rat," Neurotoxicology, 32(2), pp. 206–14, 2011.

[20] B. J. Proskocil, D. A. Bruun, C. M. Thompson, A. D. Fryer, and P. J. Lein, "Organophosphorus pesticides decrease M2 muscarinic receptor function in guinea pig airway nerves via indirect mechanisms," PloS One, 5(5), pp. 01-11, 2010.

[21] K. Funai, et al., "Skeletal Muscle Phospholipid Metabolism Regulates Insulin Sensitivity and Contractile Function," Diabetes, 65(2), pp. 358–70, 2016.

[22] F. Seebacher, J. Tallis, K. McShea, and R. S. James, "Obesity-induced decreases in muscle performance are not reversed by weight loss," Int. J. Obes., 41(8), pp. 1271–8, 2017.

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Population Level Analysis of Acute Stroke Care Patterns in Hungary

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***Abstract*—Stroke is a global health challenge and it represents a significant economic and social burden. The treatment of stroke requires urgent and coordinated procedures. In this clinical data analysis study, our aim is to identify anomalies in the stroke care system. We analyze the stroke care patterns using case records of all 281,948 publicly financed cases between 2010 and 2017 in Hungary. The essence of the method is creating care events of some basic types, organizing event series into episodes, classifying episodes with respect to relevant care patterns, computing 'spectra' of episode type frequencies for the providers and forming clusters of the providers based on the correlations among their spectra. A similar method is applied for postal code areas. The results show that two clusters can be defined that divide the 61 clinics into a smaller and a larger cluster with significantly different care practices. The spatial analysis also revealed that the clusters of the postal code areas form geographically co-located patches marking anomalies in the stroke care system. The novelty of the paper is the proposed method and its application to stroke care. The findings may be used for quality management of the national stroke network.**

Keywords-stroke care; patient pathways; clustering; clinical data analysis.

I. INTRODUCTION

Stroke is major cause of death in developed countries and the decreased quality of life of the survivors also means a heavy social and economic burden, making this disease the focus of several epidemiological studies [1].

The currently recommended best practices for the treatment of acute stroke involves in several cases thrombolysis and thrombectomia procedures, for which specialized *stroke units* are required at the care providers. Time is a crucial factor of the treatment as these procedures can only be applied during the first ca. 4.5 hours after onset according to the relevant medical protocols [2]. After the acute stroke has been diagnosed, the patient should be transferred to a stroke center as soon as possible. For the precise diagnosis, a Computer Tomography (CT) scan of the skull is normally considered a prerequisite. Due to the proven success of the specialized stroke units [3][4], a country-wide network of stroke centers with stroke units has been developed in most European countries over the past two decades.

Due to the economic and social importance of stroke, the efficiency of the care services is vital and should be monitored, yet there are no widely accepted methods for this purpose. Our study focuses on Hungary, a country with a population of ca. 10 million, where the stroke center network was set up between 2010 and 2012. We do not analyze the clinical outcome (e.g., 30-day survival) of the stroke episodes, rather, we try to identify the typical care patterns of the stroke centers and the other, non-specialized clinics as well. The results presented here build upon our earlier results in this field [5]. Since the different patterns are associated with different costs and procedural risks, such results may be used for the planning of the national stroke care network. The most important original contribution of the paper is the proposed analysis method. To our best knowledge, no similar methodology has been used to date to characterize the stroke healthcare network at the population level. In the most closely related, recent analysis, the authors analyzed acute stroke-care quality for the cases of 74,000 patients in Great Britain, according to the connection between time of the day and the day of the week of the start of the care and the 30-day survival [6]. In our study, the main objective is to identify anomalies in the care system.

This paper is organized as follows. In Section II and III, we present the input data and the analysis methods. The results are stated and visualized in Section IV, and discussed in Section V. Finally, conclusions are drawn.

II. INPUT DATA

Hungary has a single, centralized health care insurance system which makes it possible to gain access to the data of *all* publicly financed cases of the past 20 years in an anonymized Data Store (TEA) of the National Healthcare Services Center. The private domain care volume in this filed is negligible. The case data include patient demography, the start and end date of an inpatient case, the associated International Classification of Diseases (ICD) codes and the codes and time stamps of the performed procedures. This is an administrative data base, so it has some definite shortcomings for clinical analysis: the start time of the case and the time of the CT scans are stored only at date precision and also the ICD and WHO coding practices of the clinics must be understood properly in order to successfully reconstruct the real sequence of events in a case.

For this study, we queried acute ischemic stroke cases from the TEA between 2010 and 2017 (eight full years) which

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had main ICD codes of I63 and I66. Since such main codes are often used too liberally for uncertain cases, we discarded cases which did not contain a skull CT scan in the time frame of -1 to 7 days of the inpatient case start date. Thus, we had a total of 281,948 cases belonging to 228,751 patients over the 8-year period.

III. METHODS

The basic methodology of care pattern analysis is based on forming and classifying 'episodes' containing care events and computing a 'care spectrum' for each provider, and it was originally proposed for another care domain [7]. The 'spectrum' contains the relative occurrence ratios of the various episode types and our basic assumption is that if these ratios are similar for two providers, then their care practice is also similar. Finally, the overall stroke care system can be assessed by finding groups of 'similar' providers at the national, i.e., population level.

A. Data cleaning

Since the TEA data was collected for financial reimbursement purposes, first we had to go through an elaborate data cleaning process:

1) Patients for whom the gender, age, or residence data was missing or unclear, were excluded from further analysis.

2) Since we wanted to assess the care profile of the care providers, we excluded the cases and the individual procedures if the provider could not be identified from the TEA records.

3) Based on the case data, we created a list of care events for each patient. We had only four possible event types, the CT event, the thrombolysis event (TL), the thrombectomy event (TE) and the simple care event (C), i.e., an event in which the status of the patient is assessed by a medical professional without imaging. This may happen for example when the doctor decides to refer the patient further to another clinic, possibly a stroke center.

For more details on data cleaning, please see the study by Vassányi et al. [5].

B. Creating and classifying episodes

An 'episode' means as all care activities related to a new acute stroke occurrence. Technically, we prescribed that an episode must be preceded by at least one event-free day and it may not last longer than two days (five days only in case of repeated TL/TE procedures). Since the transfer of an acute patient from a provider to another involves a time delay and a medical risk, we distinguished episodes involving a transfer from those that do not. We defined five episode types as shown in Table I. The table also shows the number of episodes of the respective types in bold face.

C. Clustering the providers

We created clusters from the providers as follows.

1) We assigned each episode to a single clinic, which in the case of the type 4 and 5 episodes, was the first clinic, i.e., the clinic where no procedure was performed.

2) We created a profile for each clinic. The profile is a template that consists of five numbers which are the frequencies of the clinic's episodes of the above five episode types.

TABLE I. EPISODE TYPES

Type Code	Event sequence
1	An episode without CT, with no further referral to another provider and no procedure performed. This may be due to a light stroke that requires no further clinical care or a late delivery to the clinic (over the 6-hour time window). Number of Type 1 episodes: **21,983**
2	A CT was performed, but there was no TE or TL and the patient was not transferred to another clinic. The reason for this may be a not so severe stroke or a late delivery (over the 6-hour time window). Number of Type 2 episodes: **220,061**
3	A CT and a TE or TL was performed, and the patient was not transferred to another clinic. The typical case for this type is a severe stroke patient that was delivered straight to a stroke clinic, within 6 hours from onset. Number of Type 3 episodes: **10,794**
4	The patient was delivered to a clinic, where no CT or TL/TE was performed, then the patient was transferred to another clinic (in most cases, a stroke center) where a CT and TL/TE was performed (the TL/TE is optional). This is a less favorable scenario, because the patient should probably have been transferred straight to the second provider. Number of Type 4 episodes: **15,678**
5	Same as Type 4 with the difference that a CT was taken at the first clinic. Such an episode type may emerge from a case when the CT suggests a TL/TE procedure, but first clinic has no such facilities and they are still within 6 hours. Number of Type 5 episodes: **2,182**

3) We used Pearson's correlation as a measure of similarity between any two pairs of clinics, to build up a symmetrical correlation matrix in which the element$_{i,j}$ is the correlation between the *i*-th and *j*-th clinic's profile.

4) We created a network using this correlation matrix in which the nodes are the clinics and the edge weights are the linearly transformed matrix elements. Thus, two clinics following a 'similar' clinical care practice were connected with an edge of a heavy weight.

5) We used the Louvain network clustering algorithm based on modularity functions to identify significantly strongly connected sub-networks, i.e., clusters of clinics, of the above network [8].

6) In order to characterize the spatial distribution patterns of the episode types, we also used the clustering process described in the steps 3-5 above to cluster the postal code (ZIP) areas. Since the patient demography data contained the postal area code of the patient at the time of onset, we could compute the profile for each area from the episode types of the area's patients. For that, we used the number of episode types per 1000 inhabitants of the area.

For more algorithmic details on steps 3, 4 and 5, please refer to the study of Vassy et al. [7].

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D. Software tools used for the analysis

The data cleaning and provider profiling was performed using MS SQL Server 2014 database server. For the Louvain clustering we used the Modularity Optimizer tool, version 1.2.0. Statistical pre- and post-processing was implemented with the R 3.1.1 tool. Data visualization for heat maps was created with the SeaBorn package in Python.

IV. RESULTS

At the end of the data cleaning process we had 904,089 events, out of which there were 617,276 CT, 274,292 C, 11,813 TL and 708 TE type events.

The total number of episodes is 270,698 with an average of 2.09 events per episode. Table I shows the number of episodes of the respective types.

There were 37 stroke centers in operation in Hungary in the analyzed period. Considering only the 37 dedicated stroke centers, the clustering procedure did not find significantly different clusters. When we considered all 61 clinics that have a total episode count over 200, two distinct clusters were identified:

1) A small cluster of 9 clinics, of which there was only one specialized stroke clinic;

2) A large cluster of the rest 52 clinics.

The frequencies of the five episode types, as well as the average number of episodes for the two clusters are shown in Table II.

In order to visualize the homogeneity of the two clusters, Figure 2 shows a graphical visualization of the correlation matrix in the form of a 'heat map' in which the correlations are color-coded according to the color ramp key at the left side, light shades meaning strong correlation. The 9 clinics of the small cluster are located in the first 9 rows of the symmetrical matrix.

We also performed the clustering with slightly different algorithmic parameters of the Modularity tool and with another clustering methods, but there was no significant change in the cluster assignments, showing that the clustering method is quite robust.

The clustering of the 2,637 postal code areas also resulted in two clusters. The cluster parameters are shown in the columns 'Cl. 1 (all)' and 'Cl. 2 (all)' of Table III. Cluster 1 had a very high intra-cluster average correlation of 0.97.

TABLE II. CLINIC CLUSTER FEATURES

Cluster feature	Cluster 1	Cluster 2
Number of clinics	9	52
Avg. ratio of Type 1 episodes	0.13	0.08
Avg. ratio of Type 2 episodes	0.37	0.83
Avg. ratio of Type 3 episodes	0.003	0.043
Avg. ratio of Type 4 episodes	0.50	0.04
Avg. ratio of Type 5 episodes	0.004	0.013
Avg. No. of episodes per clinic	1,118.44	3,284.19
St. dev. of the No. of episodes	831.74	1,939.32

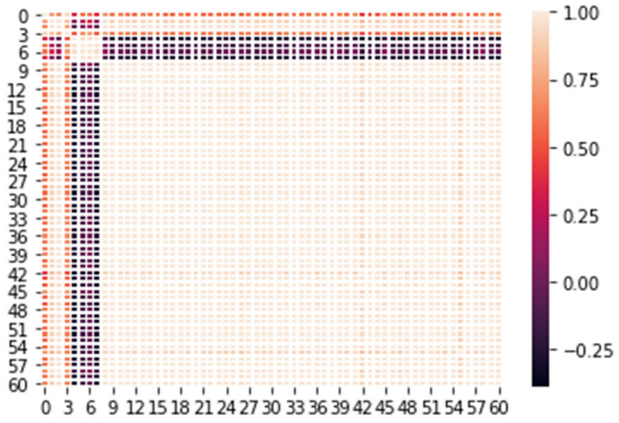

Figure 1. Heat map of the two provider clusters

When we excluded the regions with less than 1000 inhabitants, we had very similar results that are shown in the in the columns 'Cl. 1 <1000' and 'Cl. 2 <1000' of the same table. The table shows the number of episodes / 1000 inhabitants in the areas belonging to the cluster.

TABLE III. POSTAL CODE AREA CLUSTER FEATURES

Cluster feature	Cl. 1 (all)	Cl. 2 (all)	Cl. 1 >1000	Cl. 2 >1000
Number of areas	592	2,045	296	1,173
Avg. # of Type 1/1000 inh.	1.77	1.26	1.60	1.30
Avg. # of Type 2/1000 inh.	13.42	17.91	12.22	16.85
Avg. # of Type 3/1000 inh.	0.72	0.96	0.68	0.89
Avg. # of Type 4/1000 inh.	5.02	0.30	4.01	0.34
Avg. # of Type 5/1000 inh.	0.28	0.22	0.26	0.17

We visualized the spatial location of the areas belonging to the same cluster to see whether they appear randomly at any part of the country or they form homogeneous patches. The resulting two maps are shown in the Figure 2.

V. DISCUSSION

The features of the two clusters of the clinics show quite characteristic differences.

- In general, Cluster 1 is characterized by less valuable clinical services (c.f. the higher ratio of CT-less episodes) and a relative preference of 'forwarding' stroke care to other clinics, proven by an order-of-magnitude difference in the type 4, and also a huge difference in type 5 episode frequencies.
- Cluster 2, containing five sixths of the clinics, is characterized by a relative preference of on-site treatment, with or without a TL/TE procedure. This pattern is more in line with the expected practice according to the protocol.

The very high correlation coefficients within the clusters and the low inter-cluster values (dark shades) in Figure 1 show a marked difference between the two groups.

Since the cause of treating a stroke case without taking an emergency skull CT may be either a too late delivery of the

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patient to the clinic or the inability to perform a CT a possible reason for a clinic to belong to Cluster 1 could be a lack of proper imaging infrastructure or skilled staff. A possible interpretation of this cluster is that it is an outlier group as contrasted to the 'normal' majority of the other clinics, but this requires further investigation. On the other side, a high frequency of too late deliveries in the vicinity of a clinic may mean anomalies in logistics or emergency services.

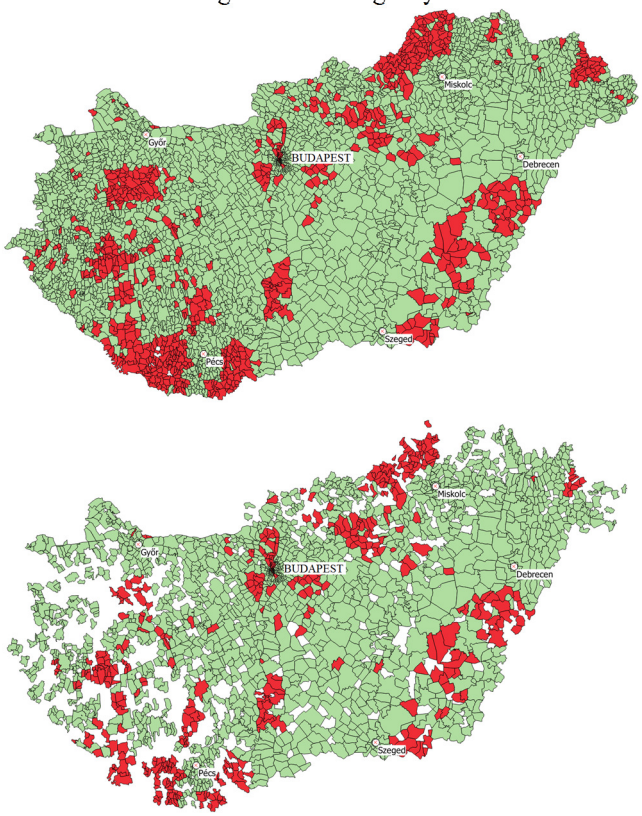

Figure 2. Postal code area clusters for all areas (upper) and without areas with a ppopulation of less than 1000 (lower). Cluster 1: red patches, Cluster 2: light green patches, areas with less than 1000 are white

As Table III shows, the two postal code area clusters, with huge differences in the number of Type 4 episodes, are very similar in nature to the two clusters of the clinics. The visually apparent, quite large red patches in Figure 2 show the regions where stroke services should be reviewed. Since we used no geographical information for the formation of the clusters, any contiguous patches of a cluster mean an anomaly in the care network. In our earlier work, we observed a similar spatial effect in the care patterns of ischemic heart diseases [7].

It should be noted that the ICD coding practices may vary slightly from clinic to clinic, which may add a bias to our survey. In other words, whether or not a case is coded as an acute stroke may depend on the subjective opinion of the medical professional in charge. Such variations, however, cannot be assumed for the CT, TL, and TE procedures, because a procedure has either been performed (and paid for) or not. The clear identification of the *de facto* heterogeneous care practices can be used when planning the care services at the national level.

VI. Conclusion and Future Work

We proposed a comprehensive methodology for the assessment of the stroke care network at the national level. The analysis identified significantly different clusters of both clinics and geographical areas. The anomalies cannot be explained by different coding practices. Hungary, and Central and Eastern Europe in general has yet to reach the Western European quality parameters of stroke treatment [9]. The results presented in the paper provide a clear, fact based starting point to start in the right direction.

Future work includes the analysis of the connection between the episode types and clinical outcomes as well as the associated costs of the treatment.

Acknowledgment

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References

[1] A, Wutzler et al. "Stroke prevention in patients with acute ischemic stroke and atrial fibrillation in Germany - a cross sectional survey" BMC Neurology, vol. 19(25), https://doi.org/10.1186/s12883-019-1249-y

[2] E, Jauch et al. "Guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association" Stroke, 2013 March, vol. 44(3) pp. 870-947, https://www.ncbi.nlm.nih.gov/pubmed/23370205

[3] S, Morris et al.,"Impact and sustainability of centralising acute stroke services in English metropolitan areas: retrospective analysis of hospital episode statistics and stroke national audit data." BMJ, 2019 Jan; vol. 364:(l1), https://www.bmj.com/content/364/bmj.l1

[4] V, Demarin and H, Budinčević. "Ischemic stroke – the challenge continues" Croat Med J., 2016 Jun; vol. 57(3), pp. 217–218, https://dx.doi.org/10.3325%2Fcmj.2016.57.217

[5] I, Vassányi, T, Kováts, G, Surján, and Z, Nagy. "Analysis of patient pathways in acute stroke care episodes" Proc. Pannonian Conference on Advances in Information Technology (PCIT'2019), Veszprém, Hungary, 31 May - 1 June 2019, ISBN 978-963-396-127-8, pp. 71-76

[6] B, Bray et al. "Weekly variation in health-care quality by day and time of admission: a nationwide, registry-based, prospective cohort study of acute stroke care" The Lancet, 2016 July, vol. 388,(10040), pp. 170-177, https://doi.org/10.1016/S0140-6736(16)30443-3

[7] Z, Vassy, I, Kósa, and I, Vassányi. "Correlation Clustering of Stable Angina Clinical Care Patterns for 506 Thousand Patients" Journal of Healthcare Engineering, vol 2017, Article ID 6937194, https://doi.org/10.1155/2017/6937194

[8] N, Bansal, A, Blum, and S, Chawla. "Correlation Clustering",. Machine Learning (2004) 56: 89, pp.89-113 https://doi.org/10.1023/B:MACH.0000033116.57574.95

[9] The CEESS Working Group. "Management of ischemic stroke in Central and Eastern Europe", Int. J of Stroke, 2015, vol. 10(SA100), pp. 125–127., https://doi.org/10.1111/ijs.12575

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Software Implementation of the EU Patient Summary with Archetype Concepts

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Abstract— **The design and software implementation of the International Patient Summary (IPS) is recently in the focus of several updates of major eHealth standards and technical specifications in European Union (EU) countries. These updates are built exclusively on Health Level Seven (HL7) Fast Healthcare Interoperability Resources (FHIR) and HL7 Clinical Document Architecture (CDA) technologies. The purpose is to develop a single, common specification of the minimal and non- exhaustive set of clinical data that can be used by all clinicians for cross- border, unscheduled care of a patient. It requires reusability and semantic interoperability of such data segments that are delivered essentially in terms of Archetype concepts. At the same time, the relation of the Archetype paradigm to patient summary standards and specifications is not well investigated in the current draft versions of these documents. This research investigates the application of the CEN 13606 and openEHR archetypes in the design and software application of IPS sections. The objective of the numerical experiments is to identify the level of compatibility between technologies, related to Archetype paradigms, and the software technologies employed in the current draft versions of standards and specifications of the IPS. The obtained results are novel because the Archetype paradigm is not considered in these draft versions. They serve to extend the practical experience in cross-border sharing of clinical data represented in terms of semantic interoperability of archetype concepts.**

Keywords-semantic interoperability; software for health; international patient summary; medication summary; archetype concept.

I. INTRODUCTION

The research work for the development of a standard for an International Patient Summary (IPS) has a long history. It has started with the European Patients – Smart Open Services (epSOS) project having as a main objective to enable a service infrastructure for cross-border interoperability between EHR systems in Europe [1]. This pilot infrastructure has been planned to allow a citizen from one EU country to receive relevant treatment for unscheduled health need in another country. The outcomes of this project have laid the foundations for sharing and exchanging patient summary and electronic prescription records. Research work has continued in several other EU projects like the Joint Action to support the eHealth Network project (JAseHN [2]) and the obtained results have been implemented in the eHealth Digital Service Infrastructure (eHDSI [3]) or adopted by the eHealth Network (eHN [4]).

The European Commission for Standardization (CEN) in a collaboration with HL7 [5] [6] produced this year draft versions correspondingly of a standard (prEN 17269 [7]) and a technical specification (FprCEN/TS 17288 [8]) for an IPS. These two documents provide a detailed abstract specification of an IPS model from which concrete models can be derived and implemented. Therefore, the IPS model is described in terms of clinical relevant data set that is "*minimal*", "*specialty-agnostic and condition- independent*".

The objective of this paper is to investigate these newly published documents from the point of view of the software implementation of the proposed domain information model and the data set specifications. For example, it is important to learn how well this IPS model can be expressed with CEN 13606 and openEHR, where CEN 13606 [9] is the EU approved standard for semantic interoperability. The reason to explore this subject in prEN 17269 is that the collaboration of CEN with HL7 has led to a rather unbalanced interpretation of the use cases in terms of software technologies exclusively related to HL7 FHIR [10] and HL7 CDA [11]. Indeed the data set references to ISO 21090 [12] make this model compatible with the data sets used in information models based on American Standards HL7 v3, HL7 FHIR or an EU standard like CEN 13606. On the other side, the IPS draft standard prEN 17269 does not provide guidance for implementing semantic interoperability in the exchange of IPS records. In fact the draft version of FprCEN/TS 17288 provides just a short informative reference to CEN 13606 and openEHR archetypes, while semantic interoperability appears to be out of the scope of this IPS model. Moreover, the evaluation of the IPS model is presented only in terms of the Messages Paradigm of HL7 CDA and HL7 FHIR making use of a specific ART-DECOR template exchange format with Native XML databases (NXD) [13]. Besides, practical experience shows that the support for semantic interoperability of the Messages paradigm is problematic and it is difficult to scale it at National levels [14].

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Our approach to evaluate the IPS model is based on designing and implementing the IPS document with archetype concepts satisfying the Archetype Object Models of CEN: 13606 [15] [16] and openEHR [17]. It is a novel research work because it aims to evaluate newly published draft versions of a standard and the accompanying it technical specification for IPS, where the Archetype paradigm is superficially taken in consideration. Note that the ART-DÉCOR template format is not directly compatible with the Archetype Description Language (ADL) [15] [17]. The above formulated issues are currently poorly explored in the existing literature especially regarding their software implementation. In this paper, we take one of the required sections of the IPS as a case study to validate the application of our approach for introducing semantic interoperability support in the scenarios for managing IPS extracts. The details of our approach are as follows:

- Implement the IPS Medication section in prEN 17269 both in terms of CEN 13606 Archetype Object Model (AOM)and in terms of the openEHR AOM.
- Explore the compatibility of the obtained CEN 13606 Archetype conceptual design with respect to the requirements of an openEHR engine for running openEHR Operational templates.
- Explore the W3C XML Schemas of IPS archetype conceptual models with respect to potential practical implementations of the proposed standard.
- Develop a client- server application for testing the openEHR Operational template on an openEHR engine in a local and cloud environment.
- Propose a methodology for transforming a CEN 13606 or openEHR archetype conceptual models into a format that enables the creation of archetype instances compatible with NXD.

This paper is divided into sections as follows. In the following section, we present the IPS archetype conceptual design; where we adopt a well-structured archetype modeling methodology [18] and explore the compatibility between different AOM. In Section III, we present our software implementation details. In Section IV, we summarize the obtained results and on this basis a methodology for implementing the Archetype paradigm with the IPS standard is proposed. Section V makes a conclusion and provides remarks on future work.

II. IPS Design with Archetype Concepts

The draft standard prEN 17269 represents the IPS as a set of reusable data blocks integrated with ontologies such as SNOMED-CT [19]. The data blocks are organized in four groups- *Header*, *Required*, *Recommended* and *Optional* sections. Without loss of generality, we consider the *Medication Summary* section, which is one of the three *Required* sections.

The data structure and the data types used in section are described in full details in Table 26 of the prEN 17269 standard. The draft version of this standard describes the same way the rest of the sections of the IPS, where the data set borrows data types from ISO 21090.The detailed description of the IPS contains all the information necessary for building a conceptual model in terms of archetypes. In our research work, we explored the design of this model with CEN 13606 and openEHR archetypes. For this purpose, we follow a five-stage methodology for archetype design [18]. It allows us to transform correctly a clinical document like the IPS into an archetype conceptual model. We have also compared the application of different software tools in obtaining the desired conceptual model. For example we have found that LinkEHR Studio [20] is more suitable for creating a CEN 13606 AOM, while the Template Designer and Archetype Editor [21] are more specialized and appropriate to employ with the openEHR AOM.

These tools allow us to bind semantic context to the archetype conceptual model from terminology servers and this way map terms to national standards like LOINC, SNOMED-CT, and ICD-10. It allows the IPS conceptual model to deliver meaningful, reliable, semantical clinical information at the point of care. The obtained conceptual models are displayed in Figure 1. We have preserved the names for the concepts, the semantics of the data types from ISO 21090 and the constraints on occurrences as they are specified by the draft standard for the IPS. The AOM of CEN 13606 allows to represent the conceptual model of the IPS in the *Medication Summary* section as a single archetype (Figure 1.).

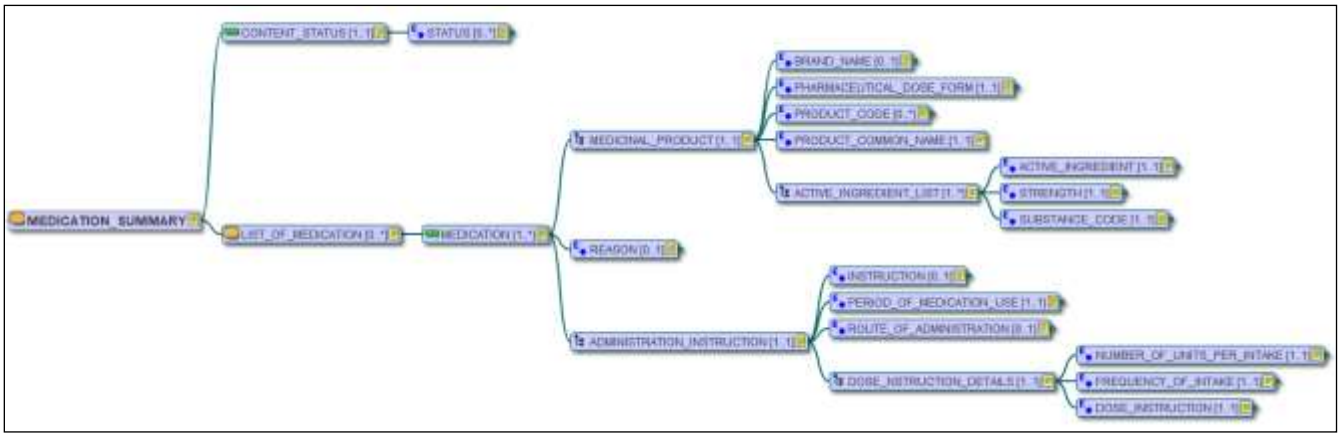

Figure 1. Mind map design of the IPS Medication Summary Section in prEN 17269:2018 with a CEN 13606 archetype.

On the other side, the AOM of openEHR requires to design separate archetype models for COMPOSITION archetype (representing the whole IPS) with slots for SECTION archetypes (representing slots for each of the sections of the IPS) and specialized ENTRY archetypes (representing the CONTENT_ITEM in each one of the IPS sections). For example, the *Medication Summary* section has been created an INSTRUCTION specialization of the ENTRY archetype. Finally, all the COMPOSITION, SECTION and INSTRUCTION archetypes have been assembled in a single template, shown on the right side in Figure 2.

Both conceptual models can be exported to valid openEHR Operational templates no matter the structural differences in the explored conceptual model. Moreover, it has allowed us to execute the obtained openEHR conceptual model in a client- server application making use of an openEHR engine for processing instances of the *Medication Summary* section Operational template. The conceptual design of the IPS section of the archetype models can be explored in W3C XML Schema format. This approach to investigate the IPS conceptual model is a novelty in the existing literature because a W3C XML Schema Definition Language (XSD) model of the IPS is not presented in the proposed prEN 17269 standard. At the same time, its practical implementation implies the use of web services, where the XSD model specification is important.

The XSD model of the *Medication Summary* section is shown in Figure 3 in CEN 13606 concepts. This model is suitable for implementations in NXD, where XQuery can serve as a good replacement for the absence of an Archetype Query Language in the AOM of CEN 13606.

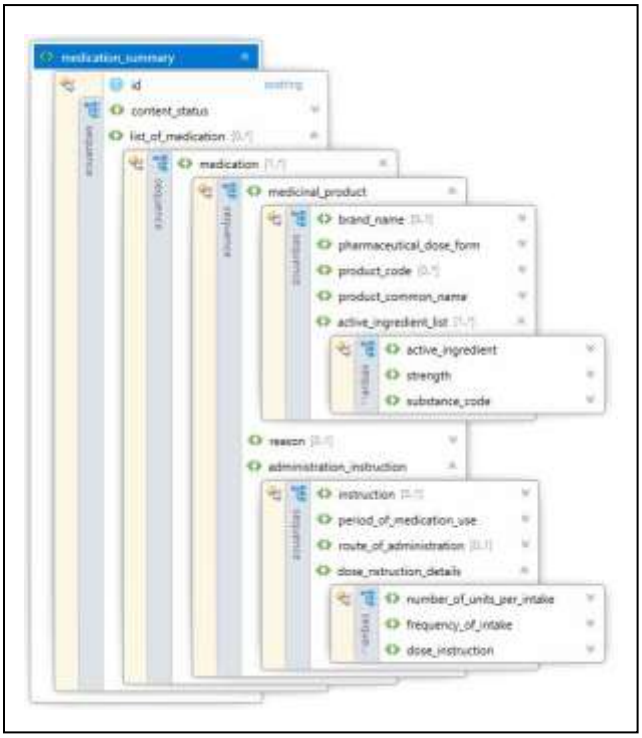

Figure 3. W3C XML Schema of an IPS Section in CEN 13606 AOM.

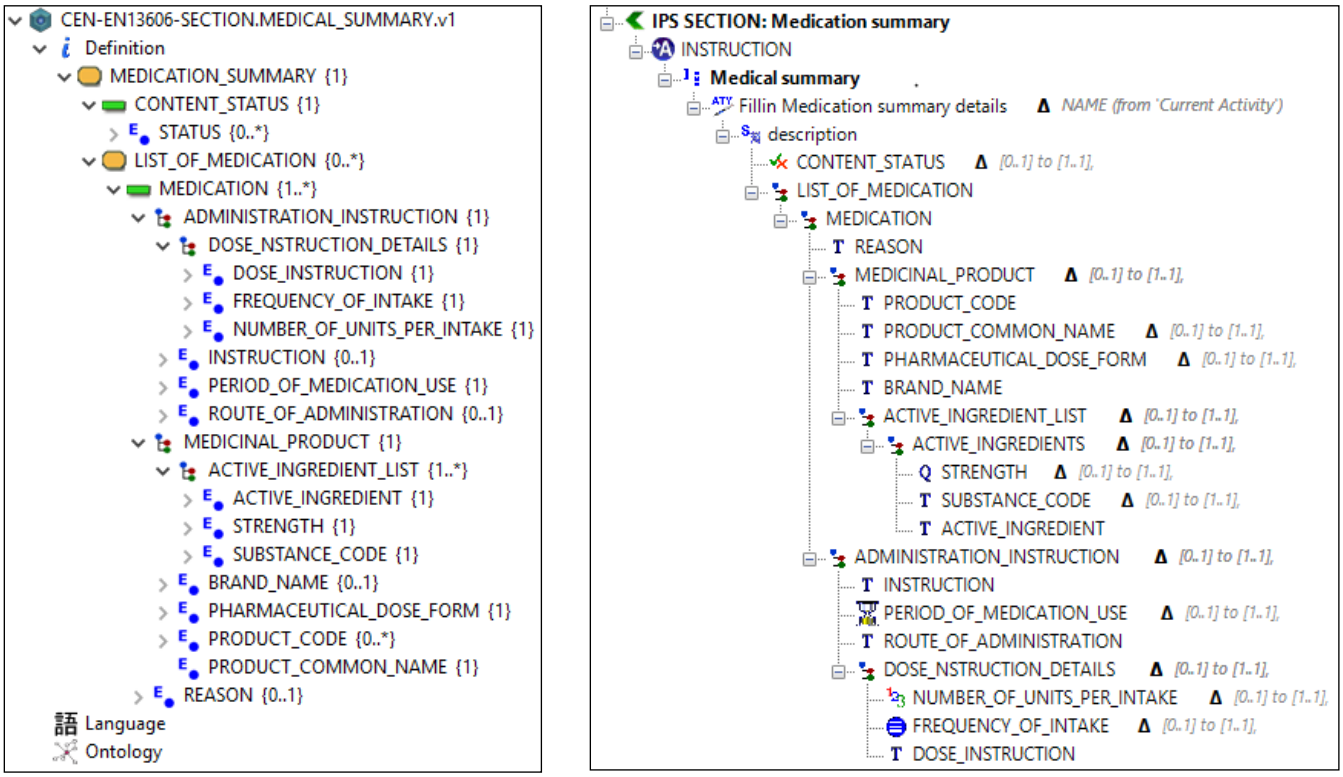

Figure 2. IPS Medication Summary design as a CEN 13606 archetype (left side) and as a template of openEHR archetypes (right side).

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For comparison, the XSD model of openEHR concepts includes a lot of metadata payload. Real- life IPS applications process large numbers of openEHR XSD model instances. Therefore, it is not practicable to employ NXD for storage and the management of such instances.

III. SOFTWARE IMPLEMENTATION

The software implementation of the IPS conceptual models in a client server application has been developed with the objective to evaluate the applicability of the Archetype paradigm in implementing the proposed IPS standard. For this purpose, the openEHR Operational template of the *Medication Summary* section has been installed and run on both a local CaboLabs openEHR engine [21] and a cloud-based Code4Health platform [22]. A client PHP application has been developed to store and read instances of the Operational template from the openEHR server by means of RESTful API. A snapshot of the client application is shown in Figure 5.

The user interface of the client can be auto generated from the archetype conceptual model. A client application can use a custom defined graphical user interface as well. This application links each instance of the Operational template to a unique Patient ID that is displayed in the query string of the HTTP GET request. The sample client application makes use of SNOMED-CT codes (see fields *Route of Administration* and *Substance code* in Figure 5) and real *Medicinal Product Details* to prove that the semantic context embedded in the archetype conceptual model can be interpreted correctly by any client that manages instances of that model. By selecting an archetype conceptual model, the client agrees to follow the mapping of terms to standards provided by the terminology servers linked to the selected model.

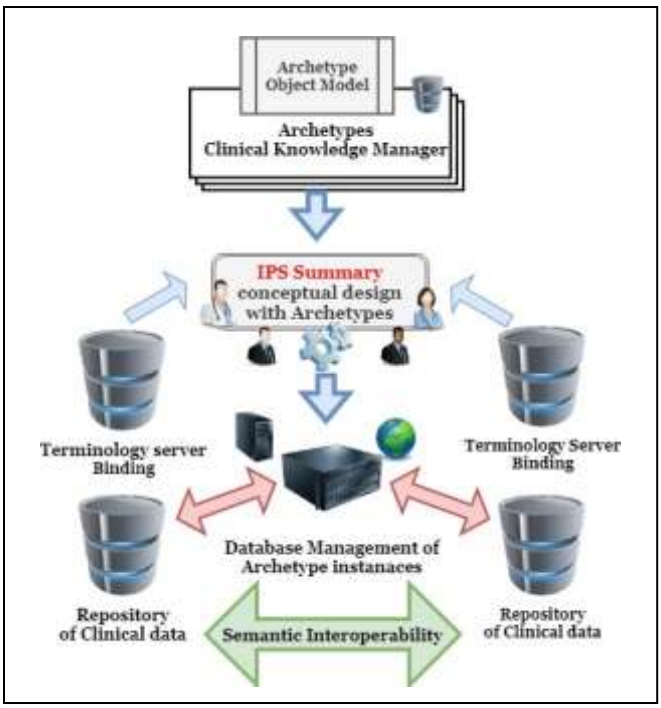

Figure 4. Methodology for semantic interoperability of the IPS.

IV. DISCUSSION

In this paper, we have evaluated the applicability of the Archetype paradigm in software applications that implement the draft version of the IPS standard. Although the Archetype paradigm is not in the focus of this standard, we have demonstrated that it can be successfully employed in software applications apply this standard.

The practical experience in producing the here reported results allow us to propose a methodology for applying the proposed IPS standard in use cases where semantic interoperability is a requirement (Figure 4). The first stage in this methodology is to create a correct conceptual model on the IPS document. The archetypes in this model serve as "*plug-and-play*" building blocks for semantic interoperability that can be imported from a repository known a Clinical Knowledge Manager. It is important to note at this stage the requirement for binding of the archetype model to Terminology servers. Therefore, it would be useful the final version of the IPS standard to provide public access not only to a promised standard set of SNOMED-CT code set, but also to publish a set of standard CEN 13606 archetypes together with their XSD representations. The obtained archetype conceptual model is ready for reuse in software applications. Clients select an archetype conceptual model and manage instances of that model in terms of semantic interoperability. Unlike the Messaging Paradigm the implementation of the Archetype paradigm with the proposed IPS standard makes possible all data, information and knowledge in each system to be available in a uniform and standard way.

Finally, we note that in the existing literature there is evidence that openEHR archetypes can be transformed to CEN 13606 archetypes making use of the common ISO 21090 data set [23] The mapping from CEN 13606 to openEHR is not explored so far. As a side result, we have established that it is not possible to convert CEN 13606 archetypes directly into openEHR archetypes. The reason is that the concrete class ENTRY from the Reference model of CEN 13606 is mapped to the abstract class ENTRY in the Reference model of openEHR. Therefore, we can export a CEN 13606 archetype into a valid openEHR Operational template. However, it is not possible to create instances of that template. In openEHR there are concrete specializations of class ENTRY like OBSERVATION, EVALUATION, INSTRUCTION and ACTION. Hence, it is very difficult to map a concrete ENTRY class in CEN 13606 to some of these specializations of the openEHR class ENTRY.

V. CONCLUSION AND FUTURE WORK

This paper has investigated the design and software implementation of the International Patient Summary according to the current draft versions of prEN 17269 and FprCEN/TS 17288. These versions make use exclusively of HL7 FHIR and HL7 CDA technologies with the purpose to develop a single, common specification of the minimal and non- exhaustive set of clinical data that can be used by all clinicians for cross- border, unscheduled care of a patient. Our analysis of these documents shows that they are built exclusively on top of the Message paradigm information

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model and data set. Therefore, in this paper, we explore how the objectives of this standard can be achieved by applying the Archetype paradigm approach. In the literature it is recognized that reusability and semantic interoperability of clinical data like the IPS segments can are delivered essentially in terms of Archetype concepts. The obtained results provide evidence that the IPS can be designed in terms of CEN 13606 and openEHR archetype concepts. Both archetype models support binding to semantic context provided by terminology servers like SNOMED-CT.

We have established that the CEN 13606 AOM cannot be used to create instances compatible with the openEHR AOM. It is an important conclusion because the compatibility of transformation from CEN 13606 to openEHR has not been explored in the existing literature. The numerical experiments demonstrate that both archetype models can be exported in W3C Schema definitions, where the XSD of openEHR AOM contains considerably larger payload of metadata. Therefore, it is preferable to manage instances of openEHR archetype models by means of operational templates on native openEHR engines.

It is noteworthy, that the draft versions of both the IPS standard and its technical specification do not consider a XSD model of the IPS. At the same time, practical implementations of this standard rely on web services where the specification of the XSD models is important. We have demonstrated this approach in a client server application with real medicinal data and terminology codes, where the same operational template of the IPS section can run both on a local and on a cloud-based openEHR engine. Accordingly, instances of CEN 13606 archetypes can be managed in NXD as it is demonstrated in the use cases of FprCEN/TS 17288 with HL7 concepts.

We plan to explore the feasibility of this different approach for enabling IPS semantic interoperability in our future work.

In summary, the obtained results are presented in a uniform methodology for implementing the IPS in terms of the Archetype paradigm. These results are novel because the Archetype paradigm is not considered in the draft version of the IPS standard. They serve to extend the practical experience in cross-border sharing of clinical data represented in terms of semantic interoperability of archetype concepts.

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REFERENCES

[1] European Patients Smart Open Services (epSOS) , "D3.2.2 Final definition of functional service requirements- Patient Summary," 29 October 2012. [Online]. Available: https://ec.europa.eu/digital-single-market/en/news/cross-border-health-project-epsos-what-has-it-achieved. [retrieved: August, 2019].

[2] European Commission, "Joint Action to support the eHealth Network [JAseHN][677102] - Joint Actions," 30 June 2018. [Online]. Available: https://webgate.ec.europa.eu/chafea_pdb/health/projects/677102/summary. [retrieved: August, 2019].

[3] eHealth DSI, "PS Use Case," 30 April 2019. [Online]. Available: https://ec.europa.eu/cefdigital/wiki/display/EHOPERATIONS/PS+Use+Case. [retrieved: August, 2019].

[4] eHealth Network, "Guideline on the electronic exchange of health data under Cross-Border Directive 2011/24/EU.," Brussels, 2016.

[5] HL7 International, "International Patient Summary," 2018. [Online]. Available: http://international-patient-summary.net/mediawiki/index.php?title=IPS_implementationguide_1 [retrieved: August, 2019].

[6] HL7 International, "HL7 Version 3 Standard: Pharmacy; Medication Order, Release 2," 2019. [Online]. Available: http://www.hl7.org/implement/standards/product_brief.cfm?product_id=65. [retrieved: August, 2019].

[7] CEN/TC 251, "prEN 17269. Health informatics - The Patient Summary for Unscheduled, Cross- border Care," European Committee for Standardization, Brussels, 2018.

[8] CEN/TC 251, "FprCEN/TS 17288. Health informatics - The International Patient Summary: Guidance for European Implementation," European Committee for Standardization, Brussels, 2018.

[9] CEN/TC 215, "ISO 13606-1:2008 Health informatics -- Electronic health record communication -- Part 1: Reference model," 2 2008. [Online]. Available: https://www.iso.org/standard/40784.html. [retrieved: August, 2019].

[10] HL7 FHIR, "FHIR Release 4. International Patient Summary Implementation Guide," 27 December 2019. [Online]. Available: https://build.fhir.org/ig/HL7/fhir-ips/. [retrieved: August, 2019].

[11] HL7 International, "HL7 Version 3 Clinical Document Architecture," 2019. [Online]. Available: http://www.hl7.org/implement/standards/product_brief.cfm?product_id=7. [retrieved: August, 2019].

[12] ISO/TC 215 Health informatics, "ISO 21090:2011 Health informatics -- Harmonized data types for information interchange," Feb 2011. [Online]. Available: https://www.iso.org/standard/35646.html. [retrieved: August, 2019].

[13] ART-DECOR, "ART-DECOR Open Tools," 2019. [Online]. Available: http://art-decor.org/art-decor/decor-project--hl7ips. [retrieved: August, 2019].

[14] G. Freriks, G. de Moor and D. Kalra, "White paper: Archetype paradigm: an ICT revolution is needed," 13 March 2007. [Online]. Available: http://www.eurorec.org/files/filesPublic/ArchetypeParadigmFeb2007.pdf. [retrieved: August, 2019].

[15] ISO/TC 215, "ISO 13606-2:2019. Health informatics -- Electronic health record communication -- Part 2: Archetype interchange specification," ISO, 2019. [Online]. Available: https://www.iso.org/standard/62305.html [retrieved: August, 2019].

[16] ISO/TC 215, "ISO 13606-1:2019 Health informatics -- Electronic health record communication -- Part 1: Reference model," ISO, 2019. [Online]. Available: https://www.iso.org/standard/67868.html. [retrieved: August, 2019].

[17] openEHR Foundation, "10. Archetypes and Templates," openEHR, December 2018. [Online]. Available: https://specifications.openehr.org/releases/BASE/latest/architecture_overview.html#_archetypes_and_templates. [retrieved: August, 2019].

[18] D. Moner, J. A. Maldonado and M. Robles, "Archetype modeling methodology," Journal of Biomedical Informatics, vol. 79, pp. 71-81, 2018.

[19] SNOMED International, "SNOMED CT," 2019. [Online]. Available: http://www.snomed.org/snomed-ct/get-snomed-ct. [retrieved: August, 2019].

[20] VeraTech for Health, "LinkEHR Ineroperability Platform," 2019.

[21] P. P. Gutiérrez, "Towards the Implementation of an openEHR-based Open Source EHR Platform (a vision paper)," in MEDINFO 2015: EHealth-enabled Health: Proceedings of the 15th World Congress on Health and Biomedical Informatics, São Paulo, Brazil, 2015, pp.45–49.

 ISBN: 978-1-61208-742-9

[22] Code4Health, "Code4Health Platform," 2019. [Online]. Available: https://github.com/code4health-platform. [retrieved: August, 2019].

[23] T. Beale, "openEHR to ISO 13606-1, ISO 21090 mapping," 15 May 2015. [Online]. Available: https://openehr.atlassian.net/wiki/spaces/stds/pages/5373954/openEHR+to+ISO+13606-1+ISO+21090+mapping. [retrieved: August, 2019].

Figure 5. Snapshot of a client application creating an openEHR archetype instance of the IPS Medication Summary Section.

The Role of School Administartion in Providing and Promoting Health Education in Schools in Nabatieh (Lebanon) Area

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***Abstract*—In the framework of the current Lebanese environmental conditions, with the increase in the number of refugees, and the rapid spread of diseases among students in schools, it is important to raise awareness concerning health and healthy behaviors. Healthier students are better learners, more motivated, focused and less likely to be absent, thus their academic achievement would be higher. Schools are considered the perfect place to promote health. This present study was done to determine the role of schools' administrations in providing and promoting health education to students in schools in Nabatieh area in the five fields: 1-nutritional, 2-physical, 3-personal health and hygiene, 4-mental, and 5-sexual health. Besides, the authors intended to determine the difference in health education implementation between private and public schools in Nabatieh area. The results revealed a significant role played by schools' administrations in health education implementation in the five fields with a slight difference in health education implementation between private and public schools.**

Keywords-school health education; health educators.

I. INTRODUCTION

School health is considered a vital topic. An official concern of school health in Lebanon has been increasing since the 1980s [1]. Between 1997 and 1999, health education has been integrated within the Lebanese curriculum, with a unit to monitor its implementation in the Ministry of Education and Higher Education (MoEHE). Two years later this unit faced many obstacles and its work limited to some duties. The first published assessment of the health education implementation in Lebanese schools was in 2005 by Soweid & Jaoude. They conducted a Global School Health Survey (GSHS) to assess health education implementation by studying health risk behaviors. Their results showed a high prevalence of health risk behaviors [2]. A similar study was done to assess the prevalence of health risk behaviors in Lebanon showed an increase in those risk behaviors [3].

The following study aimed at determining the role of school administrations in providing and promoting health education through assessing current state of health education in schools, exploring the role of latter in providing nutritional education, physical health education, personal health and hygiene, sexual education and mental health education, and determining the difference in health education implementation between private and public schools.

To investigate the research questions, the authors developed 2 pairs of hypothesis:

1. H01 Schools in Nabatieh area provide and promote health education.
2. H02 There is a difference in health education implementation between public and private schools.

The remainder of this paper is organized as follows: Section II reviews the literature, Section III describes the methodology used, and Section IV presents the results. Section V discusses the results obtained. The conclusion and the acknowledgment close the article.

II. LITERATURE REVIEW

According to the World Health Organization (WHO), health is defined as *"a state of complete physical, social, and mental wellbeing and not merely the absence of disease*" [4]. Health has been introduced within education to increase awareness among students. The best way to introduce health within education is in school, using school health education programs.

Whether people are healthy or not is determined by the conditions they are surrounded by. Many factors/conditions affect individual health, they are called determinants of health. World Health Organization (WHO) updated the determinants of health to social, economic environment, physical environment, personal determinants and behaviors. Behavior is defined as *"an overt action, conscious or unconscious with a measurable frequency, intensity and duration."* Tending to establish healthy behaviors during childhood is more effective than tending to change behavior during adulthood [5].

A. Health Education

Health education consists of courses suitable for schools' grades from Kindergarten till 12 (K-12) that address different topics such as education concerning nutrition,

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mental health, physical activity, tobacco and substance use, violence and injury, and sexual health [6]. School health education aims at increase student knowledge, allows the student to acquire skills needed to avoid diseases and reduces unhealthy behaviors [7]. The importance of health education is summarized as the following: it improves life, reduces behaviors associated with diseases, allows acquiring knowledge, skills and behaviors concerning health, and impacts academic performance through increasing attendance [8].

B. Topic/field of health education

A Lebanese guide for health educators, co-authored by the University of Balamand and the MoEHE, lists health education topics as personal health and hygiene, accident prevention, sexual health, physical activity, nutritional health, social problems, and mental health [9].

Physical activity is defined as the body movement that produces energy and tends to reduce disease, and physical education is defined as *"Academic subjects that provide an opportunity for students to learn knowledge and skills needed to establish and maintain physically active lifestyle"* [10].

Nutritional health in school includes supporting children with an effective environment that promotes healthy eating, spreading information related to food and beverage [11]. Promoting nutritional health in schools improves the quality of food, enhances healthy literacy, allows students to acquire skills related to nutrition and reevaluates personal habits and behaviors [12] [13].

Personal hygiene and health in schools comprise body and clothes cleanliness [14], as it is defined as the practice of behaviors that keep one clean to sustain health [15] Personal hygiene reduces absenteeism, decreases infections, and enhances health and knowledge.

Mental health is defined as the ability to control emotions, behaviors, thoughts and feelings, and being confident about self and communication with others. Mental disorders affect students' learning and social communication, attendance and drop out of school [16].

Sexual health education is the process of providing knowledge to practice healthy sexual behaviors [17]. It aims at helping students understand and acquire knowledge concerning body structure, role, similarities and differences between the two genders [18].

C. Health Education in Lebanon

School health in Lebanon has been developed during the last 20 years. Health education has been integrated within the curriculum to be taught in schools within other subjects with a unit to monitor the implementation. Its components include: personal hygiene, physical activity, sexual and mental health, accident prevention, nutritional education, disease prevention, and social problems [19].

During 2002, the work of the unit has faced many obstacles. Due to the lack of assessment of implementation of health education, a study was conducted by the GSHS to assess the extent of the implementation of school health through assessing health behaviors among students aged between 13-15 years [2]. The results of the study showed a high prevalence of risk behavior among students. Another study showed an increase in the percentage of risk behavior during 2012 [3].

The implementation of the school health program is the responsibility of a group of school administrations that include school administrators, health educators, a physician, school educational body and students' parents. The implementation of school health education needs the support of the school administrators in various fields. They promote health education through: health service (providing suitable tools, following medical cases, performing cyclic checkups, performing awareness seminars and workshops), school environment (promoting cleanliness tools and materials, monitoring cafeterias and available food, and providing safety stadium), performing educational activities (activating school visits and extracurricular activities, and performing annual competitions) [7].

The health educator is responsible for the implementation of health education. He/she plays an important role in applying, monitoring and implementing health education in schools. Health educators should have specific characteristics identified by the MoEHE. The roles the health educators include supervising the process of providing safe environment and healthy water, monitoring available food, and organizing workshops and seminars. Health educators have to implement the mentioned roles and their roles are monitored by both schools' administrators and health inspectors [7].

D. Related studies

Different studies have been conducted concerning the effect of sexual, mental, physical, nutritional health education, and personal hygiene on students. Results of these studies showed a significant impact on student's behaviors, attitude, and academic achievement [20]-[25]. The results of a similar study on the role of school administration in providing and promoting health education in schools in Ghaza showed significant role played by schools in providing health education [26]. There are no similar studies that measure the implementation of health education in schools in Nabatieh.

This study attempted to provide Lebanese MoEHE and the Ministry of Public Health with information on the current state of health education in schools in Nabatieh area. Results can improve students', staffs' and teachers' health by improving school health programs and helping educational policymakers, curriculum developers and other stockholders to establish effective strategies to improve the health of Lebanese citizens.

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III. METHODOLOGY

The researchers employed the descriptive mixed method. Creswell defined the mixed method as "*a method that focuses on collecting, analyzing, and mixing both quantitative and qualitative data in a single study…the uses of quantitative and qualitative approaches in combination, provide a better understanding of the research problem than either approach alone."* [27]. The authors used a mixed method for the following reasons:

1. Clarifying contradiction between the findings of quantitative and that of qualitative, thus comparing the results obtained from a questionnaire distributed to health educators and those obtained from questioning schools' administrators.
2. The mixed method gives different insights and perspectives since the questionnaire and the interview questions focus on the view of health educators and schools administrators concerning school health education respectively.

This study classified as a descriptive mixed method as it analyses data collected from a survey conducted on health educators and interviews conducted with schools' administrators in private and public schools in Nabatieh.

A. Sampling and Population

Quantitative data were collected from a sample of 53 health educators from private and public schools in a random manner. Half of the participants were from private schools and the other half were from public schools with different years of experience and included both males and females without any discrimination. Knowing that health educators' age ranges were not' measured in the study since the study focused on health education implementation without considering age differences.

The qualitative data were collected using interview questions with schools' administrators (12) gathered from private and public schools in a random manner.

B. Instrument

The researchers were guided by a pre-validated questionnaire survey that measured school health education at the level of nutritional health education, personal hygiene and safety, physical health, sexual health, and mental health education.

The questionnaire in this research comprised three sections. The first section introduces the purpose of the survey with the assurance of anonymity and confidentiality of the information they provide. The second section consists of 5 items added by the researchers as a profile of the health educator (Gender, job status, years of experience and educational institution). The third section consists of 41 items divided into 5 fields and one open-ended question, which were evaluated on a five-point Likert scale (1-Strongly disagree, 2-disagree, 3-neither agree nor disagree, 4-agree, 5-strongly agree).

The interview questions used consist of three sections; it was aimed to support and confirm the results obtained from the questionnaire and to give detailed information concerning health education. The first section introduces the aim of this research, the second consists of two questions concerning schools, and the third consists of the 5 studied fields. Noting that the questions are yes/no questions and open ended questions.

C. Data collection

Approval from the Director of Institutional Review Broad (IRB) was obtained to conduct the research, followed by an official approval from the General Director of Education at the MoEHE to access schools. Each school was visited by the researcher accompanied with an assistant to help in collecting data. In addition to the direct contact, the researcher used the Google form questionnaire to reach a maximum number of the study sample. The interviews in this study used to collect information by questioning schools' administrators. The interviews were conducted in Arabic language with administrators from public and private schools in Nabatieh area. The answers to the interview questions were indicated within the interview in order to make it easy for the researcher to analyze results.

D. Data analysis

The researches in this study aimed to measure the extent of providing and promoting health education in public and private schools, confirm the results of questionnaire with the results of interviews, and check if there is a difference in the implementation of health education between private and public schools.

The authors compared the implementation of health education between private and public schools in the five mentioned fields. The researchers measured the private and the public mean, the percentage mean of public and private, and the difference (private-public) of each item of the questionnaire to validate second hypothesis. For the quantitative data, statistical analyses were carried out using IBM-SPSS version 21. The qualitative data were analyzed based on thematic analysis and rubrics already mentioned in the interview questions, results were also summarized and triangulated with the questions of the questionnaire.

IV. RESULTS

Concerning the results of the questionnaire, all the participants were health educators (100%), of which 94.3% were females. 45.3% of the participants have an experience of 11 years or more. About half of the participants were from private schools and the other half from public schools. The authors in this research assessed health education implementation in the 5 different fields.

Concerning nutritional health education, most schools implement nutritional health (90%), with monitoring/detecting quality of water provided to students scored the highest, whereas supplying school library with publications concerned with nutritional health had the lowest

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score. Concerning personal hygiene, health and safety, the majority of schools implement personal hygiene and health (82.45%). Following up personal cleanliness (hair-nail) scored the highest, whereas putting an evacuation plans in case of emergency/accident had the lowest score. Concerning physical health education, the majority of schools implement physical health education (82.64%). Preparing a suitable location for school stadium scored the highest, whereas raising student's awareness by presenting drawings that show the importance of sport had the lowest score. Concerning sexual and mental health education, two-thirds of schools implement sexual and mental health education. Raising awareness concerning the importance of dealing with family and connections scored the highest and displaying documentary films that show the danger of Sexually Transmitted Diseases (STD) had the lowest score with respect to sexual health. Performing leisure trips scored the highest and training teachers and counselors how to deal with students with chronic diseases had the lowest score for mental health education. These results showed that almost all schools implement nutritional, physical and personal hygiene. On average, there is a role played in health education implementation at the level of sexual and mental education but to a lesser extent than other components. This could be due to the absence of financial support, regulations and the prevailed culture that restrict the discussion of sexual topics to brief titles mentioned within books.

On average, most schools in Nabatieh area take into consideration students' health (see Table 1).

TABLE I. DESCRIPTIVE STATISTICS OF HEALTH EDUCATION IMPLEMENTATION IN PRIVATE AND PUBLIC SCHOOLS IN NABATIEH.

Health Education	N	Mean	% of mean
	53	4.23	0.70

TABLE II. DIFFERENCE IN HEALTH EDUCATION BETWEEN PRIVATE AND PUBLIC SCHOOLS.

Health Education	public schools mean	Private school mean	Public school %	Private school %	Diff (Pr-Pu)
	4.00	4.28	80.00	85.67	5.67

In comparing health education implementation between private and public schools, the results showed that the average percentage of nutritional health education in public schools was 89.10% and that of the public was 89.67%, with 0.57 Differences in Percentage Mean (Diff (pr-pu)). The average percentage of personal hygiene, health and safety in public schools was 80% and that of private 85.67% with 5.67 differences in percentage mean. The average percentage of sexual health education in public schools was 60% and that of private schools 69.67%, with 9.67 differences in percentage mean. The average percentage of mental health education in public schools was 67.83% and that of private schools 86.33%, with 18.51 differences in percentage mean. In general, the average percentage in public schools was 80% and that of private schools was 85.6%, with a difference in percentage mean reaching 6% (see Table 2).

Concerning the results of interviews, most schools adopt health education programs. Most of them provide nutritional health education through organizing visits related to public health, giving awareness seminars, following special nutritional programs, providing healthy food in cafeterias with continuous monitoring of drinkable water and cleanliness. All administrators provide safety and a healthy environment through continuous monitoring of personal hygiene, water, furniture, and rooms, providing suitable ventilation and lightening, and performing first aid seminars. More than half of them perform seminars aimed at raising awareness about dealing with direct and indirect accidents. All administrators perform cyclic checkups and awareness seminars of healthy mouths and teeth. Most schools' administrators motivate their students to join extracurricular activities. While for the last two fields, sexual and mental health, both are taken into consideration but to a lesser extent than the other fields.

V. DISCUSSION

Many researches have provided evidence of the relationship between health and academic achievement where healthier students are better learners. The authors through these previous studies confirmed the role of health on students' academic achievement/performance without interfering or checking the effect of heath on performance of students in private and public schools, this would be a research question for another study. There are no similar studies done on the field of health education implementation in schools in Nabatieh area.

Schools in Nabatieh area provide and promote health education with a need to enhance both sexual and mental health education through releasing regulation by the MoEHE concerning this issue. Physical, nutritional, and personal health and hygiene are mostly provided due to the regulations released which obliged the schools to follow nutritional program (monitoring cafeterias, performing cyclic checkups on offered food, spreading awareness, and providing safety and healthy environment), performing cyclic checkups on students health, following students who suffer from diseases, performing annual medical screening by specific teams, monitoring quality of water provided, organizing physical competitions in schools and between other schools,. Sexual and mental health education are provided with less care. This could be due to the nature of culture, absence of awareness concerning the importance of such topic, and lack of financial support.

Improving upcoming generation health has an important role in improving students' success rates in schools, so it is crucial to have cooperation between the Ministry of Public Health and the MoEHE to establish school health programs, raise awareness in public schools to the level of private schools, perform official training programs for educational body and health educators, assign counselors for each school to monitor students' health, segregate the job of teaching from health educator's job to allow them to perform their job

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properly, host experts (nutritionists, psychologists) to spread awareness among students, conduct first aid seminars, and provide health room services in case of emergencies.

The effect of health on students' performance should be highlighted. Lebanese students' are engaged in unhealthy risk behaviors as physical inactivity, violence, drug uses, unhealthy eating habits, so schools have to manage such problems by providing suitable programs, resources and educational body to monitor and follow up such cases. Educating students about their health would raise awareness and prepare them to make healthy decisions concerning their life thus motivate them to change their behaviors.

Schools' administrators also confirm the results obtained in the questionnaire that schools played an important role in health education implementation with a need for enhancement and support.

VI. CONCLUSIONS

In conclusion, this study shed light on a critical topic of the importance of assessing health education in schools in Nabatieh area in Lebanon. Health education is one example of a program that schools can establish to enhance student's health, and reduce diseases. Although schools have a major role in enhancing health, the government, policy makers, and curriculum developers can establish processes for resources to support health education programs at Lebanese schools. It would be only well provided when the government accepts and takes responsibilities to effectively put in action and improve health programs.

The authors recommended performing further studies to assess the quantity and quality of health education being taught and offered to students in schools. Besides, conduct research to take into consideration parents and students' opinions and perspectives about the provided health education.

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REFERENCES

[1] M. Kanj, "Health education through extracurricular activities in Lebanon," pp. 27-36, 2012.

[2] R. Soweid, and S. Jaoude,"Global school-based student health survey," 2005.

[3] Saint-Joseph University, "National health statistics report in Lebanon," 2012.

[4] D. NutBeam, "Health Promotion Glossory," Health Promotion International, vol 13, pp. 1-9, 1998.

[5] L. Kann, et al.,"Youth Risk Behavior Surveillance," Vol. 65, No. 6, June 2016.

[6] S. Manoj, "Introduction to Health Education, Health Promotion, and Theory," 3rd Edi, pp. 3-13, 2012.

[7] N. Khalifa, and H. Aoun, "Educational Assistant File on School Health: Health Educator Guide," 2007.

[8] American Cancer Society, the American Diabetes Association, the American Diabetes Association, American Heart Association, "Health education in schools – the importance of establishing healthy behaviors in our nation's youth," 2008.

[9] Ministry of Education and Higher Education, "School health strategy document in Lebanon," 2007.

[10] T. R. Frieden, H. W. Jaffe, J. W. Stephens, S. B. Thacker, and S. Zaza, "School health guidelines to promote healthy eating and physical activity," Centers of Diseases Control and Prevention, 2011.

[11] Center of Diseaes Control and Prevention, "At glance 2016 healthy schools the right place for a healthy Start," 2016, Available from: https://www.cdc.gov/chronicdisease/resources/publications/aag/pdf/2016/aag-schoolhealth.pdf

[12] Fernandes, et al.,"Evaluating the effect of nutrition education on the prevalence of overweight/obesity and on foods eaten at primary schools," Jornal de Pediatria, pp. 315-321, 2009.

[13] K.Williams, and A. Dill, "Wisconsin wellness: putting policy into practice," Nutrition Education, 2nd edi, pp. 9-10, 2014. Available from: https://dpi.wi.gov/sites/default/files/imce/school-nutrition/pdf/wisconsin-wellness-putting-policy-into-practice.pdf

[14] R. Charter, "Personal Hygiene. Hygiene and environmental health," 2018. Available from: https://www.open.edu/openlearncreate/mod/oucontent/view.php?id=187&printable=1

[15] G. Victoria, "School policy advisort guide," personal hygiene, 2017.

[16] Center of Diseases Control and Prevention, "Children's mental health," 2018. Available from: https://www.cdc.gov/childrensmentalhealth/symptoms.html

[17] A. Ajuwon, "Benefits of sexuality education for young people in nigeria," Africa Regional Sexuality Resource Centre, 2005.

[18] Student health service department of health Hong Kong, "Sex education at home," 2010.

[19] UNDP, "School health symposium," 2002.

[20] J. Sallis, "The Effect of 2 years physical educational proram (SPARK) on physical activity and fitness in elementary schools students," American Journal of Public Health, vol. 87, No. 8, August 1997.

[21] O. S. Kapinga, and D. F. Hyera, "Pupils perception of sex and reproductive health education in primary schools in tanzania: a phenomenological study," Journal of Education and Practice, vol. 6, no. 6, 2015, ISSN 2222-1735 (Paper) ISSN 2222-288X (Online)

[22] R. A. Sleem, and E. Mekheal, "The Effect of lebanese sex education curriculum 2009 on developing students positive sexual attitude and good behaviors," Educational Research Newspaper, 2016.

[23] K. Jabbour, "An Exploratory study of the critical need for school health programs in Lebanon," Journal of Education and Learning, vol 7, pp.231-238, 2013.

[24] C. Habib-Mourad, et al., "Promoting healthy eating and physical activity among school children: findings from Health-E-PALS, the first pilot intervention from Lebanon," BMC Public Health. 2014.

[25] A. Shrestha, and M. Angolkar, "Impact of health education on the knowledge and practice regarding personal hygiene among primary school children in Urban Area of Karnataka, India," Journal of Dental and Medical Sciences, pp. 86-89, 2014, doi: 10.9790/0853-13478689.

 ISBN: 978-1-61208-742-9

[26] S. Fodda, “The Role of School Magaement in Activating School Health Education at the Primary Stage in Ghaza,” 2012.
[27] J. Creswell, “Designing and conducting mixed methods resaerch,” 2011.

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Determining Testbed Requirements for Technology Enhanced Speech Rehabilitation after Stroke - the Informed Co-workers' View Point

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***Abstract*—This paper analyses and discusses the identified requirements for technology enhanced systems for speech rehabilitation after a stroke. To stroke patients, a speech injury can be devastating, impacting their abilities to speak, listen, read, and write. Therefore, speech therapy is recommended as early as possible. To address the challenge with a growing percentage of older adults, therapy should include a variety of Technology Enhanced Systems (TES) to support the idea of independent living. These systems must be adapted to the patients' needs and speech therapy requirements. Based on a design science approach, requirements were determined from an analysis of ten semi-structured interviews with knowledgeable informants. Findings indicate several important requirements, such as: TES should be motivating, joyful, individualised and built on patients' needs and on speech therapists' professional knowledge. Furthermore, TES services must be user-friendly and provide training in each patient's mother tongue. Added to these requirements are ease of including close relatives as supporting persons, as well as accessibility through portable devices.**

Keywords-e-health; HCI; stroke rehabilitation; independent living; speech therapy; requirements

I. INTRODUCTION

Stroke is one of the most common and serious diseases across the globe; it can cause death or a variety of disabilities [1]. Stroke is caused by an interruption of blood flow to the brain that affects neuronal cells, which leads to severe impairments in brain function [2]. Generally, a stroke patient's disability can be classified into motor, speech and cognitive injuries [3]. This paper focuses on speech injuries which impact both speech and language function, which can reduce drastically a person's abilities to speak, listen, read and write [2]. Because of that, quality of life is severely compromised and patients' overall social interactions decrease. These changes have long-lasting impacts on patients' personal and professional lives. Therefore, various types of speech therapy are recommended as early as possible after stroke [3]. A large number of traditional treatments are available for speech recovery, but providing access to treatments to all stroke patients is challenging because of the high cost for human resources and day-to-day operational requirements needed for these intervention types. For speech and language retrieval, high-intensity and long-term therapy is needed and current medical interventions cannot provide those services due to limited resources [15].

In the last two decades, Technology Enhanced Systems (TES) have been recognized as highly useful for several treatment types that involve multiple rehabilitation therapies [3]. Indeed, several therapy systems have been successfully developed using modern technologies [4]-[6]. Recent studies highlight that different types of TES can be useful for speech and language rehabilitation, combining various categories of technologies, such as: tele rehabilitation based on audio and videoconferencing [2][15], internet-based therapy [19], serious game-based therapy [21] and Virtual Reality based therapy [6].

After a stroke, however, due to brain function impairments, a patient's ability to understand and learn new things is decreased drastically, which creates challenges for patients in adopting and using TES [3]. Therefore, users' requirements need to be considered during speech and language rehabilitation and a user-centered design approach may be most effective, so that the more difficult learning process can be easier after a stroke [7]-[10]. Some studies highlighted the importance of user-friendliness and usability issues for TES [9][19]. However, a Requirement-Focused Design Science approach, where relevant stockholders such as medical caregivers and people with technical backgrounds are involved, seems to be rarely used. The requirements to develop TES for speech and language rehabilitation should additionally be considered from a clinician's perspective [19].

This study focused on the viewpoint of co-workers working with stroke patients. The co-workers were all experienced in rehabilitation procedures and patients' therapy. This study concentrated on these informed co-workers' viewpoints to determine which requirements are essential for the user-friendliness and usability of TES, distinguishing between functional and non-functional requirements. Therefore, the main research question was:

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What are the testbed requirements of technology-enhanced systems for speech rehabilitation after stroke, based on informed co-workers' viewpoints?

Presented in Section 2 is an extended background, declaring previous research on, e.g., speech rehabilitation. Section 3 describes the study's research method, which is Design Science. Declared in Section 4 are the findings from the study. Section 5 includes the discussion and presented in Section 6 is the conclusion.

II. EXTENDED BACKGROUND

Presented in the extended background is previous research on speech rehabilitation for stroke patients and requirements for TES in speech rehabilitation.

A. Speech rehabilitation for stroke patients

Stroke rehabilitation is a challenging task for both patients and healthcare providers, as it requires high motivation and hard work from the patients, and extensive resources from the stroke rehabilitation staff [5]. Difficulties related to speech and language are classified as a condition called aphasia. Aphasia is one of the common stroke impairments where a patient's cognitive performance may not be decreased, but the ability to speak, read and/or write is affected to some degree [2]. Almost one third of patients suffer from aphasia after stroke [2][11]. After a stroke, most speech and language impairments recover during the first few weeks but the rest of the recovery may take several years; t speech and language therapy has been seen to be an effective intervention to enhance the recovery process [12].

Several studies confirmed that the quality of life of people with chronic aphasia is severely affected because of their emotional suffering, social limitations, communication disorders, and their overall health condition [13]-[15]. Most aphasia patients also suffer from anomia. During anomia, a person's capacity to find appropriate words is reduced, which creates major problems in a patient's daily life [2]. Because of their speech and language disability, stroke patients can no longer express their emotions, opinions, thoughts, personality and knowledge, and that lack of expression leads to deep frustration [16]. Another impact of speech inability is increased uncertainty and fear. The patients become uncertain about what is said and what is understood, leading to doubts about what was planned in the past and a continuous fear of future unpleasant situations. Consequently, this devastating disability impacts the people living around the patient such as relatives and friends [15].

An improvement in speech and language abilities is an overall goal for aphasia rehabilitation and Speech and Language Therapy (SLT) plays an important and effective role in reaching this goal [15]. Several studies highlight the benefits of SLT such as improvement in expression, reading and writing [17]. Moreover, some evidence has shown that highly intensive, highly dosed, and long-term therapy have better results as compared to low intensity, low dosed and short-term therapy [15]. To increase accessibility and decrease the cost of such therapy, the requirements for TES to be an affective supplement in speech therapy is of special interest.

B. Requirements for TES in speech rehabilitation

Here, the functionality for TES in speech rehabilitation is divided into functional requirements and non-functional. The functional requirements include specific elements of TES that support speech therapy, such as word training. Non-functional requirements refer to general elements of TES, such as a specific color scheme.

Consideration of non-functional requirements for rehabilitation includes that it should be joyful to conduct and experience, especially since stroke patients mainly suffer from fatigue and therefore need extra encouragement to train [18]. The encouragement can be based on game-like aspects, with follow-up situations where extra training results in various gratifications. As such, functionality of follow-ups is of interest, both from a patient's and a speech therapist's perspective [18][19]. Rybarczyk et al. [18] state that other general requirements are that the TES should be based on therapeutic material and be designed according to different levels of language complexity.

The functional requirements for speech rehabilitation must be personalised based on the patient's condition and intention [19][20]. Simic et al. [19] describe the need for a user-centered design based on the patient's individual set of conditions, emphasising that most TES for speech training assumes some base level of communication. Unfortunately, this base level varies from patient to patient and may frequently be lower than TES designers assume, which results in patients who are unable to access the training at all. Patient's intention refers to their internal desires for successful rehabilitation, where stroke patients' motivation for recovery varies. Simic et al. [19] point out that a patient's intention might interfere with that of the speech therapist and could affect the training based on TES.

In personalising the TES to a patient's condition and intention, several aspects of speech therapy must be included as functional elements. For example, object identification, which includes *simple* followed by *complex* order comprehension, is described as one part of the functionality [18]. Simple order comprehension is based on the construction of a sentence including name-verb-direct complement. One such example is: "Put the knife close to the plate." A complex sentence adds a coordinate or a subordinate sentence, e.g., "Put the knife close to the plate and the fork to the left of the knife." Within the training for order comprehension, Rybarczyk et al. [21] adds functional elements, emphasising that the TES should include an ability to train writing exercises and text, word selections, and specific questions. The order of the writing exercises, or any exercise, should be easy for the speech therapist to personalise for their patients, offering various ways for developing the training based on a patient's condition and

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intent. Besides requirements mentioned earlier, the training must be based on the patient's mother tongue which means TES should be available in many languages; currently several training programs only are available in one language, e.g., English [20][21].

Identified non-functional requirements include adaptable user control interfaces, potential of using a tablet, user-friendly graphical layout, and tangible interfaces. The user control interface must be adaptable to multiple levels of patients' motor disabilities and there should be the possibility to use a tablet for training [22]. The ability to use a tablet allows more than one person to easily see and use the interface, because relatives and other members of a support network can help the stroke patient learn to use the tablet. Another helpful aspect of using a tablet is that during training this smaller device offers significant support. For example, it can support discussions between a person and a patient where pointing at a picture on a tablet is easy.

Rybarczyk et al. [18] and Rybarczyk et al. [21] stress several non-functional requirements, including the graphical layout. In [18], ease of use of a graphical layout, including oral and written instructions, for an ordinary speech training software is considered to be essential, to support patients with multiple levels of disability who may struggle to learn to use the software and/or who need the assistance of a relative or other person. They focus on potential tangible interfaces, e.g., allowing a user to touch and move objects while training ordering of words. Still, the starting point for any user interface should be a healthy person's ability to use a software program, e.g., hierarchical menus and an ordinary login based on, e.g., a mail address and a password decided by the user. Rybarczyk et al. [21] describes the context of VR as a training environment, which could support individualising the interface by allowing the stroke patient to adjust the control sensitivity with, e.g., a joystick.

III. METHOD

This study was carried out with a Design Science approach inspired by a process [23]. The five steps in this process are 1) to explicate the problem, 2) to define requirements for an artefact, 3) to design and develop an artefact, 4) to demonstrate the artefact and finally 5) to evaluate an artefact. Many design science studies, however, carry out only a subset of all five steps. For example, with the aim of defining requirements for technology enhanced speech rehabilitation, Their study was designed with the focus of a Requirement-Focused Design Science project. In Requirement-Focused Design Science Research, artefact design (step 3) is outlined, but does not involve implementation, demonstration or evaluation of the artefact (steps 4 and 5) [23]. The current study, based on an existing problem, tried to similarly define requirements based on a combination of literature review and interaction with selected experts.

As highlighted by [24], expert opinions can be useful to eliminate bad design ideas early in the design science process. Experts' negative opinions can often be more useful than experts' positive opinions to improve the design of an artefact.

A. Data collection

Data have been collected from the ten informants that are listed in TABLE I.

TABLE I. SELECTED INFORMANTS

Informant	Professional role	Years of experience
Informant 1	Speech therapist #1	25
Informant 2	The region's medically responsible doctor	25
Informant 3	Therapist #1	5
Informant 4	Physiotherapist #1	8
Informant 5	Physiotherapist #2	3
Informant 6	Chairman of the local stroke patient organisation	3
Informant 7	Speech therapist #2	4
Informant 8	CEO for a small company working with game-based stroke rehabilitation	25
Informant 9	Hardware and software specialist at a big multinational company	9
Informant 10	Head of Stroke Team	15

Informants #3 to #5 and #10 work in the mobile stroke rehabilitation team located at the region's main hospital. The entire mobile team includes one manager and five co-workers. The team is responsible for rehabilitation after initial clinical care when patients have been relocated to their homes. The mobile stroke team also has regular contact with Informants #2 and #6. Informants #8 and #9 are independent of any clinical stroke organisation.

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All informants have different important roles in contemporary stroke rehabilitation. Each was selected in a combination of purposive sampling and snowball sampling. Purposive sampling is a technique where the involved researchers rely on their own judgment when choosing informants. Snowball sampling means that researchers find new informants that are recommended by earlier informants. All informants have expert expertise in the investigated area and were carefully selected to satisfy the design science idea of using expert opinions [24].

To define requirements in this study, data have been gathered mainly by semi-structured interviews and partly by a literature review. All interviews were carried out with a common instrument with a set of basic questions that allowed adaptation to the various interviews, see appendix 1. The common question schedule included themes such as general stroke rehabilitation, speech rehabilitation, informants' understanding of the use of TES, and their views on the potential for TES' use in speech rehabilitation of stroke patients. The interviews were all conducted in person with informants; at least one researcher attended. The interviews lasted between 45 to 90 minutes.

The context for stroke patients was mainly the Jämtland/ Härjedalen region, a part of Sweden that covers spread-out rural areas and few inhabitants. Many stroke patients live in rural areas, meaning travel requirements affect the mobile stroke team. The team must limit their area for home rehabilitation visits to 70 kilometres from the hospital located in the region's city. Therefore, the patients living further away must stay at a nursing home, located close to the region's hospital, for shorter time periods (approx. two weeks) during their rehabilitation. IN addition, this spread of rural areas affects the use of TES, because rural areas may have limited bandwidth and spots without Internet access (Informants #3 - 5).

B. Data analysis

An inductive thematic analysis was conducted to find patterns and themes useful for answering the research question using interpretations rather than measurements. The analysis was based on audio recorded interviews and the transcribed recordings. Each researcher conducted an individual analysis followed by group discussions to compare analyses, resolve questions and inconsistencies, and determine which findings, and their relationships, to include. The individual analyses followed the following steps, described below: identifying meaning units, condensing meaning units to fit the study, coding units to identify requirements, categorising identified requirements, and arranging categories within themes [25]-[27]. Meaning units are expressions from the informants in favour of speech rehabilitation. After identifying interesting meaning units, each researcher wrote them down for further work. After identifying meaning units, each researcher synthesised them by creating excerpts of the core ideas that could potentially address the research question of the study. The coding identified individual requirements for speech rehabilitation, such as using patients' native languages as a foundation. The individual requirements were then aggregated into categories, based on the various speech disabilities resulting from stroke. The categories were arranged within the previously presented functional and non-functional themes. The arrangements of categories were based on various speech disabilities related to stroke and the perspective of functional or non-functional requirements. After each researcher completed the individual analysis, the group met to compare meaning units, excerpts, coding, categories, and themes. Final decisions about categories and themes were discussed and agreed upon by all researchers. Relevant findings from the analyses are presented in the next section.

IV. FINDINGS

After a stroke, due to speech and cognitive impairments, a person's ability to understand, express and communicate is decreased; therefore, the TES should be adjusted according to the patient's medical condition (informant 1, 2, 7). Informant 1 explained that described that there are many mobile phone and tablet-based applications that are recommended for speech rehabilitation; however, the success of these interventions heavily depends on the patient's medical condition, such as how much of the brain function is impaired after stroke. Informant 1, 2 emphasised that the TES should be easy to use and patients should feel a sense of joyfulness when using the TES. All but three informants, including the two speech therapists, highlighted the importance of user-centred design for the TES (Informant 1-5, 7, 9). Generally, non-medical professionals develop most of the TES for speech rehabilitation; therefore, they do not understand the needs and limitations of stroke patients. Informant 7 argued that TES should be designed in cooperation with speech therapists and they should be involved throughout the process.

Informants 1 and 7 express the following variations on speech problems for the stroke patient: dysphagia (problems with swallowing), aphasia (see earlier description), and dysarthria (reduced mobility in the muscles used in speech). Initial speech problems are mainly related to dysphagia since the patient is unable to consciously initiate a swallow. Informant 7 shows a TES that supports training to swallow, with English narration. When using the TES, Informant 7 must off the sound and talk to the patient in Swedish.

Patients with severe aphasia may suffer from complete loss of speech function; therefore, pictures and video-based applications can be helpful (Informant 1, 7). For less damaged patients, using a TES to record and replay speech is recommended as a process that can improve speech function and pronunciation.

An interesting finding is that several informants emphasise the importance of considering the patient's vision (Informant 1). Many TES have been developed for persons

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with a full field of view. For many stroke patients, the full field of view is blurred, creating problems while using many TES. Unknown and complex graphical user interfaces can also be troublesome to learn and accept. As mentioned by Informant 6, stroke patients have to relearn many everyday tasks which is a cognitive overload that can make it difficult to also learn how to navigate new user interfaces (Informant 3, 6).

The speech therapists emphasised the need for communication tools based on speech problems after a stroke (Informant 1, 7). Communication difficulties can be reduced in various ways; for example, by using images or other alternative communication strategies. The lack of TES for easy communication is evident since the demonstrated ones are adapted from technologies initially developed for children in elementary school. Informant 7 explained that most of the currently available TES are initially developed for school-going children and then speech therapists use them after making adjustments. The content is not adjusted for situations in adult lives; for example, content does not include training for describing daily routines, such as having a cup of coffee or going to the grocery store, with adjustable degrees of difficulty. Patients' communication needs are therefore unsupported. Hence, TES that supports communication training should be specifically designed for stroke patients.

To use TES, significant education and training is needed (Informant 1-5, 7), not only for the patients but the clinical staff as well (Informant 7). To set up proper training, a wide range of multimedia functions and content should be available to adjust to the needs of each patient. Thusly, the speech therapists need to understand the TES and its functions to adjust it for each patient. Informant 7 explains the need for understanding by describing necessary technical tasks; for example, bringing together appropriate interactive pictures and video-clips to demonstrate TES information and training material. One example of lack of education and training was that the staff at a stroke rehabilitation centre was not very comfortable with the use of technology for distance interaction, such as Skype or Zoom (Informant 2, 7, 10). Speech therapists needed, for example, to show a video clip while, at the same time, they instructed the patient or relative. Hence speech therapists need interactive guidance to support the stroke patients' use of Skype. Patients' personal integrity is also of importance during training and education via Skype (Informant 2-5). People do not often feel comfortable being monitored or recorded via video cameras and therefore this type of monitoring technology should not be used frequently (Informant 2). Importance of proper education and training is even more vital for stroke patients, who often are older adults. Older adults with limited previous e-technology knowledge or experience tend to have more difficulties in learning to use TES than younger adults with knowledge or experience (Informant 1-5, 7). The problem with adjustment to TES arises for stroke patients doing their rehabilitation at the nursing home, since the staff working there are seldom interested in information technology and thus do not support patients in learning to use the TES (Informant 7).

Another load on speech therapists who work with stroke patients is the lack of speech therapists working at the centre for accessibility aid. When prescribing a tablet and software to a stroke patient, the tools are rarely correctly adjusted for the patient. Therefore, the prescribing speech therapist needs to configure both tablet and software by themselves. Related to this struggle is the concept of Bring Your Own Device (BYOD). Three informants (informant 1, 3, 6) bring up the concept in their interview answers. BYOD means that users are not limited to use pre-configured devices, but that they also can use their own devices. BYOD must not be restricted to mobile phones and smartphones and should also include tablets, laptops and desktop computers. However, the two devices that were brought up were mobile phones and tablets. Informant 1 uses applications that can be run on simple mobile phones, while Informant 4 uses applications that need a smartphone with support for email and web login. Their main argument is that a familiar navigation system is extra valuable in a situation where the patients' cognitive ability to learn and relearn is reduced. If BYOD acronym is extended to Bring Your Own Technology (BYOT), a term coined by Intel [28], technology-enhanced stroke rehabilitation must include patients' Internet access, which could be limited in the region's rural areas.

The findings in this study can be summarised as:

- TES services should be easy to use and bring patients a sense of joyfulness
- The development of TES services should involve both users and medical professionals, and strive for an individualised design
- Speech rehabilitation services should be accessible in patients' mother tongues and not only in English
- A variety of TES services should be provided, including solutions tailor-made for older adults, considering both content and graphical design
- Stroke patients must constantly relearn, and their ability to learn new interfaces is limited
- The concept of Bring Your Own Technology seems promising, with the idea of patients using devices that already are familiar

V. DISCUSSION

Several functional requirements, including adaptability to each individual stroke patient as an overall requirement, for TES supporting speech rehabilitation is described in the literature [18]-[21]. This overall requirement is emphasised in the empirical material, which describes speech therapists doing their best to adjust to individual stroke patients by using TES that is not initially designed for the rehabilitation situation. Content of the TES, especially when perceived as

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irrelevant to patients' lives, could diminish the motivation of the patients, who thereby lose interest in continually developing their communication skills. One possible reason for the lack of adaptability could be that speech therapists rarely are involved in the development of TES for speech rehabilitation and the designers therefore lack understanding of stroke patients' various conditions and needs. Some conditions are understood in clinical terms, such as the categorisation of various conditions within anomia [2] or dysarthria. Despite the existence of clinical identifications and categorisations of conditions, commonly known by speech therapists, TES developers seemingly do not include them in TES design. In addition, TES that include narratives in the patients' mother tongue (e.g., Swedish) are scarce, resulting in frustration both for the speech therapist and the patient. For the speech therapist, this lack of language support results in increased workload; for the stroke patient it serves as a reminder of the new limitations in their life [13]-[15].

Follow-up with patients by the speech therapist is a somewhat delicate assignment nowadays. Data on follow-ups should be available to the therapist in a way that allows efficiency to see which assignments are conducted, but also guarantees privacy for the stroke patient. The patients have the right to declare their data as private, limiting access by the speech therapist. These rights are important, but therapists, on the other hand, lose control of a patients' speech development process, needing to believe in the patients' descriptions of their progress. Here, the relatives can play an important role, by being a bridge between the patient and the speech therapist. By adding possibilities for relatives, or close friends, to be part of the rehabilitation using TES, the follow-up and the patient's motivation to continue the training could be improved. These issues highlight the importance of trust between the therapist and the patient, in addition to the patient's motivation to develop his/her speech skills.

Non-functional requirements, focusing on the graphical layout, are found in the literature [18][21]. They declare that the design of the TES should be interactive, entertaining, and easy to use. To set up proper communication or training, there should be a wide range of multimedia functions and content to adjust to the needs of each patient and the different goals of the rehabilitation. Examples of multimedia functions include interactive pictures and video-clips that a speech therapist can use to demonstrate the information and training instructions or material. The requirement should focus on providing variation in types of multimedia, allowing possibilities for adjustment.

Rarely mentioned in the literature, but emphasised in the empirical material, are specific requirements for training the use of the TES. The speech therapists and stroke patients need general training for both TES and hardware, such as tablets, offering more accessible paths for communication [22]. Just as few TES are designed for stroke rehabilitation, there are few possibilities for education in TES for stroke rehabilitation. Training themselves and patients to use the TES becomes the responsibility of the speech therapist, and is impacted by the stroke patient's motivation for learning. One factor which could affect this motivation positively is the size of the region and the long distances: If patients learn to use TES quickly, its use could improve efficiency in the rehabilitation and decrease the time spent in nursing homes. Motivating the speech therapist to gain more knowledge about both software and hardware should be a result of strategic decisions made by the employer. When education is discussed in the literature, it is described as being conducted in both written and oral forms, lacking any training the form of video [18]. In addition, the lack of communication tools focusing on the stroke patient's daily life can cause additional difficulties for the speech therapist, which is rarely mentioned in the literature.

The BYOD concept is spreading to new contexts including hospitals. As in many other fields, the BYOD practice can be time-efficient and cost-effective for hospitals, but include challenges with standardisation and security. For distributed stroke rehabilitation in patients these issues seem less problematic. The authors' recommendation is to focus on usability and user-friendliness, which highlights the importance of BYOD, because stroke patients have reduced capacity to use and learn complex interfaces, requiring familiar and user-friendly navigation systems.

VI. CONCLUSION

Few available softwares for stroke patients are designed using the knowledge of the speech therapists. Shown here is that the design of the TES (Technology Enhanced Systems) should be interactive, joyful, and easy to use. To set -up proper communication or training, there should be a wide range of functions and content to adjust to the needs for each patient and the different goals of the rehabilitation. This requirement is based on the different goals with the rehabilitation, as well as the specific needs for the individual stroke patient. Example of a function is that of multimedia in which a speech therapist can use to demonstrate the information and training instructions or material. The multimedia function could include interactive pictures and video-clips. Another important requirement is that the software should be accessible for relatives or close friends to help whenever needed.

A. Future work

The applications used for speech therapy are developed with other user groups in mind. For example, applications are designed for students in elementary school, and therefore include material for children, such as pictures of kids' games and activities. Applications must be designed with material that is relevant for stroke patients. Another impediment is that the language in the software is often English, rather than the mother tongue of the stroke patients. Therefore, we propose further prototyping, development,

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and testing of TES to enrich the foundation for speech therapy after a stroke. Finally, it is also important to involve stroke patients in the future work, to get their early and continuous feedback during the development of a software prototype.

REFERENCES

[1] P. Langhorne, J. Bernhardt and G. Kwakkel, "Stroke rehabilitation", The Lancet, 377(9778), pp. 1693-1702, 2011.

[2] M. Tousignant et al., "Satisfaction With In-Home Speech Telerehabilitation in Post-Stroke Aphasia: an Exploratory Analysis", Journal of the International Society for Telemedicine and eHealth, 6, pp. e11 (11-18), 2018.

[3] A. Ahmad, P. Mozelius and K. Ahlin, "Testbed requirements for technology enhanced stroke rehabilitation to support independent living", in Editor (Ed.)^(Eds.): 'Book Testbed requirements for technology enhanced stroke rehabilitation to support independent living' (INSTICC Press, 2019, edn.), 2019.

[4] H. Zhang , Z. Shen, J. Lin, Y. Chen, and Y. Miao, "Familiarity design in exercise games for elderly", Int J Inf Technol, , 22, pp. 1 – 19, 2016.

[5] T.P. Yamato, J.E. Pompeu, S.M. Pompeu and L. Hassett, "Virtual reality for stroke rehabilitation', Physical therapy", 96(10), pp. 1508 – 1513, 2016.

[6] J. Broeren, A. et al., "Virtual rehabilitation after stroke', Studies in health technology and informatics", 136, pp. 77 2008

[7] C. Pagliari, "Design and evaluation in eHealth: challenges and implications for an interdisciplinary field", Journal of medical Internet research, 9, (2), pp. e15, 2007.

[8] R.E. Glasgow, "eHealth evaluation and dissemination research", American journal of preventive medicine, 32, (5), pp. S119-S126, 2007.

[9] A.D.V. Dabbs et al., "User-centered design and interactive health technologies for patients", Computers, informatics, nursing: CIN, 27, (3), pp. 175, 2009.

[10] L. Neuhauser, G.L. Kreps, K. Morrison, M. Athanasoulis, N.Kirienko and D. Van Brunt, "Using design science and artificial intelligence to improve health communication: ChronologyMD case example", Patient education and counseling, 92, (2), pp. 211-217, 2013.

[11] J. Greener, P. Enderby and R. Whurr, "Speech and language therapy for aphasia following stroke", Cochrane Database of Systematic Reviews, (4), 1999.

[12] A. Gerstenecker and R.M. Lazar, "Language recovery following stroke", The Clinical Neuropsychologist, pp. 1-20, 2019.

[13] K. Hilari, R. Wiggins, P. Roy, S. Byng and S. Smith, "Predictors of health-related quality of life (HRQL) in people with chronic aphasia", Aphasiology, 17, (4), pp. 365-381, 2003.

[14] K. Ross, and R. Wertz, "Quality of life with and without aphasia", Aphasiology, 17, (4), pp. 355-364, 2003.

[15] H.P Øra, M. Kirmess, M.C. Brady, I.E Winsnes, S.M. Hansen and F. Becker, "Telerehabilitation for aphasia–protocol of a pragmatic, exploratory, pilot randomized controlled trial", Trials, 19, (1), pp. 208, 2018.

[16] M.B Johansson, M. Carlsson and K. Sonnander, "Communication difficulties and the use of communication strategies: from the perspective of individuals with aphasia", International journal of language & communication disorders, 47, (2), pp. 144-155, 2012.

[17] M.C. Brady, H. Kelly, J. Godwin, P. Enderby and P. Campbell, "Speech and language therapy for aphasia following stroke", Cochrane database of systematic reviews, (6), 2016.

[18] Y. Rybarczyk and J. Fonseca, "Tangible interface for a rehabilitation of comprehension in aphasic patients", 2011.

[19] T. Simic, C. Leonard, L. Laird, J. Cupit, F. Höbler and E. Rochon, "A usability study of internet-based therapy for naming deficits in aphasia", American Journal of Speech-Language Pathology, 25, (4), pp. 642-653, 2016.

[20] P. Kesav, S. Vrinda, S. Sukumaran, P. Sarma and P.Sylaja, "Effectiveness of speech language therapy either alone or with add-on computer-based language therapy software (Malayalam version) for early post stroke aphasia: A feasibility study", Journal of the neurological sciences, 380, pp. 137-141, 2017.

[21] Y. Rybarczyk, J. Fonseca and R. Martins, "Lisling 3D: a serious game for the treatment of portuguese aphasic patients", in Editor (Ed.)^(Eds.): 'Book Lisling 3D: a serious game for the treatment of portuguese aphasic patients' (edn.), 2013.

[22] K. Mallet et al., "RecoverNow: A patient perspective on the delivery of mobile tablet-based stroke rehabilitation in the acute care setting", International Journal of Stroke, 14, (2), pp. 174-179, 2019.

[23] P. Johannesson and E. Perjons, "An introduction to design science" (Springer, 2014), 2014.

[24] R.J. Wieringa, "Design science methodology for information systems and software engineering' (Springer, 2014), 2014.

[25] S. Elo and H. Kyngäs, "The qualitative content analysis process", Journal of advanced nursing, 62, (1), pp. 107-115, 2008.

[26] M. Bengtsson, "How to plan and perform a qualitative study using content analysis", NursingPlus Open, 2, pp. 8-14, 2016.

[27] C. Erlingsson and P. Brysiewicz, "A hands-on guide to doing content analysis", African Journal of Emergency Medicine, 2017, 7, (3), pp. 93-99, 2017.

[28] A. Freeman, S.A. Becker and C. Hall, "2015 NMC Technology Outlook: Brazilian Universities", in Editor (Ed.)^(Eds.): 'Book 2015 NMC Technology Outlook: Brazilian Universities' (The New Media Consortium, edn.), 2015.

APPENDIX 1

A. First interviews

1. How do you currently work with Stroke Rehabilitation?
2. What different technology-supported solutions have you been in contact with when it comes to Stroke rehabilitation and to what extent have you used these? Pros and Cons?
3. What requirements do you think should be met for e-solutions at rehab clinics as well as in the patients' home environment?

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4. How do you think that your patients have received technology-supported solutions? Any differences in age, gender or education?
5. Have you encountered any problems or conflicts regarding technology-supported solutions for Stroke rehabilitation, such as current ownership, use, support?
6. Do you want you to use more / have more knowledge about technology-supported readings for stroke rehabilitation?
7. To what extent do you have your workplace opportunity/budget to try new e-solutions?
8. What are your background/education and your relationship with this area?
9. Is there anything that you think I forgot to ask about?

B. Second interview with speech therapists

1. What is language reduction?
2. Can you explain the diagnosis of aphasia, dysarthria, verbal apraxia and dysphagia?
3. Can you explain the rehabilitation for aphasia, dysarthria, verbal apraxia and dysphagia?
4. Can you describe your functional requirements for an application for aphasia, dysarthria, verbal apraxia and dysphagia?
5. Can you describe your non-functional requirements for an application for aphasia, dysarthria, verbal apraxia and dysphagia?
6. Do you see any special requirements (general and for an application) in terms of speech rehabilitation for stroke patients in Region J / H?

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Implementation of a Distributed System to Collect, Search and Manage Data of Patients with Leprosy in Hiperendemic Municipalities

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***Abstract*— The state of Pará, in Brazil, with 2,351 new cases of leprosy reported in 2017, has an annual detection coefficient of 30/100,000 inhabitants, conferring it the classification of a hyperendemic state. A research group at a university in Belém, capital of Pará, develops a research work where a medical team do household visits to individuals who have been diagnosed with leprosy. The objective of this work is to present a distributed computer system that helped the team to collect and analyze the patient's data without the need of printed medical records. The system is composed of four components: a database, a mobile application, a server application and a reports application. Tests on the system were made by the team while doing their research. Patient's data were collected from three municipalities in the state of Pará. From the feedback provided by the team, there was a reduction in their costs by not having to use printed forms and reduction in the delay of having the data ready to be analyzed, since it was being registered directly in digital format. In total, the system was used to store data of 1101 individuals, of which 276 are leprosy patients and 825 are contacts of these patients. 149 new cases were diagnosed that had not been notified prior to the team's visit. Among these 149, 48 are under the age of 15; 122 have type multibacillary (MB) and 27 type paucibacillary (PB) leprosy.**

Keywords-Leprosy; Distributed System; Mobile Application; Decision Support.

I. INTRODUCTION

Leprosy is characterized as a chronic infectious disease caused by the intracellular bacillus Mycobacterium Leprae that has preference for cells found in the peripheral nerves and macrophages in the cutaneous tissue [1]. Its slow reproduction, about 2 to 7 years, results in an insidious clinical evolution of the disease, which manifests mainly through lesions on the skin and peripheral nerves, especially in the eyes, hands and feet [2].

In Brazil, there is a high incidence of leprosy in the states of the Northeast, Center-West and North compared to those in the south and southeast regions [3]. The state of Pará, in the North region, with 2,351 new cases reported in 2017, has an annual detection coefficient of 30/100,000 inhabitants [4]. This gives it the hyperendemic status classification.

A descriptive case study was carried out in which a computational solution was developed to solve a data management problem of a group of researchers from the Federal University of Pará (UFPA), who studied leprosy in hyperendemic regions of the state of Pará. This group used the solution *in loco* to collect data of leprosy patients and constantly provided suggestions for improvements and corrections to the solution in order to adapt it to their needs.

There are five sections in this paper: In Section 2, we present some works related to this one or used as base to develop it. In Section 3, we describe the materials and methods used to model and develop the system. In Section 4 is shown each individual component of the system, describing how it works and how it communicates with each other. In Section 5 is described how the system was tested on field with the help of the medical team. Also, a summary of the data collected during the tests is displayed in table format. Finally, in Section 6, we present the conclusion of the work and some concerns about the usability of the system.

II. RELATED WORKS

The base of this paper is the work of Barreto [6] that helped create a medical form to collect data from patients that were starting or were being treated for leprosy. This form was created based on the one used in Brazil [4] in a nationwide system to detected illness like leprosy. This form is used by health professionals to store patient's data temporarily before submitting it to an online system used by the government to know which areas needs more help to deal with the detected illness.

This methodology does not prove as efficient as it could be. Other works [10][11][12] that needed to access the data from this system to make some studies, reported that the data is very inconsistent due to the amount of noise that is possible to rise between the translation of the content in a

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printed form to an online system [10]. This was one of the issues faced by Paschoal [11] when his team needed to create a database based on these data to make a study about the illness in a specific region in Brazil.

It can be seen in works such as from Rafael [12] that this problem can be reduced if the technology is used more thoroughly. Instead of using papers that later needed to be typed into a computer, his work proposed the use of a mobile application to serve as a digital form that could be taken by health professionals in household visits to collect the patient's data, which would be transferred to a remote server through the internet.

Barreto's work was used to model the data managed by the system. With the use of mobile devices, we extend his work by creating a distributed system that takes his original patient medical record and translate it into a digital format. Instead of using pens and markers to draw and paint crucial data of a leprosy patient, such as wound locations and sensitive degree points, a finger swiping a touchable screen in a smartphone is used, ensuring a better control over how the data is inserted in the medical record.

III. MATERIALS AND METHODS

The system was structured in a client-server architecture [5] and consists of four components: database, server application, mobile application and reports application. All of these components interact with each other through the internet.

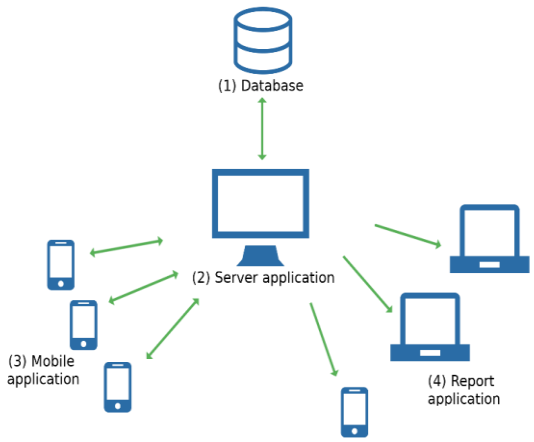

Figure 1. The client-server architecture used in the system.

The server application (2) in Figure 1 accesses patient data in a database (1) which then passes it on to clients in mobile applications (3) and reports applications (4). The green arrows indicate data exchange. Bi-directional arrows indicate that data can either be received or sent by the component, unlike one-way arrows, where the component can only receive data.

The database will be the system data source. It will be responsible for storing and providing data on patients with leprosy and ensuring their integrity so that inconsistent data (e.g., preventing the insertion of an unnamed patient) is not available. The server application will be a web application that connects the database and the other components of the system. It will facilitate access to data by providing an Application Program Interface (API) so that components do not have to worry about the specific access rules related to that database. The mobile app will be an electronic medical record that works on mobile phones or tablets with Android. It will have the responsibility of collecting the patient's data in the field and sending them to the server application. It can also request data for browsing and editing. The reports application will be a web application that provides reports of patient's data, which can be accessed from any device with an internet connection (cell phone, tablet, computer, etc.).

IV. SYSTEM DESCRIPTION

For each component presented in the previous section, we will provide a short description on how it is modeled and how it can present data to users or other components.

A. *Database*

In order to include all the attributes of the chart created by Barreto [6], 31 tables were implemented in a relational database structure [7]. This set of tables represents one patient. Among the stored data, we can mention: personal data, household data, diagnostic data, location of lesions in the patient's body and neurological evaluation data.

B. *Server application*

Five endpoints were implemented in Representational State Transfer (REST) [8] that allow access to certain patient data from other system components. Each component performs a HyperText Transfer Protocol/2 (HTTP) request [8] to the server application through one of these endpoints, which will then process this request by collecting data from the database and arranging them in JavaScript Object Notation (JSON) [9] to be returned to the component that made the request. Some endpoints also have data synchronization capabilities, allowing the mobile application to send its database to have its data registered in the database of the system.

C. *Mobile application*

The application for mobile devices was implemented as an Android application that has an electronic medical record that allows the collection and browsing of data from patients with leprosy. This platform was chosen due to the number of free tools available in the internet that aids in the development of applications for it. Some screenshots of the application can be seen in Figure 2.

A patient form has more than 10 sections that are organized into tabs by which the user can navigate. The collected data is stored in a local relational database on the mobile device before being sent to the server application, thus allowing the user not to depend on a stable connection to the internet to perform data collection. The local relational database has the same number of tables and same structure as the main database of the system to allow the

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mobile application to understand the data sent by the server application.

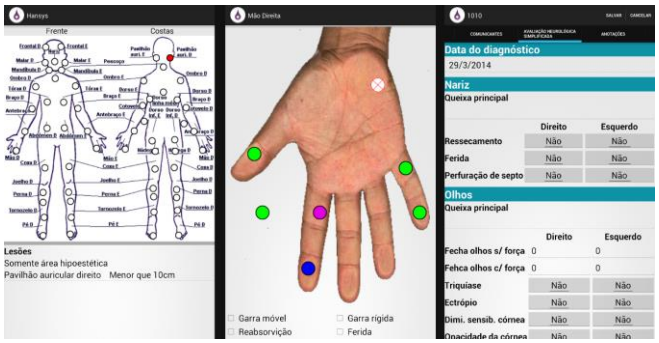

Figure 2. Screenshots of the mobile application. From left to right: record of skin lesions, record of touch sensitivity in the hand, record of neurological evaluation.

Some of the fields in the form make use of images and graphics that allows the user to better register and visualize the patient's data as he is filling the form.

D. *Reports application*

Figure 3. Web interface of the reports application.

The reports application is a web application that takes the list of available cities and reports from the server application, displays for the user to choose and generates the report in Comma Separated Values (CSV) format for download. This report can then be used to aid in any analysis on the patient's data. As shown in Figure 3, when the user selects a trip (on the left) and reports type (on the right) and clicks the "Generate Report" button, the report is downloaded in CSV format.

V. System Tests and Results

The system was tested both *in loco* and in the laboratory. However, it was the tests with the research team collecting the data of the patients in their households that contributed the most to the maturing of the system modeling.

The research team was multidisciplinary. There were dermatologists, physiotherapists, nurses and community health agents. The data collection was carried out in hyperendemic municipalities in the state of Pará. Before visiting any municipality, they contacted the local health team of the municipality to collect the data of the patients who already had or are being treated for leprosy, to then schedule with these household visits. During a visit, socioeconomic data and blood and lymph samples are collected from the patient and his/her contacts. To test the mobile app, one more member has been added to this team, which is the IT expert. This member was responsible for collecting data from the patient and his/her contacts.

The system was used to collect and visualize the data of 1101 individuals distributed among three cities in the state of Pará, Brazil: Breves, Redenção and Santarém. In each city, an average of one week was used to collect the data. Tables 1 and 2 show these numbers in more detail.

TABLE I. TOTAL NUMBERS COLLECTED AND MANAGED BY THE SYSTEM.

City	Individuals totals	Contacts totals	New cases totals
Redenção	432	311	29
Breves	311	229	75
Santarém	358	285	45
Total	1101	825	149

TABLE II. TOTAL NUMBERS OF CHILDREN AND MB AND PB TYPES FROM DETECTED CASES.

City	Students cases totals	Less than 15 years cases totals	MB cases totals	PB cases totals
Redenção	6	6	19	10
Breves	46	26	61	14
Santarém	8	16	42	3
Total	60	48	122	27

Students and children younger than 15 years old are a very important data to collect because they are a strong indicative of infected areas. For a child to develop an illness that takes up to 7 years to show symptoms, he/she had to be overexposed to the bacillus.

One big benefit brought by the system for the team that used it was the reduction of monetary costs. Before starting using the system, they needed to print roughly about $250 worth of paper forms for each trip they made to collect patient's data. Now, with a one-time investment in a couple of tablet devices, they reduced this cost to zero, only having to deal with possible maintenance in the electronic devices. Also, the time taken by the team to have the data ready to be used for its research was reduced from a couple of days to a few minutes. With the printed forms, after a week of collecting patient's data, the team had to manually type in the data in a computer. Now, after the collection step is done, they just need to sync the data with the server and access the reports application to access the relevant data for their research.

Instead of only working with diagnosis data and household contacts as in the system used in Brazil [4] and in the work developed by Rafael [12], the system also deals with socioeconomic data (monthly income, access to basic sanitation, help from government programs, etc.), household historic data (from where the patient came and where he

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plans to go in the near future) and spatial information (Global Position System (GPS) coordinates). With this data, it is possible to have a greater knowledge about the patient's condition and how he is contributing in helping spread the disease in its region if not treated. As mentioned in the Related Works section, the difference from Barreto's work [6] is the use of technology. The main issue he reports in his work was inconsistency in collected data. Since he had to work with a big team, issues related on how each team member was registering each patient started to rise, such as illegible handwriting and important patient's details been taking as side notes. This kind of problem is reduced with the usage of a software that restricts how each patient data should be collected, imposing clear standards that are enforced in the workflow of the team.

It is worth mentioning that the system itself does not provide decision support for suitable treatments and follow-ups. This information should be provided by the responsible doctor evaluating the patient and the system will only store its data for historical usage to see how the patient is progressing. The system is well suited to manage patient's data thanks to its focus on diagnosis data, providing a well-defined mapping of the possible regions of the body that can present wounds and mapping of the areas of the hands and feet that are losing sensibility due to leprosy. Also, the form provides fields to store data about laboratorial analysis. All of these data are visible through the mobile application and reports application.

VI. CONCLUSION

The developed system completely replaced the use of the paper charts used by the research team that assisted in its modeling. This work presented a case study that proposed to solve a specific data management problem of a research team. The way the system is modeled may not make it practical to solve problems outside the scope of this team, but it has served to validate how computational systems can positively impact the management of complex data, such as data on leprosy patients. It is worth noting that the system is still only a tool. It is necessary the commitment of the team that will use this system in understanding its operation and restrictions and possibly even change its work process to be able to adapt the use of the tool in the collection of data of the patients. An electronic medical record actually helps reduce the chances of error in recording patient data, but it is up to the professional who is handling the medical record to take care and ensure that all data entered corresponds to the reality of that patient.

REFERENCES

[1] M. G. Araújo, "Leprosy in Brazil". Journal of the Brazilian Society of Tropical Medicine. 36(3): pp. 373-382, may. – june., 2003.

[2] V. D. Costa, "Experiences of Amazonian women living with leprosy". [s.l.] Dissertation. Federal University of Rondônia - UNIR. Health Center. Porto Velho, Rondonia., 2011.

[3] A. Figueira, "Evaluation of the coverage of basic health units in the fight against leprosy in the city of Santarém / Pa through spatial analysis". Postgraduate Program in Biosciences. Federal University of Western Pará. Master's Dissertation in Human Physiology, 2015

[4] Brazil, "National Health Surveillance System: progress report: Pará". Ministry of Health, Health Surveillance Secretariat. – 5th edition – Brasília: Ministry of health, 2017.

[5] G. Coulouris, J. Dollimore, T. Kindberg and G. Blair, "Distributed Systems Concepts and Projects". Bookman Editorial Company Ltd. 5th edition. 2013, Porto Alegre, RS. pp. 56-60.

[6] J. F. Barreto, "Spatial and Serological Epidemiology of Leprosy in the State of Pará". December 16, 2013. 151. PhD Thesis in Tropical Diseases - Federal University of Pará. Belém – 2013-12-16.

[7] R. Elmasri and S. B. Navathe, "Database systems". 6th edition. São Paulo: Pearson Addison Wesley, 2011.

[8] J. F. Kurose and K. W. Ross, "Computer Networking and the Internet - A Top-Down Approach". Pearson Education. 3rd edition, 2011. São Paulo, SP. pp. 23 – 204.

[9] Ecma, "International. Standard ECMA-404" – The JSON Data Interchange Syntax. Ecma International Standard Publications, 2nd edition, 2017.

[10] S. M. T. Nardi, L. H. S. C. Marciano, M. C. L. Virmond, and R. Baccarelli, "Information system and physical disabilities in leprosy". BEPA - Paulista Epidemiological Bulletin; 3(27): 3-7, mar. 2010.

[11] V. D. A. Paschoal *et. al.*, "Creation of a data bank for sustainability of leprosy post elimination". BEPA - Paulista Epidemiological Bulletin; 6(12): 10-15, mar. 2016.

[12] B. Rafael, "A mobile health information logging application by community agents" – Dissertation. Federal University of Rio de Janeiro - UFRJ. Health Center. Grande do Sul – Unijuí, 2012.

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HemiPhysio App:

A smartwatch-based application for measuring upper limbs movement in children with Hemiparesis

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***Abstract*—A smartwatch's constant contact with the wrist provides opportunity to measure the differences in the movements of hands (upper limbs) in children with Hemiparetic Cerebral Palsy (CP) while performing daily physical activity (e.g., walking, eating). Children with Hemiparesis have significant weakness (spastic, contractures) on one side of the body that leads to impaired functions on that side. This paper gives the concept and design of a "HemiPhysio" app to collect the activity-related data of both upper limbs using sensors in a smartwatch. The machine learning models trained on collected data are then used to detect the impaired functions by the smartwatch. The child is then instructed for appropriate movement or correcting posture using alert or haptics. The HemiPhysio app should work for dynamic motion activities (e.g., walking) and for the static posture activities (e.g., eating), as well as the related upper limbs movements in these activities. The goal of our application is to encourage Hemiparetic children to use both hands during daily activities.**

Keywords-Smartwatch; Hemiparesis; machine learning; alerts and haptic feedback; activity and gesture detection.

I. INTRODUCTION

Today's smartwatches are like strapping a networked computer with sensors to one's wrist [1]. Recently, the hardware and software capabilities of smartwatch technology has advanced to an extent where these smartwatches can be used to diagnose certain medical conditions. The latest smartwatches have many sensors with sufficient computing to recognize variety of human physical activities [2]. These sensors provide accurate data to apps to track user's movements and other health related activities. However, it is still too early to know that smartwatches will work as truly independent computing devices.

Motor skills are heavily affected in the children with the Hemiparesis or weakness on one side of the body (arm-dominant or leg-dominant) [3]. Hemiparesis is often associated with Cerebral Palsy (CP) or pediatric stroke, and characterized by functional motor impairment [4]. Children with impaired function on one hand (arm dominant) typically experience problems with day-to-day activities that can range from using the bathroom, and eating to difficulty participating in sports or playing video games. This functional impairment is due to muscle weakness and/or mild paralysis on the affected side of the body.

These children tend to use only the normal side to do all their routine tasks and they need a constant reminder of using weak arm and hand as well. These physical impairments can impact social and emotional health and cause significant stress on the family. Physical and occupational therapies are natural approaches to rehabilitation that encourages the use of two hands during daily activities, and hence improving the gross and fine motor skills. However, it is costly in terms of therapy sessions, transportation, and time for parents and caregivers.

Hemiparesis leads to muscle weakness, decreased coordination, decreased control of muscles and muscles spasticity. Spasticity prevents the stretching of muscles and tendons and if not treated it causes contraction where the muscles and tendons are stuck in the shortened position, and forming difficulty with fine- or gross-motor movement. For example, if ankle is spastic it can lead to toe walking.

A smartwatch's constant contact with wrist and high user acceptance makes it ideal to collect, understand, measure, and compare hand, wrist, forearm, elbow, upper arm and shoulder movements of both upper limbs of hemiparetic children using accelerometer and gyroscope sensors.

Section II describes the existing work using smart devices and wearables in health informatics. Section III gives high level functional requirements and the conceptual design of HemiPhysio app. The acknowledgement and future work close the paper.

II. SENSOR BASED ACTIVITY AND GESTURES RECOGNITION STUDIES

Smartphones and smartwatches today come with many advanced sensors and programming interfaces to interact with them. These sensors collect real time data about the world around these devices. Most smartwatches have at least accelerometer, gyroscope, and pedometer sensors. These smartwatches give a unique opportunity to understand user's hand and arm movements. In the remaining section, some related work to evaluate the progressive use of sensors technology, mainly in health, is discussed.

A study conducted with young, healthy participants showed that smartphone applications and wearables using

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pedometer and accelerometers are accurate for tracking steps count [5]. The smartphone applications included iOS and Android apps, whereas waistband and wrist devices were used as wearables.

The accelerometer and gyroscope sensors in smartwatch can identify user's arm, hand and finger gestures [6]. Motion energy measured using the smartwatch is sufficient to uniquely identify hand and finger gestures. Accelerometer and gyroscope data reflects the movement of tendons (passing through the wrist) hand and fingers gestures. These features uniquely identify 37 (13 finger, 14 hand and 10 arm) gestures with an accuracy of 98%. The finger gestures are especially challenging to detect using smartwatch since the movement in the wrist when doing a finger gesture is very small and it is not clear whether it can be recognized uniquely. The possible application of gesture recognition is to remotely control the devices such as televisions, computers, and smartphones.

A recent study showed high usability and high technology acceptance when a mobile app (mHealth) was used and evaluated by the patients for frozen shoulder physiotherapy [7]. The mobile app provides instructions for exercise at home and tools to monitor patients training compliance and progress. The training compliance and progress data are then used by physiotherapists and physicians to assess the mobility of the shoulder and pain in shoulder movement and adjusting the therapy accordingly. The app includes a mobile phone sensor–based mobility measurement for monitoring the progress of the effect of the treatment of frozen shoulder.

Another study evaluated the accuracy, precision, and overall performance of seventeen wearable devices (fitness trackers, body sensor devices) with direct observation of step counts and heart rate monitoring [8]. The study focused on accelerometers used in applications of trackers on Android or iOS devices. Data of accelerometer sensors was recorded and the mean step count, standard deviation, accuracy, and precision were estimated for each tracker. The accuracy of the tested wearable devices ranged between 79.8% and 99.1%, while the coefficient of variation (precision) ranged between 4% and 17.5%.

Another smartwatch-based activity recognition study using a machine learning approach has shown a high accuracy in recognizing hand-oriented activities [9]. It showed that smartwatches are more accurate (93.3%) for recognizing specialized hand-based activities than smartphones (77.3%) and can form the basis of new health applications. The study focused on apps capable of tracking eating activities to replace the manual methods for maintaining a food diary. The eating-related activities (total 5) have the lowest prediction accuracy than non-eating (a total of 13 e.g., walking, kicking, typing, etc.). Among machine learning algorithms, the Random Forest (RF) algorithm showed overall highest accuracy in classifying activities.

Real-time and Online Assessment and Mobility Monitoring (ROAMM) is a smartwatch-based framework for mobility monitoring and data visualization of personal health [10]. The smartwatch application component is for collecting and preprocessing data and a server component to store, retrieve, and remote monitoring. The framework is limited to measure average minutes spent on some movement activity without requiring any machine learning approach.

The above applications and framework show the suitability of smartwatches in health systems and are considered a replacement of specialized devices for recognizing physical activities.

III. HEMIPHYSIO APPLICATION DESIGN

This section discusses the requirements and conceptual design of HemiPhysio application.

A. Motivation and Requirements

As discussed in section II, the existing applications using smartwatches do not collect and identify differences in the upper or lower limbs movements of children with Hemiparesis. Also, the existing studies either recognize gestures of hands, fingers, forearm, etc., independent of any physical activity or recognize the physical activities without considering gestures in that activity. Our work is recognizing the activity as well as the gestures or movements in that activity.

Following are some high level requirements:

1. Collection of patient's data from accelerometer and gyroscope of physical activity and the activity related gestures and movements. For example, a walking activity consists of hands, wrists, elbows, forearms movements. Samples are collected from weak and healthy limbs simultaneously. The HemiPhysio framework will work for dynamic motion activities (e.g., walking, running) and static posture activities (e.g., eating, standing). It will also work for activities where gestures or movements in both limbs are usually symmetric (e.g., walking) and for activities where one limb moves more than the other.
2. Training machine learning models on collected data. Patients are different in terms of spasticity and contractures therefore models trained on patient's own data are preferable. The machine learning models trained using only the participant's own data of activities performed much better in activity recognition than the impersonal models trained on the samples from all participants applications [9].
3. Identify child's spastic parts of upper limb and the resulting contractures using the machine learning models.
4. Measuring the difference in movements of weak and healthy limbs.
5. App reminds the patient to move or use weak limb in order to participate in activity.

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B. HemiPhysio Design

Our proposed design has two main components: the training component, and the detection and notification component. In the first phase as shown in Figure 1, two smartwatches are used, one on each hand, to collect timestamped sensors data from both limbs for a certain physical activity. This data is used to train and create customized Machine Learning (ML)vmodels to recognize sufficient gestures from the dominant (normal) limb and the corresponding impaired functions data from the weak limb.

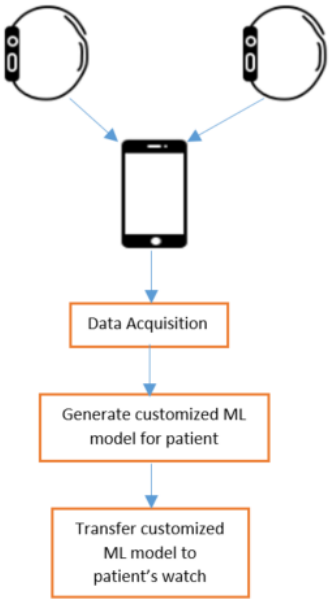

Figure 1. HemiPhysio App training phase.

Figure 2 shows the second component of our design that deals with real time activity detection (e.g., walking or eating). When a certain activity is detected our app running on the smartwatch starts to collect gesture or movements. This data is then fed to the on-device ML model at regular intervals. The ML model will be able to detect if there was insufficient movement on the weaker limb. The app will then instruct the child to move the weaker limb through alerts and haptics. The insufficient movement event is then recorded in the application's database to be synchronized later on with devices of caregivers and parents as this data will be of immense help to them to identify patterns of insufficient use of upper limbs in children.

Currently, we are developing HemiPhysio application on Apple platform as devices (Apple Watch and iPhone) and developers APIs come from same vendor. We found issues with Google's WearOS support for Samsung and other smartwatches. However, later we will test our app on other platforms as well. Apple iOS and WatchOS provide stable framework WatchKit and app services, such as CoreMotion for sensors data, HealthKit for monitoring physical activities, CoreML for creating machine leaning models [11]. CoreMotion API of WatchOS also provides us with software based sensors, such as CMDeviceMotion, which provides us various values of rotation and acceleration of the smartwatch, which can help us better detecting gestures during an activity.

The current health kits that are available on mobile and smartwatch platforms focus more on common activities such as walking, running, climbing steps and storing and retrieving various health related data. Though smartwatches have progressed to detect conditions such as cardiac problems thanks to a heart sensor, however they cannot detect impaired functions on a weak hand in a condition, such as Hemiparetic CP, which our work aims to tackle.

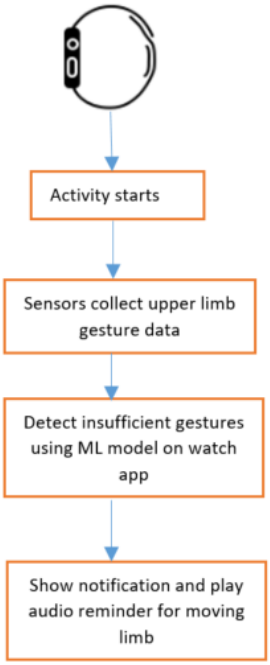

Figure 2. HemiPhysio Detection phase.

C. Data Collection

In our proposed app, the movement data is collected from smartwatch sensors of both (normal and weak) upper limbs. Movements include: arm movement (lateral arm lift, frontal arm lift, lateral external rotation, and back rotation), elbow movement, hand movement, wrist movement, and finger movement. HemiPhysio App prototype will support two sensors initially: accelerometer and gyroscope. An accelerometer measures the linear acceleration of movement. We will use accelerometer to detect the linear orientation of upper limb. A gyroscope adds an additional dimension to the information supplied by the accelerometer by tracking rotation or twist.

D. Machine Learning Models

ML leaning algorithms such as Naïve Bayesian, Neural Networks, Binary decision, Random Forest e.g., will be used as they have been already tested in physical activities

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classifications [9]. Running ML classifiers on the watch itself ensures the privacy of data and works even without paired device.

IV. CONCLUSION AND FUTURE WORK

We do not argue that these health applications can replace the need for human physiotherapists but augment the work of therapists and caregivers. Health or mobile health (mHealth) apps running on smart devices can be an affordable solution for children and parents and can improve healthcare system. This research will open the doors to extend the benefits of collected data in other health applications for Hemiparetic children. We hope to achieve with HemiPhysio app the CP management goal to increase functionality, improve capabilities, and sustain health in terms of locomotion [4]. The treatment includes physical therapy depending on patient's specific symptoms. Physical training increases muscles strength and possibly improves motor activity in Hemiparesis patients.

Once the application development is complete we will test its working and accuracy on the collected data from the patients. This will be done with the help of healthcare professionals and the feedback from patients and caregivers. The experiment results will be analyzed for the appropriateness of training data collection, the detection of insufficient mobility during the activity, and the alerts to patient from smartwatch to engage the weak side in ongoing activity. This research will help us to develop future apps and games for children with Hemiparetic CP. This includes instructional physical therapy, reminding using voice commands to encourage the use of weaker upper limb, etc. This work will help us in developing an architectural framework that can be used for developing similar health apps, which use machine learning on a smartwatch to detect similar medical conditions.

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REFERENCES

[1] R. Rawassizadeh, B. A. Price, and M. Petre, "Wearables: Has the Age of Smartwatches Finally Arrived?," Communications of the ACM, vol. 58, no. 1, pp. 45-47, 2015.

[2] P. Lamkin, "Best smartwatch 2019," [retrieved: August, 2019], https://www.wareable.com/smartwatches/best-smartwatch-buyers-guide-2019-7283.

[3] P. Humphreys, P. Whiting, and B. Pham, "Hemiparetic cerebral palsy: clinical pattern and imaging in prediction of outcome., The Canadian Journal of Neurological Sciences, vol. 27(3), Aug 2000, pp. 210-219.

[4] K. W. Kirigger "Cerebral Palsy: An Overview," American Family Physician, vol. 73, no. 1, pp. 91-100, 2006.

[5] H. A. Burwick, M. A. Case, and K. G. Volpp, "Accuracy of Smartphone Applications and Wearable Devices for Tracking Physical Activity Data," Journal of American Medical Association (JAMA), vol. 313, no. 6, pp. 625-626, 2015.

[6] C. Xu, P. H. Pathak, and P. Mohapatra, "Finger-writing with Smartwatch: A Case for Finger and Hand Gesture Recognition using Smartwatch," HotMobile '15 Proceedings of the 16th International Workshop on Mobile Computing Systems and Applications, New Mexico, USA, ACM, Feb 2015, pp. 9-14.

[7] T. Stütz, G. Emsenhuber, D. Huber, M. Domhardt, M. Tiefengrabner, G. Janneke, U. Fötschl, N. Matis and S. Ginzinger, "Mobile Phone–Supported Physiotherapy for Frozen Shoulder: Feasibility Assessment Based on a Usability Study," JMIR Rehabilitation and Assistive Technologies, 2017.

[8] F. El-Amrawy, B. Pharm and M. I. Nounou, "Are Currently Available Wearable Devices for Activity Tracking and Heart Rate Monitoring Accurate, Precise, and Medically Beneficial?," Healthcare Informatics Research, vol. 21(4), p. 315–320, 2015.

[9] G. M. Weiss, J. L. Timko, C. M. Gallagher, K. Yoneda and A. J. Schreiber, "Smartwatch-based activity recognition- A machine learning approach," in IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI), NV, USA, 2016.

[10] M. Kheirkhahan, S. Nair, A. Davoudi, P. Rashidi, A. A. Wanigatunga, D. B. Corbett, T. Mendoza, T. M. Manini and S. Ranka, "A smartwatch-based framework for real-time and online assessment and mobility monitoring," Journal of Biomedical Informatics, vol. 89, pp. 29-40, 2019.

[11] "Apple Developer Documentation," [retrieved: August, 2019], https://developer.apple.com/documentation.

[12] S. Jusoh, "A Survey on Trend, Opportunities and Challenges of mHealth Apps," Journal of Interactive Mobile Technologies (iJIM), 2017.

[13] M. A. Case, H. A. Burwick, K. G. Volpp, and M. S. Patel, "Accuracy of Smartphone Applications and Wearable," Journal of American Medical Association (JAMA), vol. 313, no. 6, pp. 625-626, 2015.

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Automated Measurments of Echocardiographic Global Longitudenal Strain

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***Abstract*— Echocardiographic determination of Global Longitudinal Strain (GLS) by manual tracing of endocardial borders is time consuming and operator dependent, whereas visual assessment is inherently subjective. In this paper, the development of a fully automated software using machine learning-enabled image analysis is presented. For a total of 30 patients, apical 4, 2 and 3-chamber views were collected from a center that assessed GLS using manual tracing. Manual tracing was done by the same user to calculate user inimitability. In addition, datasets were saved in a centralized database, and machine learning-enabled software (AutoStrain, TomTec-Arena 1.2, TomTec Imaging Systems, Unterschleissheim, Germany) was applied for fully automated GLS measurements. AutoStrain measurements were feasible in 95% of studies and the average analysis time was less than 3 sec/ patient. Interclass correlation coefficients and Bland-Altman analysis revealed good ratios compared to manual tracing and user to user ratios. Fully automated analysis of echocardiography images provides rapid and reproducible assessment of left ventricular GLS compared to manual tracing.**

Keywords-Global longitudinal strain; Echocardiography; Machine learning.

I. INTRODUCTION

As medical technology in healthcare continues to get more advanced, medical companies invent new algorithms claiming to facilitate everyday workflow. Technology involves lots of research and development, which results in selling those algorithms in the form of software. The purpose of those pieces of software is to facilitate the everyday workflow of end-users making the workflow more atomized. Atomization, artificial intelligence, augmented intelligence and machine learning are all dependent on algorithms targeting time management and consistent reading.

Cardiology is one of the major fields in healthcare where automated measurements have been widely spread. According to the results seen, critical decisions are taken by cardiologists towards their patients. Measurements like Left Ventricular Ejection Fraction (LVEF) were, for a long time, one of the main values cardiologists look into to evaluate the heart function. Lately, Two-dimensional STE-derived Global longitudinal Strain (GLS) appears to be reproducible and feasible for clinical use and offers incremental prognostic data over LVEF in a variety of cardiac conditions, although measurements vary among vendors and software versions [1].

The quantification of left ventricular (LV) size, geometry, and function represents the most frequent indication for an echocardiographic study and is pivotal for patient evaluation [2]. LV volumes, Ejection Fractions (EFs) and GLS can be measured using different imaging modalities. 2-dimensional echocardiography continues to be the most commonly utilized technique in clinical practice due to low radiation doses, feasibility and availability of this modality. Although the recommendations are to use 3D echocardiography to evaluate volumes and strains [3], 2D echocardiography is still by far the most common used technique.

Visual assessment is still popular within cardiologists while manual tracing lacks reproducibility in a very sensitive marker in cardiac function [4][5]. In this study, we used a novel, fully automated software to generate GLS from biplane views of the LV and compare them with manual tracing.

In Section 2, we will explain the methodology we used to prepare the data sample and extract numbers. In Sections 3, we will discuss the results. Section 4 will present the conclusion and future works.

II. METHODOLOGY

A total of 30 cases were collected from a Lebanese cardiology lab randomly. The collected studies were anonymized to ensure data privacy. Afterwards, Apical 4 Chamber (4-C), Apical 2 Chamber (2-C) and Apical 3 Chamber (3-C) views where selected with a minimum 1 heart cycle; see Figure 1.

All studies were imported to TOMTEC-Arena 1.2 (TOMTEC Imaging Systems, Unterschleissheim, Germany), a computer vision vendor-independent software package that applies a machine-learning algorithm for DICOM images [6]. AutoStrain, a fully automated software algorithm to calculate GLS in a very simple way was applied. A standard workflow requesting to allocate 4-C, 2-C and 3-C views was followed. The same workflow was followed all over the studies in Auto-Strain and manual tracing to ensure consistency and minimize any user workflow errors.

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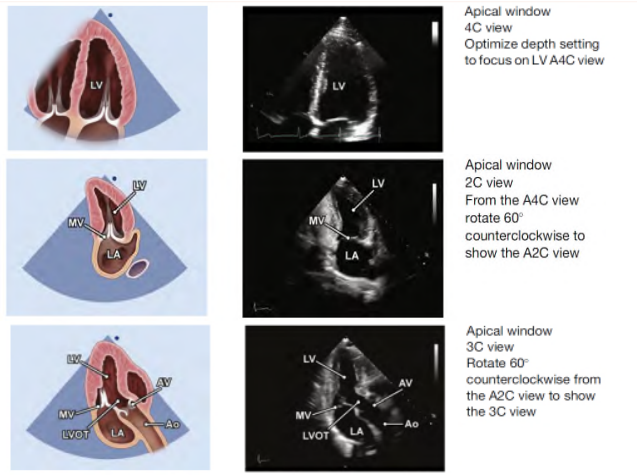

Figure 1. Apical 4C, 2C and 3C views.

The algorithm would then run the automated boarder detection and identify the end systole and end diastole; see Figure 2.

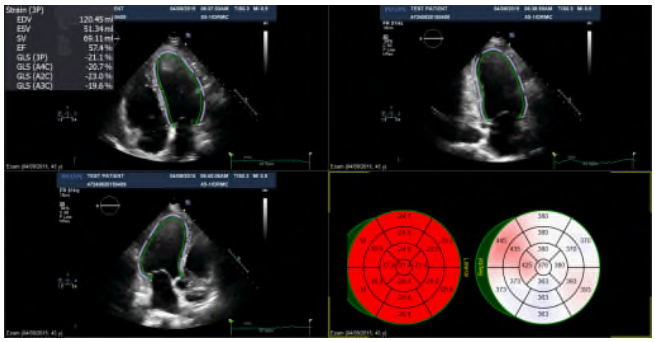

Figure 2. AutoStrain software, tracing of 4-C, 2-C and 3-C views; GLS (3P) automatically calculated.

GLS triplane, GLS (3P), will be saved and same frames will then be given to an expert investigator to manually change boarder detection in case the auto-tracing was not correct. As the boarders are being edited, software is automatically applying corrections all over the targeted heart cycle. New GLS (3P) is generated and saved offline to be compared with AutoStrain results.

To measure imitability ratio, the same studies are manually traced again by the same investigator following the same workflow and using the same frames. New GLS (3P) measurements were collected.

Due to poor image quality and missing Echo Cardiogram (ECG) data, for studies were eliminated (study 1, 20, 22 and 30). ECG data is essential for the software to detect End-Systole and End-Diastole.

III. RESULTS

While Auto-strain has 100 % reproducibility, manual tracing has an obvious inimitability ratio; see Figure 3.

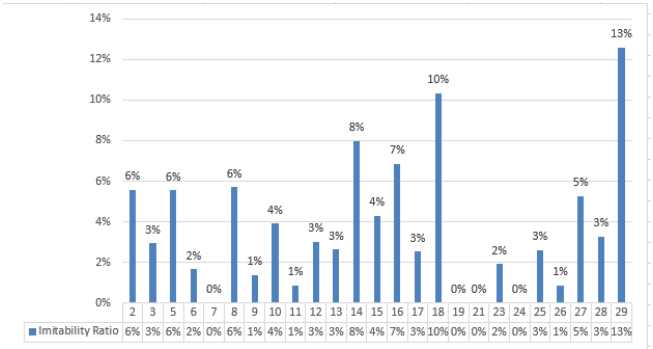

Figure 3. Manual tracing imitability ratio.

Figure 3 shows recordings for the GLS (3P) variance percentage between manual tracing 1 and manual tracing 2. Although same user was involved, same studies and frames, it is obvious that manual tracing lacks consistency. The average variance was 4% all over the data set in comparison with a 3% variance between manual tracing and automatic tracking; see Figure 4.

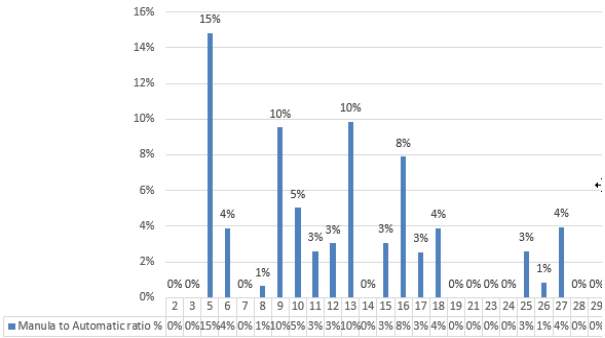

Figure 4. Manual tracing to Auto-Strain ratio.

Figure 4 shows recordings of the ratio between manual tracing results to Auto-Strain GLS values. Auto-strain has a huge advantage in terms of reproducibility and time saving in comparison to manual tracing. In the data sample we worked on, we had patients with poor GLS and others with normal GLS. Data accuracy does not depend on GLS value and patient condition, but on image quality and the right acquisition windows.

IV. CONCLUSION AND FUTURE WORK

The goal of the work reported here is to prove the functionality of machine learning automatic algorithms. Those algorithms can never replace cardiologists in the daily work they do, however, as they claim, their main purpose is to facilitate the workflow and increase reproducibility and accuracy. Physician will always have the superiority, especially when it comes to irregular anatomy, for example patients with congenital heart diseases, where

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no algorithm can detect the anatomy and explain the physiology of the heart.

As future work, increasing the number of analyzed studies will provide more accurate results. Moreover, comparing results from different user's manual tracing ratio is a result to monitor.

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REFERENCES

[1] R. M. Lang, L. P, Badano, V. Mor-Avi, J. Afilalo, A. Armstrong , L. Ernande, F. A. Flachskampf, E. Foster, S. A. Goldstein, T. Kuznetsova, P. Lancellotti, D. Muraru, M. H. Picard, E. R. Rietzschel, L. Rudski, K. T. Spencer, W. Tsang, and J. U. Voigt. Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Associationof Cardiovascular Imaging.

[2] M. Wong, G. Johnson , and R. Shabetai , for the V-HeFT VA Cooperative Studies Group. Echocardiographic variables as prognostic indicators and therapeutic monitors in chronic congestive heart failure. Veterans Affairs cooperative studies VHeFT I and II. Circulation 1993;87: pp.65–70..

[3] R. M. Lang, L. P. Badano, and V. Mor-Avi, Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr 2015;28: pp.1–39.e14.

[4] S. A. Reisner, P. Lysyansky, and Y. Agmon. Global longitudinal strain: a novel index of left ventricular systolic function. J Am Soc Echocardiogr 2004;17: pp.630.

[5] J. U. Voigt, G. Pedrizzetti, and P. Lysyansky. Definitions for a common standard for 2D speckle tracking echocardiography: consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging. Eur Heart J Cardiovasc Imaging 2015;28: pp.183–193.

[6] C. M. Bishop. Pattern Recognition and Machine Learning. New York, NY: Springer, 2006.

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