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AI For Business – MIS716

Assignment 1

Trimester 1 2022

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Executive Summary

Medical appointment no show is a consistent issue across most hospitals and medical providers that has financial and non-financial missed opportunities associated with this problem. In a study run by the Western Australian government in 2019, it is estimated that in a 12-month period, more than 160,000 outpatient appointments have been missed in private and public medical clinics and hospital across the state. This equates to an estimated of \$26 million lost in underutilised resourcing.

This does not only have a financial cost associated, but also a non-financial cost. For example, this can extend out wait times on waiting lists, as a missed appointment spot could have been utilised by another patient waiting for an appointment.

There is also plenty of research that specifies that there are certain patient characteristics that put them into a higher risk of treatment discontinuation once a patient has missed an appointment, thus it is imperative to identify these patients and have systems in place to reduce the no show rate with these higher risk group of patients to ensure continued medical treatment (Kurasawa, et al., 2016).

The proposed solution will be an integrated solution with the existing data and database infrastructure to support the following:

- Identify appointments dates/days where there is a high percentage of patients who is most likely to skip an appointment. This will prompt for a percentage of overbooking to mitigate empty slots.
- Identify patients who are at substantial risk of skipping an appointment and then continuing to discontinue their treatment. Using AI, these groups of patients will then receive a follow up call to confirm and remind them of the upcoming appointment.

Literature Review

From our research on the use of artificial intelligence used in managing health appointments, one of the clear observations and similarities is that the use of supervised machine learning is prevalent in the sector. Before we discuss the similarities and differences, we must first understand what artificial intelligence is and the different types of artificial intelligence.

Artificial intelligence (AI) can be defined as leveraging of the use of computer systems to perform tasks that usually require human intelligence. It is the combined use of computer systems, and robust data sets to problem solve. Presently all AI solutions are considered weak AI, instead of strong AI. Weak AI is used to automate regular and time-consuming tasks, and it simulates human cognition. Strong AI refers to AI that can exhibit human behaviour which is presently unavailable. Within the field of weak AI, it can be broken down further into the following groups of AI – Assisted Intelligence, Augmented Intelligence and Autonomous Intelligence.

Augmented intelligence primary role is to support human decision making with the use of machine learning, natural language processing, image recognition and neural networks. This type of AI learns from past data and through human feedback on output (Padma, 2020). Assisted intelligence is the most basic form of AI and is used to automate regular tasks and processes that usually require human input, this AI leverages of the use of big data, cloud platforms and data science and is not used for decision making and used to improve processes efficiency. Autonomous intelligence is AI systems that can adapt to different

situation without any human intervention, examples of these include self-driving cars, and military drones.

From our research, the main types of AI used in healthcare to manage missed appointments are mainly under the umbrellas of Assisted and Augmented Intelligence, the most popular being the use of appointment reminder SMS's which is a form of assisted intelligence. There are mixed opinions on the efficiency of SMS in reducing the missed appointment rates, and recent studies show that a more targeted approach in SMS may be useful (Bellucci, et al., 2017). In a study based on data collected across a span of 46 months, it was found that the nonattendance rate was much lower prior to the implementation of SMS reminders, this same study also found that there various other factors that is impacting nonattendance such as if the appointment was going to be done by a trainee doctor, number of consecutive appointments where the study found that patients are more likely to miss an appointment as the number of their appointment increases (Bellucci, et al., 2017).

There has been plenty of research in building predictor models to predict the likelihood of a patient missing an appointment, and some of the key findings from my research was that the following factors contribute to an increased likelihood of nonattendance.

- Previous nonattendance at appointments (Elvira, et al., 2017)
- Government health subsidies – patients with subsidies are more likely to miss an appointment (Karpagam, et al., 2017)
- Appointment day and time – Sundays and morning appointments tend to see highest rates of nonattendance (Karpagam, et al., 2017), (Salazar, et al., 2021)
- Appointment Lead Time - Longer lead time increases the likelihood of nonattendance (Mohammadi, et al., 2018)
- Lower income and higher unemployment leads to higher nonattendance (Mohammadi, et al., 2018)
- Cooler weather and rainy days tend to see higher nonattendance (Salazar, et al., 2021)
- Number of hospital attendance – the nonattendance rate is lower for patients who needed to be admitted into hospital frequently (Almuhaideb, et al., 2019)

The tables below summarises few key research that has utilised machine learning to manage nonattendance rates at appointments.

AI Techniques	Data Source & Content	AI Application	AI Type	Business Context	Pros & Cons	Application at MWHealth	Journal Article
<ul style="list-style-type: none"> Supervised Learning & Unsupervised Learning Algorithms: Logistic Regression, Monte Carlo Clustering 	<ul style="list-style-type: none"> Source: Medical centre EHR system Content: Age, Gender, Appointment Lead Time, Season, Examination Set, Group booking, Holiday, Late cancellation, cancellation date, 	<ul style="list-style-type: none"> Dynamic booking threshold to identify days where overbooking is required and days where additional doctors are required. 	<ul style="list-style-type: none"> Assisted Intelligence - Used to identify periods with high no shows, demographics with high no show probability. Augmented intelligence - used to cluster appointments and overbook when there is high cluster of patients with high probability of no show 	<ul style="list-style-type: none"> Cluster patients based on estimated individual cancellation probabilities Identify suitable overbooking limit to identify suitable balance between revenue, costs, patient experience and operational resources 	<ul style="list-style-type: none"> Reduces missed appointment slots and wasted resources Increases likelihood of patient wait times at hospital if all patients that have been flagged as likely to not attend, attends their appointments 	<ul style="list-style-type: none"> Implement overbooking policy Estimate number of slots to overbook 	<ul style="list-style-type: none"> overbooking for physical examination considering late cancellation set-resource relationship

AI Techniques	Data Source & Content	AI Application	AI Type	Business Context	Pros & Cons	Application at MWHealth	Journal Name
<ul style="list-style-type: none"> Supervised learning Algorithms: Logistic Refressions, Support Vector Machine, Recursive partitioning 	<ul style="list-style-type: none"> Source: Medical centre EHR system Content: Previous missed appointment Travel distance, appointment date and time, gender, age, hospital referral, mode of communication, subsidization, 	<ul style="list-style-type: none"> Identify factors contributing to missed appointments 	<ul style="list-style-type: none"> Assisted intelligence - used to analyse past data and identify variables and factors causing missed appointments 	<ul style="list-style-type: none"> Understand what reason is contributing to high missed appointment rate 	<ul style="list-style-type: none"> Pros: The research identified variables causing missed appointments Cons: The data used in the study was incomplete, and study was completed with quite a few assumptions 	<ul style="list-style-type: none"> identify internal (booking system ease of use, length of time between appointments) and external (distance to appointment, health subsidy) factors that are contributing to high missed appointments. 	<ul style="list-style-type: none"> Predicting appointment misses in hospitals using data analytics

AI Techniques	Data Source & Content	AI Application	AI Type	Business Context	Pros & Cons	Application at MWHealth	Journal Name
<ul style="list-style-type: none"> Supervised Ensemble Learning Algorithm: Gradient Boosting (GBM) 	<ul style="list-style-type: none"> Source: medical centre appointment scheduler Content: patient id, gender, appointment date and time, date request, medical specialty, monographic, appointment type, consultation, centre, accomplished, previous appointment history 	<ul style="list-style-type: none"> Develop predictive model to predict patients likelihood of not turning up to appointment. Develop predictive model to reduce both patient and doctor wait times based on no show prediction 	<ul style="list-style-type: none"> Augmented intelligence to predict patients that are likely to be no show to appointment 	<ul style="list-style-type: none"> Reduce missed appointments % Identify patients likely to skip appointment and implement intervention procedures 	<ul style="list-style-type: none"> Pros: Limit the use of bulk SMS for all appointments to a more targeted approach to only SMS patients highly likely to skip appointment. Basic model based on past appointment history, does not include other factors affecting missed appointments such as demographic background 	<ul style="list-style-type: none"> Identify patients that are most likely to skip appointments and send SMS to only these patients. 	<ul style="list-style-type: none"> Machine-Learning-Based No Show Prediction in Outpatient Visits

AI Techniques	Data Source & Content	AI Application	AI Type	Business Context	Pros & Cons	Application at MWHealth	Journal Name
<ul style="list-style-type: none"> Supervised & Deep learning Algorithm: Logistic Regression, Naive Bayes & Artificial Neural Network 	<ul style="list-style-type: none"> Source: patient data from community centre EHR system & Appointment Data Content: New/Existing Patient, Transaltor, Ethnicity, Race, Gender, Marital Status, Cell Ownership, Email availability, Use of patient portal, Employment Status, Insurance, Tobacco use, Age, Sex, Income, 	<ul style="list-style-type: none"> Developed and compared predictive models to better undersand appointment adherence in underserved populations 	<ul style="list-style-type: none"> Augmented intelligence to predict factors/variables that are associated with missed appointments 	<ul style="list-style-type: none"> Models designed to predict missed appointments should be clinic/facility specific as variables contributing to missed appointment vary by each clinic/facility Reduce no show rate to improve clinical efficiency 	<ul style="list-style-type: none"> Pros: Having clinic/facility tailored models can improve model's overall performance, as a standard model designed for all facilities may not be suited due to the differences in patient characteristics. Cons. This study did not touch on any practical implementation of the models 	<ul style="list-style-type: none"> Develop slightly different versions of the prediction model for emergency, general medical, intensive, corornoary care, surgical services and specialised support 	<ul style="list-style-type: none"> Data Analytics and Modeling for Appointment No-show in Community Health Centres

AI Techniques	Data Source & Content	AI Application	AI Type	Business Context	Pros & Cons	Application at MWHealth	Journal Name
<ul style="list-style-type: none"> Supervised Learning Algorithm: Logistic Regression 	<ul style="list-style-type: none"> Source: Missed appointment patient history data from EHR system. Content: Sex, Age, Frequency of clinic visit, probability of visit five on day of week, Appointment date, Date Appointment Booked, interval between appointments, attended/Missed appointment, medicine prescribed, length of prescription, total amount of medications a day, laboratory results 	<ul style="list-style-type: none"> Develop a prediction model to identify patients who may miss an appointment and discontinue treatment following the missed appointment 	<ul style="list-style-type: none"> Augmented Intelligence to predict high risk group of patients who are likely to discontinue treatment Assisted intelligence to push notification of high risk patient to hospital for follow up call 	<ul style="list-style-type: none"> Reduce missed appointment rates which leads to discontinued treatment Reduced treatment discontinuation in high risk patients 	<ul style="list-style-type: none"> Pros: Targeted approach to identify patients who are not only likely to miss an appointment, but also discontinue treatment. Intervention can be put in place early on to ensure these patients receive the continued medical treatment. 	<ul style="list-style-type: none"> Identify high risks patient who need a follow up call with regards to keeping their appointments. 	<ul style="list-style-type: none"> Machine-Learning - Based Prediction of a scheduled clinical appointment by patients with diabetes
AI Techniques	Data Source & Content	AI Application	AI Type	Business Context	Pros & Cons	Application at MWHealth	Journal Name
<ul style="list-style-type: none"> Supervised learning Algorithm: Random Forest 	<ul style="list-style-type: none"> Source: Patients & Appointments Data from Medical Centre. Weather and Disease data from external sources. Content: patient id, sex, appointment date, attended?, No-Show Reason, Type of Disability, Age, Date of entry into medical centre, City, disease code, health unit, temperature, rainfall, heat intensity 	<ul style="list-style-type: none"> Develop a prediction model using health and weather data to predict probabilities of appointment cancellations 	<ul style="list-style-type: none"> Augmented intelligence to predict cancellation/no show rate based on day and weather conditions. Assisted intelligence: notification to scheduling system that due to weather conditions estimated cancellations will be a certain percentage. 	<ul style="list-style-type: none"> Reduce missed appointment rate Establish if weather conditions are contributing to high missed appointment rates - any seasonality trends 	<ul style="list-style-type: none"> Pros: This model is one of few that includes external variables that constitute to missed appointments such as weather. Cons: No practical implications on how to integrate daily weather data into model to enable live real time predictions 	<ul style="list-style-type: none"> MWHealth can replicate a similar model to understand seasonality trends (Winter vs Summer No Shows) and use the insights from the model to put processes in place to mitigate seasonality cancellations 	<ul style="list-style-type: none"> Applications of Machine Learning Techniques to Predict a Patient's No-Show in the healthcare sector.

Proposed Solution

Based on the findings of the research and the existing use of SMS by MWHealth, we will not propose the use of further SMS technologies to manage nonattendance as it is found to not effectively reduce these rates and may cost the business copious amounts of expenses in the long run.

The solution that I am proposing is an integrated and hybrid approach solution that utilises a mix of supervised learning and unsupervised learning techniques.

Using the current data infrastructure, data from both the MWHealth patient HER and Appointment Scheduler system will be extracted into a data lake for real time analysis. From here, the first stage is to utilise an ensemble supervised learning model that is made up of a stack of models (Logistic Regression, Decision Tree, Support Vector Machine) to predict and identify patients with a high likelihood of not showing up for an appointment, these tags are then dynamically integrated back and tagged against each patient record in the EHR and scheduler system daily. Reason for opting with an ensemble model here is due to each of the individual models having their own strengths and diverse ways of working with live data, thus ensuring the predictions are more robust and accurate.

Once the model predicts patient that are likely to miss an appointment, these patients are then integrated into an unsupervised learning clustering model using Kmeans to then identify high risk patients that are likely to discontinue their treatment following from a missed appointment, as research shows that there are certain demographic and social indicators that can be used to predict instances of treatment discontinuation (Kurasawa, et al., 2016). Once the high-risk cluster is identified, this information is then integrated back to the EHR system and recorded as elevated risk for treatment discontinuation against the patients record.

From here, using those 2 tags, we can use the data for a few purposes such as below:

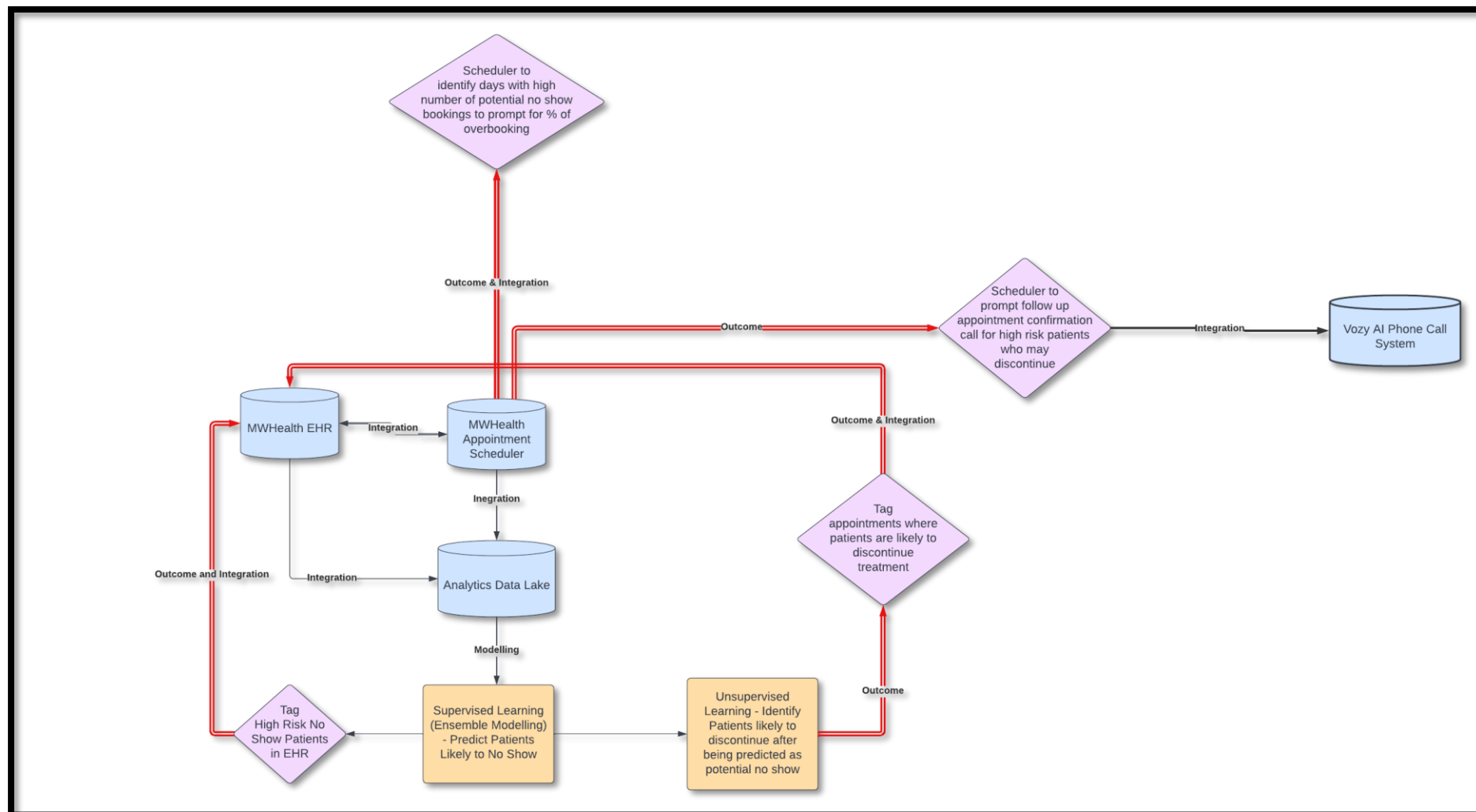
- Scheduling system to flag appointment dates with high number of patients who may not attend, and use this as a basis to overbook, or prepare short notice waiting list for other patients.
- Scheduling system to use data to avoid booking in patients who have been flagged as potential no show on days and times where there is higher no shows (Sundays, morning appointments) to reduce likelihood of patient not showing up
- Use of Vozy which is an AI system to make follow up phone calls to patients flagged as elevated risk of discontinuing treatment.

The tables below demonstrates the infrastructure, vendors and data required to build the proposed solution above. The proposed data flow and solution integration can be viewed in image 1 below.

By integrating the following recommendations, MWHealth will be equipped to identify days with high probabilities of no show, and proactively overbook or create a short notice waiting list to fill the appointments to reduce wasted resources and missed appointment costs. This solution will also identify patients that require further intervention to ensure treatment discontinuation, I am confident that a phone call will work better than an SMS, as a conversation could be had using the AI bot, and using natural language processing, the AI both will be able to ask prompting questions to reinforce the importance of not missing the appointment.

Model & AI Type	Data Required	Development Required	Resources Required	Vendors
<ul style="list-style-type: none"> •Supervised Learning - Ensemble Model to predict patients that are likely to not show up •AI Type: Augmented AI & Automation 	<ul style="list-style-type: none"> •Previous appointment history, Age, Sex, Ethnicity, Patient Location, previous admission details, medical condition severity, Use of illicit substances (drugs, alcohol, smoking), employment status of patient, medications prescribed 	<ul style="list-style-type: none"> •API development to design plug in to dynamically update potential no show tags against patients record in EHR system •Development in MWHealth Scheduler to notify days with high percentage of potential no shows to allow for overbooking 	<ul style="list-style-type: none"> •Developer to design API •Data Engineer & Scientist •EHR System Administrator •Scheduling System Administrator 	<ul style="list-style-type: none"> •Holly:Overbooking scheduler: https://www.nimblr.ai/ •AWS (Machine Learning): https://aws.amazon.com/machine-learning/
Model Type & AI Type	Data Required	Development Required	Resources Required	Vendors
<ul style="list-style-type: none"> •Unsupervised Learning - Clustering K Means Model to predict high risk patients who will discontinue treatment from a no show. •AI Type: Augmented, Assisted & Automation 	<ul style="list-style-type: none"> •Previous appointment history, Age, Sex, Ethnicity, Patient Location, previous admission details, medical condition severity, Use of illicit substances (drugs, alcohol, smoking), employment status of patient, medications prescribed 	<ul style="list-style-type: none"> •API development to design plug in to dynamically update potential no show tags against patients record in EHR system •Development in MWHealth Scheduler to push data into Vozy for AI phone call •Purchase of Vozy system 	<ul style="list-style-type: none"> •Developer to design API •Data Engineer & Scientist •EHR System Administrator •Scheduling System Administrator 	<ul style="list-style-type: none"> •Vozy: AI Phone Call System: https://www.vozy.co/

Diagram of proposed solution (Image 1)



References

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Appendix

There are a few assumptions made with regards to the proposed solutions that needs further investigating, and they are:

- MWHealth's patient electronic health records (HER) system and the scheduler is integrated.
- Both the EHR system and scheduler has API capabilities enable plugins or other tools to be connected on top of both these systems
- MWHealth has an analytics data lake that is integrated with a cloud-based analytics and machine learning tool such as Azure.