Take a deep breath : Spiroartis – the first artbased spirometry platform for adolescent asthma patients

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Abstract

There is tremendous potential to apply artbased incentive gamification in diagnostic, monitoring and therapeutic management of chronic diseases such as asthma and cystic fibrosis. There is also an increasing need for more customised transdisciplinary approaches to diagnostic and monitoring health technologies. Spirometry is an indispensable technique employed in the initial diagnosis to detect and quantify the degree of airflow obstruction, assessment of severity, and follow-up of chronic respiratory diseases such as asthma and cystic fibrosis. There is a range of incentive animations currently employed in spirometry to engage children and adolescent patients to achieve required values for a correct diagnosis. However, not all children are interested in sporting games used as incentive games or simple animations, and the resultant novelty effect means that interest and use taper off by the age of ten. Spiroartis is the first arbased spirometry platform to produce original and creative digital artworks generated by the breath of patients during lung volume testing. A proof-of-concept platform has been designed and tested on a group of adolescent asthma patients, with all participants in the cohort preferring the SpiroArtis artworks generated over incentive animations currently being used. SpiroArtis also promotes better engagement, and motivation in patients with respiratory diseases such as asthma and cystic fibrosis.

Keywords

Artbased, Asthma, Spirometry, eHealth, Gamification, Novelty, Motivation, Engagement, Licensing, Commercialisation.

Introduction

The novelist Tim Winton has written “It’s funny, but you never really think much about breathing. Until it’s all you ever think about.” [1] And that’s so true for those children suffering from Asthma, the world’s leading chronic disease in children. [2] Asthma is a condition that causes narrowing and inflammation of patient airways and bronchial tubes. Along with the resultant production of mucous, it causes severe difficulty in breathing, oftentimes leading to hospitalisation, and sometimes in acute cases, death. [3] Currently, there are 5.1 million children under the age of 18 with asthma, - 460,000 in Australia. 1,000 people a day die from it, but hospitalisation and deaths from asthma are preventable.[4]

Apart from the obvious physical symptoms of inflammation and airway obstruction, asthma can also produce a variety of psychosocial effects on children, with the potential to engender psychological and social problems later in their lives. [5] The chronically ill child, with many physical limitations, may also have difficulty developing a healthy self-concept, and it’s not unexpected that many children with asthma tend to be anxious, stressed, prone to depression and problems with self-image. [6] Paediatric and adolescent asthma patients not only tend to experience episodic depression but, because of it, to be less compliant when it comes to adhering to medication regimes. [7]). In addition, it has been found that depression has been a comorbidity factor in children who are in the cohort presenting a higher risk of death from severe asthma. [8] For a number of these young patients with asthma, the effects of depression, along with feelings of low self-confidence, stress, and anxiety, can be just as demanding to handle as their physical symptoms. [9] These come together in the chronically ill young patient and have the resultant effect of making it more difficult for the child in terms of developing resilience and a healthful self-concept. [10]

Spirometry means “the measuring of breath”, and is the term applied to the range of lung function tests that have as their objective the measurement of air that is expired and inspired. [11] Spirometry is an indispensable technique employed in hospitals in the initial diagnosis to detect and quantify the degree of airflow obstruction, and assessment of the severity of respiratory diseases such as asthma and cystic fibrosis. Spirometry is a fundamental technique that is applied in the initial diagnosis to detect and quantify factors such as the degree of airflow obstruction and assessment of severity. (see Figure 1)

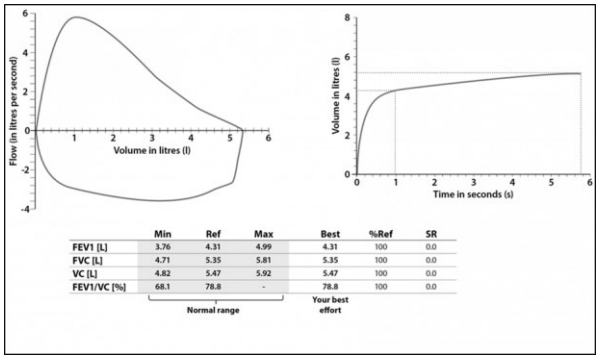

Figure 1. Example of (normal) spirometry result for a hospital spirometer (Source - Ruppels Manual of Pulmonary Function Testing, 2016)

It is the primary source of basic exploration of pulmonary function used in medical practice. [12] It is also used in therapeutic and monitoring modalities in a home environment using Bluetooth spirometers and mobile phone apps. Given an escalation in the prevalence of paediatric asthma, and the corresponding increase in mortality rates, there is a growing demand from public health professionals to encourage patients to monitor their asthma at home, using mobile spirometry devices. [13] Spirometry allows the patient to monitor their lung volume, thereby preventing asthma attacks and potential hospitalisation.

Many adolescent and younger patients do not have an adequate awareness of their condition, go through their daily life with sub-optimal control of their disease, and would make some improvement in their condition by engaging in self-supervising behaviours using spirometry. Through effective asthma self-management daily, patients can also bring about a reduction in symptoms and biopsychosocial effects such as anxiety and stress. [14] Spirometry testing is physically and psychologically demanding, and requires full compliance from the patient, as forced exhalation needs to be carried out over a six second period, as fast as possible. Given these conditions, spirometry testing and treatment for younger respiratory patients has been found to exacerbate mood disorders, and depression. [15] There is a range of incentive animations currently employed in spirometry to engage some children and adolescent patients to achieve the required values for a correct diagnosis or monitoring of their progress.

Spirometry and Incentive Animation Games

Spirometry can be viewed as the assessment and evaluation of lung volume tests which are expressed as lung volume plotted against time and flow curves created when a patient with respiratory disease such as asthma, produces a forced expiration over six seconds. [16] It is a demanding test and requires full attention and participation, and therefore encouragement animation incentives have been developed for younger patients to facilitate full cooperation. Through using these interactive games produced as cartoon animations, patients are expected to reach the desired outcome and score points and/or achievements through forced expiration. This can take the form of young patients blowing up balloons, driving a racing car around a track, or blowing out candles on a birthday cake.

Through providing a sustained focus for patients and a visual motivation it is expected that spirometry criteria are met for a successful test in terms of forced expiratory volume and forced volume curve. The following spirometry devices and incentives are examples of the animations currently utilised to facilitate proper spirometry behaviours in younger and adolescent patients undergoing lung function testing. They have been designed to produce maximal expiratory flow/volumes, manoeuvres which are not only dependent on effort but also skills such as understanding and cooperation. Unfortunately, the increased convenience of purpose along with expanded motivation can steadily decline on familiarity with the animated game platform. [17] Not all patients are interested in sporting games used as incentive games or simple animations, and the novelty effect and interest wear off by the age of ten, as the results of engaging with the incentives never change. [18]

RespirGames

RespirGames Inc. develops clinically effective breath biofeedback spirometer games that help children with asthma to perform spirometry and recognize and manage their changing symptoms (see Figures 2-3). RespirGames such as Ludicross emphasise “eye-breath coordination” paradigms to improve the sense and motor control of breathing (respiratory interoceptive skills) that is required for both spirometry and symptom awareness. In addition to cutting costs for health services for this common paediatric respiratory disease, RespirGames also seeks to benefit children with muscular dystrophy, cystic fibrosis, spinal muscular atrophy, and adults with COPD.

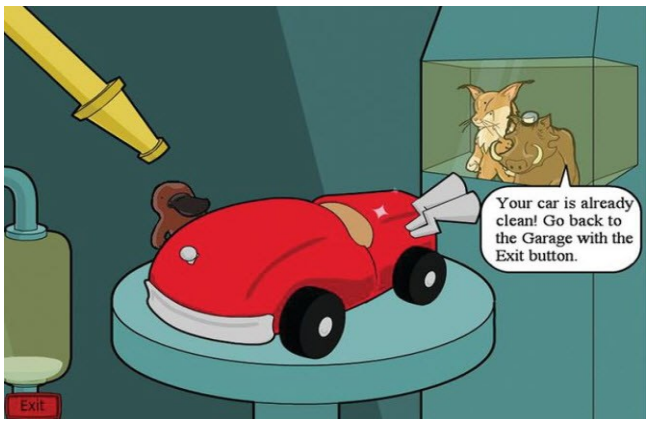

Figure 2. Screenshot of spirometry game Ludicross

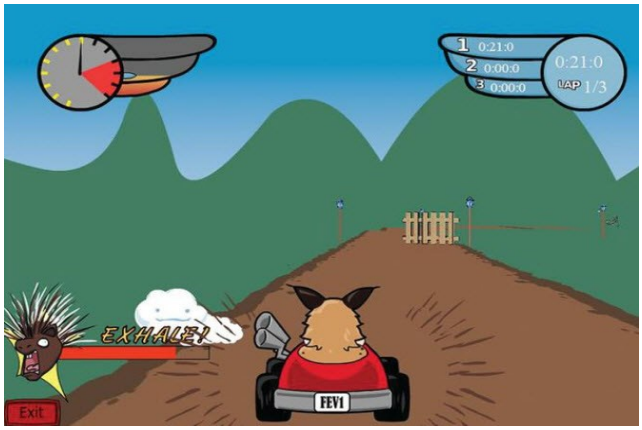

Figure 3. Screenshot of spirometry game Ludicross

In Figure 2 the player is incited to perform a forced exhalation, using the spirometer, to fill a water tank and then direct water at a race car to clean mud off of its surface. In Figure 3 the player charges up a race car, sending it zooming around a track, by charging it up with a necessary forced exhalation of six seconds.

SpiroPlay

SpiroPlay has developed a suite of spirometry games based on metaphors co-created through design workshops with paediatric patients undergoing regular spirometry testing. They were developed for younger patients to play the games at home and thereby manage their asthma regularly. The metaphors they developed respond to patients performing deep inhalations and forced exhalations. From the metaphors they developed for use in their suite of games, they found that the most popular was an elephant watering flowers in a garden, a soccer player shooting at a goal with a ball, and a dragon breathing fire (see Figures 4-5).

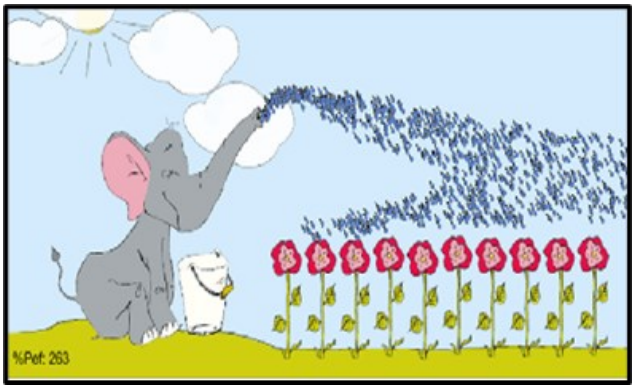

Figure 4. Screenshot of the elephant animation that waters flowers in the SpiroPlay suite of spirometry games

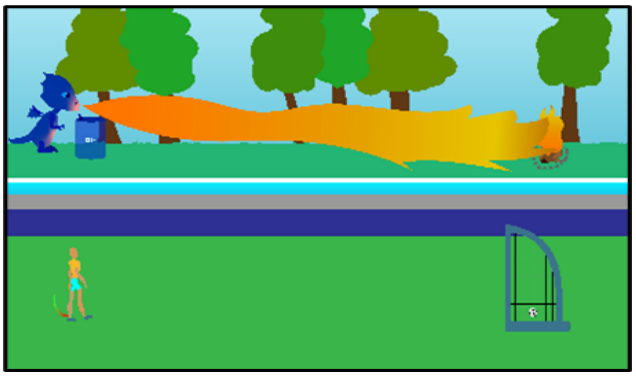

Figure 5. Screenshots of SpiroPlay dragon breathing fire and soccer player game

The SpiroPlay game in Figure 5 is showing a dragon (top shot) setting a barrel on fire with a forced expiration, and the bottom shot shows a soccer player kicking a ball into a goal with a forced expiration.

CareFusion –Hospital Incentive Spirometry Games

Carefusion hospital spirometers can give younger patients ten animated games as an aid in performing reproducible forced expiratory volume readings as well as forced volume curves (see Figures 6-7).

Figure 6. Screenshot of Carefusion encouragement animation where players must blow out candles with forced exhalation.

Figure 7. Screenshot of Carefusion encouragement animation for paediatric patients – player expected to blow the house of straw down with forced exhalation

Rationale for SpiroArtis Development

The design and testing of the SpiroArtis prototype was part of a Doctorate in Creative Industries, providing an example of how an ArtScience research project could be developed and eventually commercialised using a transdisciplinary ArtScience technology transfer and knowledge management framework. The other motivations which underpinned the development of the first artbased spirometry platform for adolescent patients with respiratory conditions such as asthma were:

There is always an initial motivation and impetus for engaging in most types of research and sustained interest and passion for research at the postgraduate level. SpiroArtis owes as much to my child-hood years as a chronic asthma patient, and my parallel lives in art practice and studies in biomedical science, as it does to the two Masters' degrees in interdisciplinary ArtScience research and commercialisation, which preceded it. From this arose a desire to develop, test, and commercialise an artbased spirometry platform which could keep patients engaged and sustain motivation in spirometry testing, and address issues of stress, and anxiety which arise in testing.

There is a range of incentive animations currently employed in spirometry to engage children and adolescent patients to achieve required values for a correct diagnosis. However, not all children are interested in sporting games used as incentive games or simple animations, and the resultant novelty effect means that interest and use taper off by the age of ten. There is nothing to engage adolescent patients with respiratory diseases. Compliance from respiratory disease patients with testing regimes such as spirometry decreases in adolescence, as rebellious behaviours increase, increasing fears of peer group rejection, and not wanting to be defined by their disease. [19] [20]

SpiroArtis Methodology

The doctoral research aimed to answer these questions: Can a spirometry platform be designed for adolescent patients with respiratory diseases, which could keep them engaged and motivated in regular testing in both hospital and home environments? Could an artbased approach be utilised in the design of the platform to overcome novelty effects? Could this artbased approach also leave the adolescent target cohort with a sense of creative accomplishment whenever an original artwork is produced with their breath in spirometry testing? There is an increasing need for more customised approaches to asthma testing, monitoring and management for children and adolescents. [21]

A proof-of-concept artbased spirometry platform was developed with funding from the Institute of Health and Biomedical Innovation and QUT. When a patient started a forced exhalation over six seconds to produce the required forced expiratory volume reading, a kaleidoscopic animation would be activated, and if the patient successfully completed the forced exhalation, a unique, static artwork would be formed. Every time the SpiroArtis platform would be used in spirometry testing, the kaleidoscopic sequence and the final static artwork would be exceptional to the patient and the test. A cohort of six adolescent asthma patients was then recruited over several months in 2021 at the Queensland Children's Hospital by Andrew Coates – Lead Respiratory Scientist. It was hoped more patients could participate in the design trial, but fears of Covid prevented more parents and their children volunteering for the trial.

The cohort was interviewed for suitability and provided with a parent/guardian information statement for prospective participants, as well as parent/guardian consent form. The inclusion criteria were:

- Diagnosis of asthma by Andrew Coates – QCH Clinical Lead, Respiratory Scientist Respiratory, and Sleep Studies Unit
- Ability to produce/collect a range of artworks to be digitised and used for SpiroArtis
- FEF 25-75% < 65% of predicted as a marker for small airway disease
- Informed consent by parent or legal guardian
- Patient cohort of males and females in the target demographic of 12-16 years of age
- Able to take part in the SpiroArtis design trial

Over two weekends in September 2001, the six participants in the design evaluation trial, engaged with a Spiro USB spirometry device in producing correct and maximal Forced Spirometry readings with results expressed as a graph (See Figure 1).

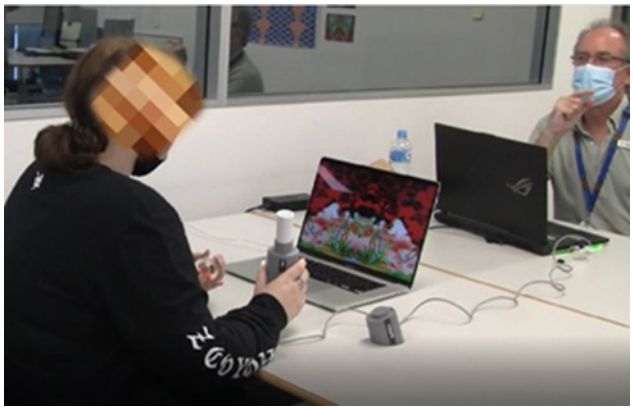

Figure 8. Figure 8. Patient successfully completing SpiroArtis test to produce unique artwork to be printed for patient in A3 form.

As the Senior Respiratory Scientist for the Queensland Children's Hospital, Mr. Andrew Coates conducted, monitored, and evaluated both SpiroArtis (See Figure 8) and baseline spirometry test results (See Figure 9). For each visit from the cohort chosen, spirometry was performed with and without the SpiroArtis platform in a randomised fashion. In this manner, results were comparable without a time lapse in between the 2 modalities, so as soon as the conventional spirometry test had been performed, the participant immediately did the SpiroArtis test.

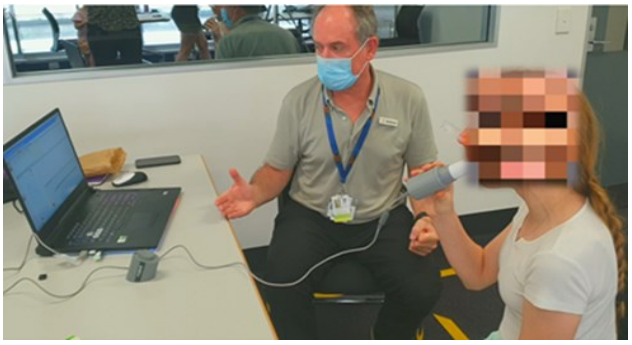

Figure 9. Andrew Coates carrying out baseline spirometry testing with patient.

In each of these sessions, the participants engaged with the SpiroArtis platform and by doing so, produced a novel and original artwork. Participants were given copies of their artwork in the form of colour A3 prints (See Figure 10). Feedback was elicited at the beginning and end of each design evaluation trial from each of the six participants. This feedback was captured through semi-structured interviews. Participants were asked to compare hospital spirometry animations results with artwork resulting from engagement with the SpiroArtis proof-of-concept platform.

Results

The six participants were asked to rate their experience with hospital incentive animations compared to SpiroArtis, on a 6-point Likert Scale (1= boring to 6 = very interesting) with the results shown below in Table 1. All the participants preferred using the SpiroArtis platform over hospital animation games, which they all had not used since the age of ten to eleven. It should also be noted that spirometry values (FEV1 and FEV2 measures) for 3 out of the 6 participants were higher (15-17%) using the SpiroArtis platform. Participants were also asked whether they would use SpiroArtis in a Bluetooth spirometer format with mobile interface, with all results being sent to their hospital doctor or local GP. Artwork produced in this format could be stored in a virtual gallery in a mobile phone app. All six participants agreed they would use this format on a regular basis to monitor their lung capacity.

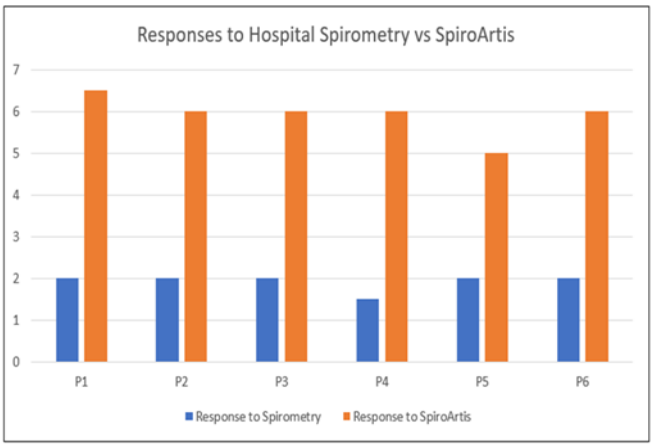

Table 1. Comparison between Likert Scale (6-Point) between Hospital Spirometry Animations and SpiroArtis

Figure 10. Artworks generated by SpiroArtis trial participants

Conclusion and Future Work

Research with paediatric asthmatics in a randomised controlled trial utilising an art therapy intervention and was able to show that young asthmatics were able to gain considerable benefit from art therapy in terms of a boost in the quality of life, as well as a decrease in stress and levels of anxiety. [22] This research established that the essential factors which enabled ill children to feel empowered, can function as deeply normalising catalysts for those children who are undertaking clinical tests and procedures in therapeutic and treatment modalities. Feasibility testing with the 6 participants assessed the likability of the kaleidoscopic video and unique artwork generation from a curated set of 450 images as a motivating and incentivising system. The design evaluation trial results present favourable data in support of using SpiroArtis as the first artbased platform for adolescent spirometry testing. There is tremendous potential to apply an artbased gamification approach in diagnostic and therapeutic management of chronic respiratory diseases such as asthma and cystic fibrosis.

The next stage for SpiroArtis is to secure funding and an industry partner to develop a functional model which can be used in clinical trials at the Queensland Children's Hospital and Westmead Children's Hospital. Organisations such as Asthma Australia, the Lung Foundation of Australia, and Cystic Fibrosis Australia are being approached for involvement in in the project.The following are application scenarios for a mobile-based SpiroArtis application and a SpiroArtis postoperative incentive spirometry application for adults who need post-operative rehabilitative spirometry. After clinical testing, commercialisation will take place through industry partners through licensing arrangements and assignment of copyright for artworks created in the curated collection.

John Atmos is a 15-year-old chronic asthmatic. He is 1.5m tall and weighs 42 kgs and has had asthma since the age of 3. He has been hospitalised numerous times and he has been hospitalised on several occasions through allergenic asthma as well as pulmonary infections. On each of these occasions, John has not been aware of reducing lung function before an attack or infection requiring hospitalisation. As a younger patient, John was very compliant with his asthma management and medication regime, but as an adolescent he is now exhibiting signs of challenging behaviour when it comes to managing his asthma, and he is tending to ignore his symptoms to fit into his peer group, but by doing so he is delaying treatment and endangering his health.

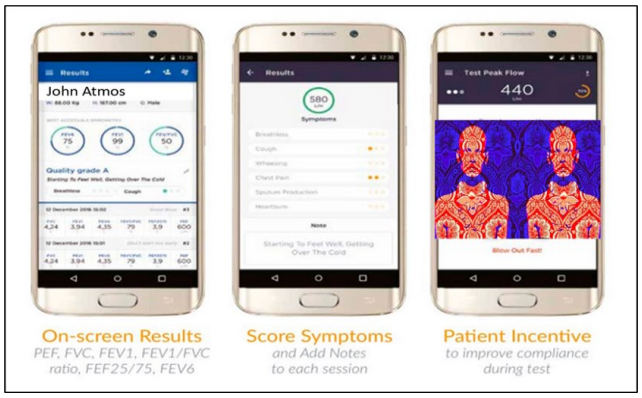

Figure 11. Mockup of data and artwork incentive on SpiroArtis mobile interface, to facilitate increased patient compliance at home with regular spirometry testing.

He attends the Respiratory Clinic at the Qld Children's Hospital every few months and has recently started using the SpiroArtis platform when conducting his spirometry tests and has enjoyed making art with his breath. He also has started using the mobile version of Spiroartis at home (See Figure 11). It is 8.15 a.m. and John uses his Bluetooth spirometer in conjunction with the SpiroArtis app on his mobile phone to track his peak expiratory flow rates (PEF, FVC, FEV1, FEV1/FVC Ratio, FEV6, FEF 25/75) at home, before he goes to classes. The results of his spirometry are displayed on his mobile phone in an online gallery format, where clinical data from testing can be relayed to his hospital or family GP. The Lobby is entered from a loading page and comprises rooms in a virtual gallery exhibiting successful spirometry readings, each displayed with a date and title for the image produced (Fig.12).

Figure 12. Example of one of the virtual gallery spaces with two successful SpiroArtis artworks produced from 2 tests which reached the desired criteria for (FEV1, FVC) appropriate spirometry results.

The number of rooms are available for customisation in terms of number as well as appearance. with 50 rooms holding a total of 300 images / tests. The Lobby also provides access to the Curator's Office, where John can personalise his social media profile and any personal information he wishes to share online. Figure 13 shows the clinical data which is produced whenever John performs a test, and is part of the generated artwork.

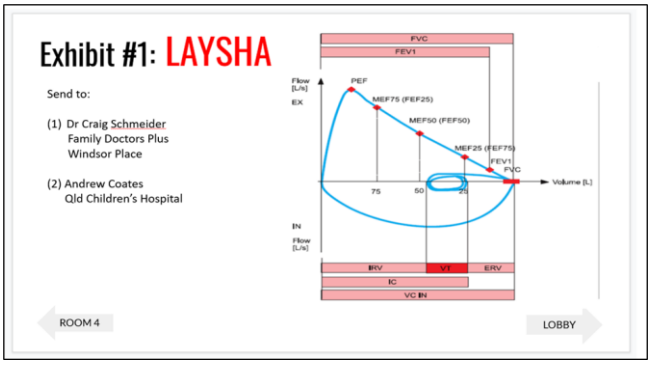

Figure 13. Clinical Spirometry Data from SpiroArtis artwork in Test 1 Room 1

From the data provided to his GP and the Qld Children's Hospital, John either gets an automated message "liking" his artwork as an example of a 5 out of 5 spirometry test,(A 1 to 5 scale where 1 to 4 are noncompliant results and 5 is a clinically accepted spirometry reading) or a message encouraging him to do better in the form of something like "look forward to seeing a stronger blow as I want to see a

great artwork". These messages can be changed automatically over time.

Figure 15. Example of Patient Bio in Curator's Office in SpiroArtis Gallery

The GP can also contact John if clinical values are predicting a bad asthma attack coming on and suggest he contact the hospital. John can also curate biographical information in the mobile version of SpiroArtis (See Figure 15) if he wishes to share it with friends. This can take the form of his age, interests, games he likes etc.It then links him to a community of patients online and enables him to share information and connect with other patients in a positive and creatively inclusive manner which then builds his confidence and resilience.

Figure 16. Social Media Posting Platform in SpiroArtis mobile version

Figure 16 is a feature of SpiroArtis mobile version and provides options for John to share his SpiroArtis artwork with other patients around the world. He can customise the social media platform(s) he wishes to use and set details around posting time and number of posts. This is an important function for asthma patients, but even more so for adolescent cystic fibrosis patients who have difficulties meeting face-to- face due to risks of cross-infection and death. SpiroArtis affords patients a sense of community and creative. expression while at the same time clinical data sharing between patient, GP and hospital

Future applications of SpiroArtis also include a version for adults who are postoperative surgery patients needing spirometry as a rehabilitative function. A customised SpiroArtis incentive platform for post-operative patients from gastric, pulmonary, cardiac surgery and rehabilitation from spinal cord injury will involve daily use of the platform to generate novel artwork. In addition to every artwork produced over, for example a 16-day period, it will also comprise of an image being developed in a 16-cell grid which will be completed for the patient on the final day of incentive spirometry. The SpiroArtis platform for adult post-operative patients will therefore yield daily results as well as a goal-oriented activity to realise a larger artwork to be determined by the duration of incentive spirometry exercises needed for that particular post-surgery type. This larger image will further serve to motivate patients to keep using the incentive spirometry daily and to overcome the novelty effect. SpiroArtis can assist in encouraging and motivating adolescent patients with respiratory diseases such as asthma to use spirometry on a regular basis, but it can also aid in giving asthma patients the sense that while they may have asthma… asthma does not have them.

Take a deep breath. SpiroArtis is here.

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