

Lymphaticus – a learning game designed for lymphoedema patients to promote better understanding and treatment concordance.

Lymphaticus is a game for lymphoedema patients (Lymphies) to learn about the importance of the lymphatic system in fighting infection and maintaining lymph flow and fat absorption. This is a first-person shooter (FPS) video game designed for mobile devices that places players inside Lymphie Jo's lymphatic system to fight infection and improve lymph flow with weapons and super-powers (the body's natural defences and the nutrients collected on their journey in the lymph). Gameplay matches real-world strategies used to manage lymphatic disorders successfully to improve quality of life.

Serious games are those that have a clear and specific educational purpose. Such games have been used effectively for education and training of clinicians and patients (Kato *et al.*, 2008; Kato, 2010; Ellaway, 2016). Serious games can be a useful learning tool using a patient-centred approach, through interactivity, problem-solving, repetition and continuous feedback (Kirriemuir and Mcfarlane, 2004). They have the potential to enhance motivation for learning by stimulating curiosity offering active learning with targeted information in a meaningful context within the learner's control (Kirriemuir and Mcfarlane, 2004; Kato *et al.*, 2008).

Games designed for patients support their likely compliance with treatment (Kato, 2010). Designing a game specifically to support Lymphies may improve their knowledge and confidence, reduce stress and provide a sense of autonomy in the management of their condition.

Game objective

Lymphaticus is designed to help Lymphies to improve management with greater confidence and reduce health risks such as infection. Based on accurate science, *Lymphaticus* provides support by giving players a sense of power and control and encouraging treatment concordance by:

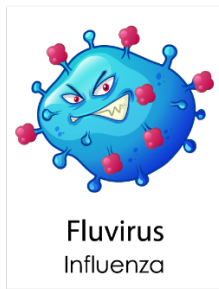
- outlining basic lymphatic anatomy and physiology (A&P) to develop the player's understanding;
- demonstrating how infection occurs and is fought by the body;
- promoting engagement with A&P through immersive play;
- problem-solving aligned to real-life decisions about lymphoedema management; and
- motivating players using proven game-based learning principles.

Game design:

The player enters Lymphie Jo's lymphatic system, which has been invaded by pathogens initiating their first mission to fight the enemy. Players will germinate from a progenitor cell upon commencement. The player, however, is not seen in the game as they have a first-person view. A symbol of their progenitor cell features in the play area. There are five main characters featured in *Lymphaticus*. The core characters represent the enemy pathogens infiltrating the lymph and a mage called Immunata.

Character design authentically depicts cells with the essence of the character's cell-type built into its appearance in a cartoon-style design. The artwork is colourful and lively with animated scenarios to emulate the activity naturally occurring within the lymph.

Enemy pathogens



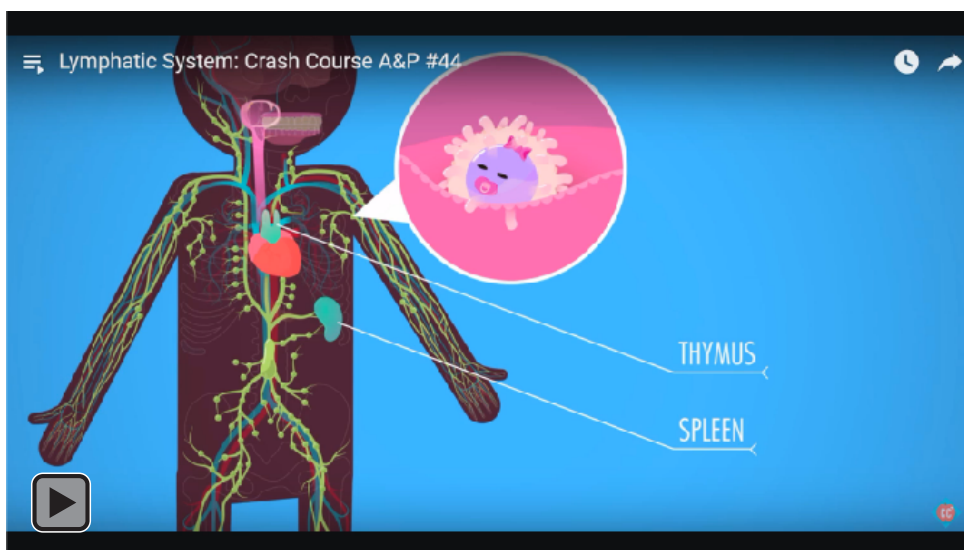
Immunata



Immunata is a mage who represents the robust immune system. She appears after level completion supplying an antibody key to unlock the next level. Immunata helps to support in-game decision-making at any time with on-demand and just-in-time learning (Gee, 2003).

Gameplay

The player's journey begins in the thymus where Immunata will introduce the lymphatic map and player navigation. The player will learn about lymphatic A&P. Attempts to navigate through the lymphatics will reinforce this learning as the lymphatics are unidirectional and the game will mimic this navigation. This embodies Gee's Active, Critical Learning Principle in which situated meaning comes through actively and critically problem-solving the navigational barriers to move forward (Gee, 2003: p.48).



Video 1: The Lymphatic map helps guide players to the lymph nodes where missions occur. The map assists the player to understand the lymphatic A&P through a simplified model of the real thing, crucial for game navigation. This exemplifies Gee's Semiotic Principle affording a visual literacy through the use of images, symbols, diagrams and artifacts (Gee, 2003: p.207).

The overall long-term goal is to save Lymphie Jo by restoring lymphatic flow and resolving the infection. Gameplay requires the player to venture through the lymphatics on a search and find

mission defeating pathogens, advancing to the next level with each defeat. Three missions will be fought in the gut, axilla and brain lymph nodes. Each mission has four levels. The first mission is outlined below.

The player will:

- Navigate through the lymphatic system from the thymus to the gut lymph;
- Collect ammunition and Vities along the way to build Lymphie Jo's resistance to pathogens (resource management);
- Select and fire the right ammunition at the pathogen in each level gaining Health Points (HP) and Experience Points (XP):
 - o Level 1 – defeat Fluvirus;
 - o Level 2 – defeat Strepto;
 - o Level 3 – defeat Baci;
 - o Level 4 – defeat Staphy.
- Collect skills such as massage, dry brushing, and compression for use in following missions.

A player will:

- Gain HP by collecting Vities that build immunity.
- Gain XP by collecting ammunition and skills and defeating pathogens.
- Use Vities to restore health.
- Lose health by failing to defeat pathogens which allows their proliferation. Loss of health will slow the character's movement through the lymph and make their attack on pathogens less effective.

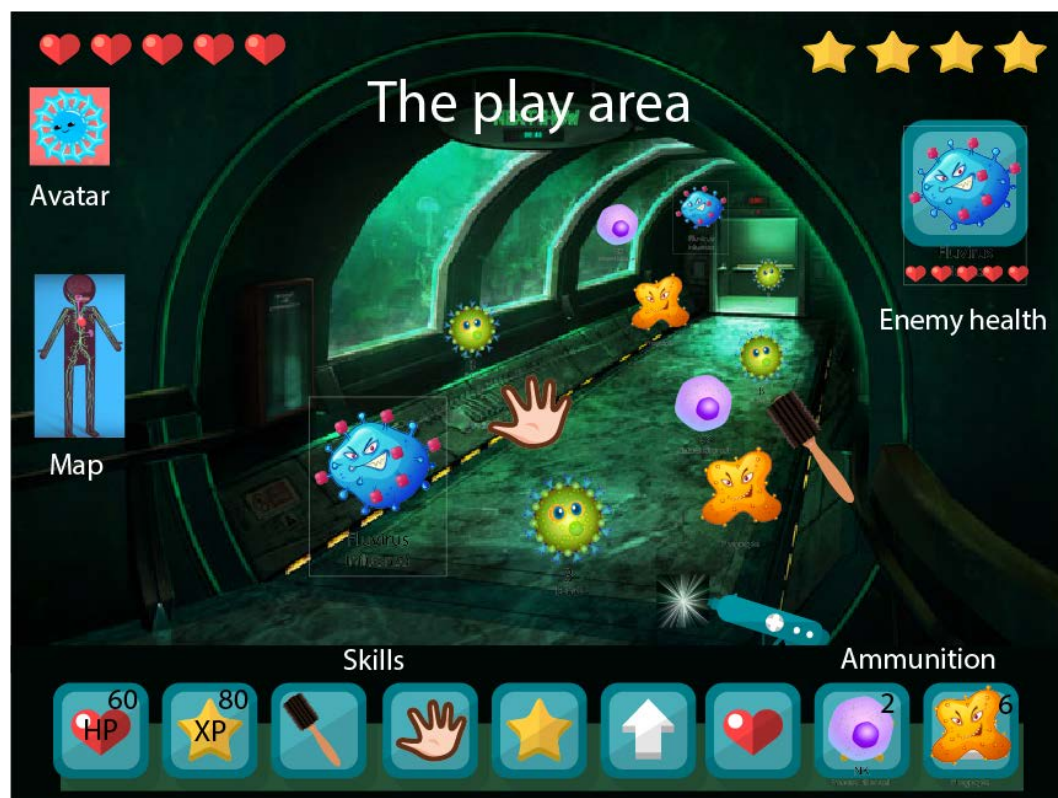
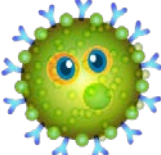
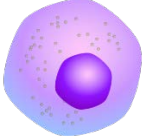


Figure 2: A mock-up of the player area showing resources, skills, map, player HP and XP

Ammunition

 T T-Cell	T-Cells - have the power to multiply then seek out and destroy infected cells. Collect and deploy during play.
 B B-Cell	B-Cells - have the power to clone, morph into plasma cells and produce antibodies that recognise and destroy pathogens. Collect and deploy during play.
 Macrophage	Macrophages - engulf pathogens. Collect and deploy to fight pathogens.
 NK Natural killer cell	NK – Natural Killer cells - collect and use to distinguish infected cells from uninfected cells by deploying an NK to hover over a cell with a magnifier to determine if it is infected or not.
 Plasma cell	Plasma cells – produce antibodies. Collect and deploy to fight pathogens.
 Vities vitamins and nutrients	Vities – collect and deploy fat-soluble vitamins such as Vitamin D to build immunity and maintain health, shown as HP.
 Antibodies	Antibodies – Y-shaped protein produced by plasma cells used to neutralise pathogens. These are the keys that unlock each level after defeating pathogens.

The losing conditions include:

- running out of time during a battle with a pathogen;
- running out of strength (health bar runs down); and
- being overwhelmed by the enemy pathogen or multiple pathogens in harder levels.

Feedback is given via groans from Lymphie Jo when a loss occurs, signalling the discomfort from the infection-related pain. This offers the player the ability to empathise with problems that they can relate to, sharing an identity or way of being with Lymphie Jo (Gee, 2009).

Progression and challenge

Power-ups are rewarded on successful level completion and when collecting items, increasing strength and immunity to pathogens depicted by XP and HP. For example, defeating Fluvirus grants the player a blue antibody key making the player more powerful and resistant to that pathogen in later missions. It is a colour-coded visible armour on the surface of the player's 'avatar', representing immunity to a particular pathogen (Fig 3.). This symbolism personifies Gee's Semiotic Principle (Gee, 2003).

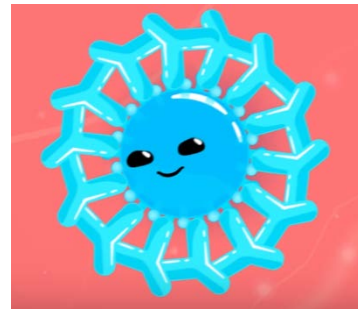


Figure 3: Example of Fluvirus key on player avatar

Increasing game difficulty occurs by making the enemies harder to defeat in each level with pathogens that are more sinister and proliferate faster. Demonstration of Gee's Practice and Ongoing Learning principles occurs through players gaining skills by repeated practice within levels. These principles are further reflected by the challenge of changing conditions with exposure to pathogens that are more resistant, requiring the player to adapt how they use the resources collected (Gee, 2003). To overcome the difficulty, the user will have to play better, use items collected and level-up their character. This reflects Gee's Ongoing Learning Principle where the player's current skill level is challenged with cycles of new learning integrated (Gee, 2003).

Players will unlock the next mission, each progressively more difficult, after completing four levels in the previous mission. This inspires the player to adapt to new conditions and tests their regime of competence (Gee, 2003). Immunata will appear on level completion to award a colour-coded key to unlock the next level.

The player is rewarded with a short animated cut-scene about the lymphatic system including tips for managing infection and improving lymph flow. It will contain a lesson about using the skill collected and a vital clue for solving the next level. McGonigal, (2011) suggests that feedback systems are learned first in a game, helping to achieve the goal and understand the rules generating motivation. This feedback also embodies Gee's Explicit Information On-Demand and Just-in-Time Principle where the learner is given information progressively when it can be best assimilated with prior knowledge gained (Gee, 2003). A player can call on Immunata at any time in the game and re-watch the cut-scenes.

McGonigal, (2011) states that games are defined by the goal, the rules and the feedback system paired with voluntary participation. Levels offer skill acquisition, and learning is promoted through repetition. *Lymphaticus* exemplifies a discovery learning approach including the ideas of

scaffolding and transfer (Becker, 2017) with the advantage of supporting learning through trial and error combined with feedback (Gee, 2009).

The player's final mission occurs in the brain. A mega battle will be fought with pathogens banding together to create a [biofilm](#) that is difficult to penetrate, with enemies harder to defeat than in previous missions. This will require sufficient XP, HP, maximum resources, and acquisition of all available skills to break through the biofilm and defeat the pathogens. Gee's Regime of Competence and Ongoing Learning Principles are reflected in the increasing challenge (Gee, 2003).

Educational game design advantage and constraints

Lymphaticus gives Lymphies an opportunity to explore information that is often technically difficult to comprehend. Voluntary participation affords the player freedom to play of their choosing, providing safe and pleasurable play (McGonigal, 2011). Csikszentmihalyi, (2014) states that 'in flow, a person is fully concentrated on the task at hand' (Csikszentmihalyi, 2014: p24). Motivation and flow happen through repetition and discovery-based learning that includes feedback on progress through progressively challenging missions, skills acquisition and connection to real-life situations, gaining information on-demand and Just-in-time (Gee, 2003; Whitton, 2010; Csikszentmihalyi, 2014). In-game goals align with real-life problems that players want to solve which may build intrinsic motivation to play *Lymphaticus* (Whitton, 2010; McGonigal, 2011).

Situated learning occurs via the central character of Lymphie Jo that the player can identify and create an attachment with, supporting Gee's Identity Principle (Gee, 2003, 2009). Aligning the character to Lymphies allows players to learn about their condition and fulfils the Self Knowledge Principle providing Lymphies new insights into their current and potential skills and knowledge (Gee, 2003). In turn, in-game problem-solving can support the Lymphie to form new strategies for lymphoedema management through their play experiences.

Play typically is voluntary, intrinsically motivating, involves active engagement, and has a fantasy quality (Rieber, 1996: p. 44). *Lymphaticus* meets all of these qualities of play. Fantasy and real life converge in *Lymphaticus* which permits engagement and motivation with the fantasy aspect of the game while relating to the player's actual life issues offering opportunities for knowledge transference for better decision-making about their health in the real world (Gee, 2009; Ellaway, 2016). Game goals align with recommended management goals such as fluid management to improve lymph flow and minimising infection that might encourage transfer and better decision-making in real-life.

Evaluation is achieved through in-game feedback, giving the player information about how close they are to reaching their goal (McGonigal, 2011). The player's completion of the game suggests that a minimum level of knowledge and skill has been attained to achieve the end state. Players receive feedback throughout gameplay via HP and XP acquisition, pathogen responses and Lymphie Jo's auditory responses.

Lymphaticus has no formal way of assessing attainment of player knowledge, nor whether play has improved treatment adherence or adoption of new health behaviours, as a result of gameplay. Implementing a player survey asking players how they have changed their behaviours could be a useful adjunct to assess learning and the game's benefits. Implementation of a pilot study could compare behaviour changes and health outcomes between a sample game-playing group against a control group who only receive standard advice. A pre and post survey could be conducted to analyse the behaviour changes with treatment and evaluate whether playing *Lymphaticus* affords improvement in health outcomes.

The production of this game may require a skilled team to bring this to fruition including a clinical specialist to ensure information is technically correct, and coders, graphic designers and developers to construct the digital game. [Unity](#) is a viable platform suitable to create *Lymphaticus* for mobile devices without a need for professional game creators. Mobile device gameplay offers the freedom to play any time, anywhere. This game could be used by clinicians to start a conversation about treatment concordance in a non-threatening manner. Creation of a multiplayer option with a social platform where Lymphies could share information would help to support the development of an affinity group to support learning (Gee, 2003).

Conclusion

Kato, (2010) outlined research demonstrating that serious games can positively affect health behaviours and outcomes. *Lymphaticus* is a feasible game design closely aligned to accurate lymphatic A&P and the helpful behaviours that health practitioners encourage lymphoedema patients to adopt. The game could be extrapolated to other disease processes such as cancer and the impact of chemotherapy on the lymphatics. *Lymphaticus* could be a useful adjunct in the syllabus for medical, nursing, physiotherapy and massage students.

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