Enhancing Resilience in Medical Students with Virtual Metacognitive Training

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Abstract

This thesis explores virtual instruction in meditation and its impact on resilience on medical students in the United Kingdom. It builds on prior research documenting a worldwide rising trend in burnout in doctors and the protective effect of resilience. The topic is viewed through the lens of cognitive load theory, with metacognitive skills acting to prevent overload.

This research is situated within the post-positivist paradigm, using mixed methods, conducted in three phases. A total of 112 medical students from four medical schools were recruited and surveyed using the Situated Subjective Resilience Questionnaire for Adults [SSRQA] to establish a baseline. In phase two, 26 students underwent an asynchronous month-long training program of virtual instruction in meditation via an online platform. All 26 students who took part in the phase two also took part in phase three, repeating the survey post-training to assess for quantitative change, followed by semi-structured interviews assessing perception of virtual instruction, and evaluating resultant behavioural changes.

At baseline, resilience was shown to be normally distributed in medical students, with no statistical differences between medical schools or year of study. Students found virtual instruction an acceptable format for meditation training. A statistically significant mean improvement of 4.88 point in resilience scores was seen with training ($p<0.001$). Improvement was correlated with lower initial score, number of training sessions, lengths of sessions and total time in training. Training resulted in higher levels of self-belief, adaptability, and emotional regulation, but not support seeking behaviours.

Participants exhibited evidence of metacognitive development leading to higher resilience levels and increased resilience-related behaviours following instruction. This thesis provides a proof by demonstration of a novel, effective technique to deliver enhanced resilience in medical students. Targeting metacognitive skill development poses a fresh avenue towards enhancing resilience.

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Author's declaration

I declare that this thesis has not been submitted in support of an application for another degree at this or any other university. It is the result of my own work and includes nothing that is the outcome of work done in collaboration except where specifically indicated. Many of the ideas in this thesis were the product of discussion with my supervisor Dr Julie-Ann Sime. The word length conforms to the permitted maximum.

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1 Introduction

This thesis explores the topic of resilience in medical students and establishes a method for effective training using virtual instruction, in order to enhance the level of resilience. The aim of increasing the levels of resilience is framed as a route to counter the phenomenon of burnout in medicine. The development of resilience is viewed through the lens of metacognition and cognitive load theory. It is situated in the post-positivist paradigm, with the goal of bridging the insights from both concepts, which have previously been examined separately in multiple disciplines. Theoretical and empirical lessons from the fields of neurosciences, education and behavioural psychology are brought together to provide a cohesive narrative, informing this project from the outset. It is one of the goals of this thesis to reach an operational definition of resilience, enabling a meaningful cross-disciplinary discussion and collaboration, highlighting where effective knowledge transfer can be realised. The empirical research was situated within the United Kingdom, and focuses on undergraduate medical students.

The research presented here is of a mixed methods design, utilising survey questionnaires and semi-structured interviews. In this introductory chapter, I explore the problem of burnout in medicine, the available evidence on resilience, broach the current understanding of resilience, current strategies employed for resilience training within medical education, and why the medical workforce is a distinct population, and finally, the rationale for employing virtual instruction in this context. I then go on to outline the core aspects of the research setting, and finish by outline the structure for the thesis.

Therefore, this thesis examines the distribution of resilience in the medical student population, evaluates the perception of virtual instruction for resilience, and examines the effects and impact of virtual resilience training on medical students.

1.1 Rationale for study

The goal of medical education is the production of physicians capable of meeting the healthcare needs of the wider society at present and in the future (Callahan, 1998; Phillips, 1995; Sklar, Hemmer, & Durning, 2018). This research project is aimed at identifying the theoretical means necessary for the design of an efficient and effective means to train undergraduate medical students for resilience, equipping them with the required skillset to maintain competence, and potentially serve as leaders to advance the frontiers of knowledge. Due to the rapidly evolving pace of medical knowledge, it follows that the lasting benefit of medical school is the range of skills their graduates have, rather than specific information or technical ability. In particular, this study focused on metacognition and its effects on resilience, as part of the Non-Technical Skills [NoTS] family. It is therefore the goal of this study to focus on the NoTS, leaving knowledge and up to date technical procedures to be determined by contemporary experts.

Current strategies in medical education have been observed to have a significant gap between the empirical and theoretical information, and the practices deployed in curricula (Boyd, Whitehead, Thille, Ginsburg, Brydges, & Kuper, 2018; Patel, Yoskowitz, & Arocha, 2008). The outcome of this has been observed in cohorts of practicing physicians who are not equipped with the necessary skills, particularly resilience (Answine, Lu, & Levy, 2019; Averill, Averill, Kelmendi, Abdallah, & Southwick, 2018; Beresin, Milligan, Balon, Coverdale, Louie, & Roberts, 2016; Boyd et al., 2018; Dawes & Sampson, 2003; Epstein & Krasner, 2013; Saint, Christakis, Saha, Elmore, Welsh, Baker, & Koepsell, 2000; Schuers, Griffon, Kerdelhue, Foubert, Mercier, & Darmoni, 2016). It is therefore possible that the medical education system in its current form is not optimal to deliver resilience training for medical students or the wider medical workforce. Future avenues of development are hinted at by insights from the field of neurobiology (Arnsten, Condon, Dettmer, Gee, Lee, Mayes, Stover, & Tseng, 2021; Cathomas, Murrough, Nestler, Han, & Russo, 2019; Friedlander, Andrews, Armstrong, Aschenbrenner, Kass, Ogden, Schwartzstein, & Viggiano, 2011; Murrough & Russo, 2019; Nestler & Waxman, 2020), helping design modes of teaching that play to innate abilities of the learners.

The number of physicians reportedly suffering from burnout, a phenomenon where the individual appears overwhelmed by tasks usually within their competence, has been increasing internationally (Al-Dubai & Rampal, 2010; Arnsten & Shanafelt, 2021; Lee, Medford, & Halim, 2015). Burnout represents a large burden for the medical profession, from undergraduate training to the postgraduate world (Arora, Asha, Chinnappa, & Diwan, 2013;

Cruz, Pole, & Thomas, 2007; Dyrbye & Shanafelt, 2016; Ishak, Nikravesh, Lederer, Perry, Ogunyemi, & Bernstein, 2013; Johns & Ossoff, 2005). Dewa, Loong, Bonato, Thanh and Jacobs (2014) found that burnout negatively impacts physician productivity, although the exact effect remains difficult to quantify. By extension, a physician suffering from burnout is likely to have ramifications for the wider team of colleagues (Ochoa, 2018). Evidence suggests that, independent of the level of experience, the extent of the relationship between burnout and work extends beyond total capacity and directly affects patient safety (Dewa, Loong, Bonato, & Trojanowski, 2017a; Dewa, Loong, Bonato, Trojanowski, & Rea, 2017b; Kassam, Cortez, Winer, Conzen, El-Hinnawi, Jones, Matsuoka, Watkins, Collins, Bhati, Selzner, Sonnenday, Englesbe, Diwan, Dick, & Quillin Iii, 2021; Kwan, Chan, Cheng, Leung, & Lau, 2021; Lu, Dresden, McCloskey, Branzetti, & Gisondi, 2015; Mangory, Ali, Rø, & Tyssen, 2021). The widespread impact on burnout on both the providers and recipients of healthcare is therefore a critical aspect of clinical practice.

In a recent review, Rotenstein, Ramos, Torre, Segal, Peluso, Guille, Sen and Mata (2016) observed that rates of burnout, depression and suicide within medical students and doctors are significantly above population averages, coupled with an alarmingly low rate of seeking treatment, with these findings corroborated by further research (Harvey, Epstein, Glozier, Petrie, Strudwick, Gayed, Dean, & Henderson, 2021; Irigoyen-Otiñano, Castro-Herranz, Romero-Agüit, Mingote-Adán, Garrote-Díaz, Matas-Aguilera, López-Ordoño, Puigdevall-Ruestes, Alberich, & González-Pinto, 2022; Leonardo, 2022; Muhamad Ramzi, Deady, Petrie, Crawford, & Harvey, 2021). Contemporary research has formed a link with a postulated chain of causation between burnout, resilience and physician suicide (Hoffman & Bonney, 2018; Imo, 2017; Nissen & Feller, 2019; Ventriglio, Watson, & Bhugra, 2020). A medical career across all specialties is both physically and emotionally demanding, often inducing prolonged periods of stress (Harvey et al., 2021; Navinés, Olivé, Fonseca, & Martín-Santos, 2021; Omprakash, Kumar, Kuppusamy, Sathiyasekaran, Ravinder, & Ramaswamy, 2021; Persaud, 2004, 2005). The current evidence suggests that the levels of stress experienced by physicians across all clinical environments is rising exponentially and represents a substantial threat to the medical workforce (Balendran, Bath, Awopetu, & Kreckler, 2021; Costa-Drolon, Verneuil, Manolios, Revah-Levy, & Sibeoni, 2020; Mahmoud, Honarmand, Yarnell, Young-Ritchie, Maunder, Priestap, Abdalla, Ball, Basmaji, Bell, Jeffs, Shah, Chen, LeBlanc, Kayitesi, Eta-Ndu, & Mehta, 2022; Ofri, 2013; Wilberforce, Wilberforce, & Aubrey-Bassler, 2010). From this perspective, it is important to consider enhanced resilience training of doctors as a vital direction for research.

Factors affecting the phenomenon of physician burnout have been considered in literature, with reported risk factors being younger age, longer working hours with high workload, low job satisfaction, negative or poor personal relationships and interpersonal demands, job insecurity and female gender, as well as a weak association with specialty (Afonso, Cadwell, Staffa, Zurakowski, & Vinson, 2021; Amoafo, Hanbali, Patel, & Singh, 2015; Azam, Khan, & Alam, 2017; Sharifi, Fallahi-Khoshknab, Mohammadi, Zeraati, Jamshidi, Aghabeygi-Arani, Mirzaei, Fallahi-Khoshknab, & Rasooli, 2022; Vicentic, Gasic, Milovanovic, Tosevski, Nenadovic, Damjanovic, Kostic, & Jovanovic, 2013). These findings place physicians in common with other healthcare professions (Gillespie & Melby, 2003; Kalliath & Morris, 2002; Khamisa, Peltzer, & Oldenburg, 2013). However, healthcare professions as a collected group stand apart as particularly prone to burnout (Dyrbye & Shanafelt, 2016; Tremolada, Schiavo, Tison, Sormano, De Silvestro, Marson, & Pierelli, 2015). The implication of this is to imply that risk factors are shared within the healthcare professions. This may also imply that risk reduction and prevention strategies can be applied across the spectrum. Prior to considering prevention, it is invaluable to evaluate the stressors associated with healthcare that serve to predispose these professions to burnout.

An increasing body of evidence suggests that the emotional burden of working in healthcare is directly linked to the higher risk of burnout compared to the general population (Arnsten & Shanafelt, 2021; Bartram, Casimir, Djurkovic, Leggat, & Stanton, 2012; Kovács, Kovács, & Hegedűs, 2009; West, Dyrbye, Satele, Sloan, & Shanafelt, 2012). This is further supported by comparative studies that have connected the level of psychological stress and related emotional load to burnout, demonstrating a direct correlation between them (Afonso et al., 2021; Chuang, Tseng, Lin, Lin, & Chen, 2016; Garcia, Garcia, Molon, Piva, Tasker, Branco, & Ferreira, 2014; Harvey et al., 2021; Omprakash et al., 2021). The link between burnout and depression has been widely debated in literature, with consensus being difficult to attain (Bianchi, Schonfeld, & Verkuilen, 2020; Meier & Kim, 2022; Parker & Tavella, 2021, 2022). Nevertheless, while the symptom cluster of depression and burnout tend to overlap, sometimes significantly, distinction between the two is possible (Bianchi, Schonfeld, & Laurent, 2014; Bianchi, Verkuilen, Schonfeld, Hakanen, Jansson-Fröjmark, Manzano-García, Laurent, & Meier, 2021; Hills, Montero-Marin, Zubiaga, Cereceda, Piva Demarzo, Trenc, & Garcia-Campayo, 2016;

Reime & Steiner, 2001; Thalhammer & Paulitsch, 2014; van Wouwe, Wurm, Vogel, Holl, Ebner, Bayer, Mörkl, Szilagyi, Hotter, Kapfhammer, & Hofmann, 2016). It is apparent from the evidence that although depression and burnout are connected, they may coexist in a single individual. However, establishing the distinction between them in the future may prove invaluable to direct care and support as required.

Recently, evidence for burnout as a distinct clinical entity has emerged from neuroscience. It has been demonstrated that individuals suffering from burnout exhibited diminished neurophysiological responses to stimuli compared to control subjects (Golonka, Mojsa-Kaja, Popiel, Marek, & Gawlowska, 2017). Further studies examining the evoked responses to stimuli across sensory modalities have indicated intact pathways at the sensory level, although a comparative deficit exists at the point of directing attention (Bianchi & Laurent, 2014; Sokka, Huotilainen, Leinikka, Korpela, Henelius, Alain, Müller, & Pakarinen, 2014). However, the deficit is situated at the level of performance at tasks, and did not appear to be focused on a particular cognitive process (Golonka, Mojsa-Kaja, Gawlowska, & Popiel, 2017). It is therefore possible to extrapolate that the core symptomology of burnout does not lie in memory subtypes, from sensory memory through working memory and long-term memory. Rather, the functional deficit is situated at the nexus of metacognition.

1.2 Burnout in medicine

Burnout, defined as a phenomenon where the individual is overwhelmed by tasks usually within their competence, has been increasing internationally, suggesting that the underlying cause is not isolated to a specific healthcare system or training structure, but may be related to the practice of medicine itself (Al-Dubai & Rampal, 2010; Lee et al., 2015). A career in medicine exposes physicians to high levels of demand and stresses, which has been linked to increased levels of physician burnout (Eckleberry-Hunt, Lick, Boura, Hunt, Balasubramaniam, Mulhem, & Fisher, 2009; Riley, 2004; van den Hombergh, Künzi, Elwyn, van Doremalen, Akkermans, Grol, & Wensing, 2009). The impact of burnout is seen in its effects, with reduction of individual physician's productivity, and is likely to carry ramifications for the function of the wider team, however, it remains difficult to quantify the magnitude of the effects directly (Dewa et al., 2014; Ochoa, 2018). Additionally, several studies demonstrated that when physicians suffer from burnout, there is a direct effect on patient safety (Dewa et al., 2017a; Dewa et al., 2017b; Lu et al., 2015) The widespread impact of burnout on both the providers and recipients of healthcare is, therefore, critical for healthcare in general.

Cultivating resilience in the medical workforce has been hypothesised as a potential route to protect against burnout (Dunn, Iglewicz, & Moutier, 2008; McKinley, McCain, Convie, Clarke, Dempster, Campbell, & Kirk, 2020; West, Dyrbye, Sinsky, Trockel, Tutty, Nedelec, Carlasare, & Shanafelt, 2020).

The increase in physician burnout has been attributed to administrative loads, as well as workloads in general, combined with a changing view of doctors in society, resulting in a working environment with high level of demands combined with low levels of influence, suggesting a correlation between burnout and individual autonomy (Neufeld & Malin, 2019; Nmadu, Omole, Oyefabi, Usman, Igboanusi, Gobir, & Sambo, 2019; Wainwright, Looseley, Mouton, O'Connor, Taylor, & Cook, 2019). While understanding this basis for burnout syndrome potentially allows for restructuring and remodelling of physicians' working environment, it is unlikely that medical careers will become a low demand environment. Given that burnout will remain an occupational hazard for doctors into the foreseeable future, it is imperative that doctors are equipped with the skills to manage these demands, as well as recognise and protect themselves when the demands exceed their personal capacity. This is likely to benefit the doctors and their patients (Iserson, 2018; West, Dyrbye, & Shanafelt, 2018).

1.3 The concept of resilience

The concept of 'resilience' originated within the field of engineering, and was used to characterise the capacity to withstand stressors while maintaining internal integrity and functionality (Carlson, Haffenden, Bassett, Buehring, Collins III, Folga, Petit, Phillips, Verner, & Whitfield, 2012). This has been translated to human behaviour, and the response to experienced stressors (Aburn, Gott, & Hoare, 2016; Carlson et al., 2012; Yates & Masten, 2004). However, despite a large body of empirical research into the resilience of individuals, the definition of resilience has remained elusive (Aburn et al., 2016; Blaney, Wilde, & Hill, 2020), with the most common themes being overcoming adverse situations, adapting to adversity and positive adjustment to circumstances. Despite the imprecise definitions currently available, it is reasonable to deploy resilience as a possible route to respond to the problem of burnout (Di Giuseppe, Nepa, Prout, Albertini, Marcelli, Orrù, & Conversano, 2021; Kawai & McFarland, 2022). In this thesis, the starting point for defining resilience will be the individual's ability to adapt to, and to withstand, stresses. This definition aligns with the existing medical education literature (Asnani, Tempski, Santos, Mayer, Enns, Perotta, Paro, Gannam, Peleias, Garcia, Baldassin, Guimaraes, Silva, da Cruz, Tofoli, Silveira, & Martins, 2015; Dunn et al., 2008; Houpy, Lee, Woodruff, & Pincavage, 2017; Howe, Smajdor, & Stöckl, 2012), allowing for ease of integration into the body of knowledge. This definition, as well as the alternative definitions for resilience, their theoretical underpinnings and implications are explored in chapter 2, underpinning the choice highlighted as the most pertinent to the context of medical education.

Beginning from the premise that burnout affects physicians across a range of healthcare settings, and may be a consequence of a core, and potentially immutable, component of medical practice, the primary goal of this thesis is to develop and test a training program for enhancing an individual's resilience, postulating that it acts as a protective factor. The underlying assumption of this project is that enhancing the resilience of physicians through developing their metacognitive skills will result in physicians possessing a greater capacity to withstand the demands of a medical career. This is borne out of literature demonstrating that a higher level of resilience correlates with reduced levels of burnout across multiple medical specialties, including surgery, anaesthesia, internal medicine, and psychiatry (Bohman, Dyrbye, Sinsky, Linzer, Olson, Babbott, & Trockel, 2017; Lebares, Guvva, Ascher, O'Sullivan, Harris, & Epel, 2018a; McCain, McKinley, Dempster, Campbell, & Kirk, 2018; Olson, Kemper, & Mahan, 2015; Wong & Olusanya, 2017). The relationship between high levels of resilience and lower burnout rates in medicine has been repeatedly discussed in the literature, with several studies demonstrating the correlation (Arrogante & Aparicio-Zaldivar, 2017; Dunn et al., 2008; Sands, Stanley, & Charon, 2008; Strümpfer, 2003; Taku, 2014). However, research into reliable strategies to build resilience has thus far not been as developed (Scheepers, Emke, Epstein, & Lombarts, 2019).

A key question regarding resilience is its distribution in populations. There are two competing theories of resilience discussed in the literature. The first postulates that it is an attribute which follows a binomial distribution in the population, with each specific individual either being resilient or not (Dunn et al., 2008; Dyrbye, Shanafelt, Werner, Sood, Satele, & Wolanskyj, 2017; Webb, Joseph, Yardley, & Michie, 2010). The second views resilience as a trait that is distributed within a population, an attribute which an individual can have more or less of, rather than be in possession of it or lacking it (Fletcher & Sarkar, 2013; Grafton, Gillespie, & Henderson, 2010; Howe et al., 2012). From an educational perspective, the validity of each conceptual understanding would require different training requirements and instructional approaches. Developing an existing ability poses a different educational challenge to implanting one.

However, these opposing conceptual views of resilience are further underpinned by different core beliefs. If resilience is binomially distributed, then we are led to the conclusion that there is a specific threshold that once reached, it becomes inevitable that the individual affected will be overwhelmed (Bonanno, 2004; Klohnen, 1996). However, if we take the view that there is a resilience gradient, we can deduce that while individuals may still be overwhelmed, this occurs at variable rate. Resilience therefore may be viewed as an adaptable response to stresses that is gradually overwhelmed (Cicchetti, 2010; Lutha & Cicchetti, 2000; Rutter, 2006). Individuals may then be expected to exhibit signs and symptoms of approaching their resilience capacity, which opens a window for intervention. Furthermore, if resilience is indeed present on a gradient and forms an adaptive response there is the possibility to develop it across all individuals in the population, rather than aiming to induce its inception in those who lack it.

A further complication when considering resilience in the medical workforce is the impact of the selection processes involved in recruitment into medical schools. In the United Kingdom, in common with other countries, entry into medical school is highly competitive, involving a combination of dedicated entrance examinations, interviews, and standardised educational attainment thresholds, with a heavy emphasis on prior academic success as a predictor of success in the medical degree (Conrad, Addams, & Young, 2016; Greatrix & Dowell, 2020; Rubright, Jodoin, & Barone, 2019). This has been augmented with attempts to evaluate personal suitability for a medical career, through the inclusion of situational judgement tests and interviews (Husbands, Rodgerson, Dowell, & Patterson, 2015; Kreiter, Yin, Solow, & Brennan, 2004). This is mirrored in medical school entrance across different countries (Coates, 2008; Ezeala, Ezeala, Shaikh, Akapelwa, Phiri, Kamvuma, Mulemena, Mushabati, Chanda, & Sijumbila, 2020; Knorr, Schwibbe, Ehrhardt, Lackamp, Zimmermann, & Hampe, 2018; Patterson, Roberts, Hanson, Hampe, Eva, Ponnamperuma, Magzoub, Tekian, & Cleland, 2018; Peskun, Detsky, & Shandling, 2007). Therefore, medical students and physicians can be regarded as a distinct group. The attributes of resilience in the general population cannot be assumed to apply to medical workforce, and direct evaluation of the distribution of resilience in this population is required. This is the basis of the first research question addressed.

1.4 Approaches to resilience training

Several strategies have thus far been employed to enhance levels of resilience across multiple domains, which can be grouped into the following categories: self-encouragement (Hamilton, Scott, & MacDougall, 2007; Malpass, Binnie, & Robson, 2019; Wright & Richmond-Mynett, 2019), cognitive reorganisation and challenging negative thought patterns in a manner along the lines of cognitive behaviour therapy (Dhiman, 2020; Thomason & Pond, 1995), compartmentalisation and goal setting (Lester, Stein, Saltzman, Woodward, MacDermid, Milburn, Mogil, & Beardslee, 2013) and relaxation and meditation training (Hwang, Lee, Lim, Bae, Kwak, Park, & Kwon, 2017; Rogers, 2013; Williams, 2020). Forbes and Fikretoglu (2018) considered these approaches to developing resilience, as well as their theoretical basis, which ranged from cognitive behavioural therapy, to self-encouragement and mindfulness theory, the latter aiming to enhance the metacognitive capacity of individuals.

Cognitive behavioural therapy is focused on changing the approach to negative situations, and aiming to encourage the subject to adopt a more positive viewpoint (Fenn & Byrne, 2013; Granath, Ingvarsson, von Thiele, & Lundberg, 2006). It logically follows that this is a more appropriate strategy when confronting a longstanding and consistent challenge. This has been translated into real-world evidence, where cognitive behavioural therapy has been demonstrated to benefit those facing a chronic, long-term disablement (Cuijpers, Berking, Andersson, Quigley, Kleiboer, & Dobson, 2013; Harris, Loveman, Clegg, Easton, & Berry, 2015; Martinez-Devesa, Waddell, Perera, & Theodoulou, 2007). Therefore, it is clear that this is not applicable to medical practice, which exposes the physician to multiple and varied stressors.

The self-encouragement approach has been primarily pioneered in athletics and sports (Hamilton et al., 2007; Hatzigeorgiadis, Zourbanos, Galanis, & Theodorakis, 2011). It has been shown to have powerful effects on performance in the tasks targeted, but the effects on overall resilience have not been demonstrated (Alizadeh, Nasirifard, & Karami, 2010; Safariniya & Mehmannavazan, 2015). As it is a task-oriented approach, rather than aiming to improve resilience as a whole, it is not an ideal approach for the context of medical education, which calls for resilience to a range of situational stressors. In contrast to self-encouragement, as described above, goal setting strategies aim to target more generic milestones rather than single tasks (Corcoran & Nichols-Casebolt, 2004; Grant, Curtayne, & Burton, 2009). It has been demonstrated as a route to enhance achievement at a broader level, but again does not appear to enhance resilience itself (Burns, Martin, & Collie, 2019; Fredrix, McSharry, Flannery, Dinneen, & Byrne, 2018; Locke & Latham, 2019). Therefore, it does not offer a useful approach in medical education for similar reasons.

The final approach is through mindfulness theory. In contrast to the previous approaches to resilience training, mindfulness aims at enhancing resilience itself, and does not focus on specific goals or targets (Brown, Creswell, & Ryan, 2015; Irving, Park-Saltzman, Fitzpatrick, Dobkin, Chen, & Hutchinson, 2014; Schonert-Reichl & Roeser, 2016). The underlying basis for this approach is that by enhancing resilience of the individual, they are capable of coping with a range or situations, including ones that may not be apparent. This generic approach broadens the reach of this strategy, and increases its reach to more settings. In recent literature, training with meditation and metacognitive-focused programs has been shown to have a positive effect on individual resilience (Joyce, Shand, Bryant, Lal, & Harvey, 2018a; Joyce, Shand, Tighe, Laurent, Bryant, & Harvey, 2018b; Krogh, Medeiros, Bitran, & Langer, 2019 ; Lebares, Hershberger, Guvva, Desai, Mitchell, Shen, Reilly, Delucchi, O'Sullivan, Ascher, & Harris, 2018b; Smith, Shatté, Perlman, Siers, & Lynch, 2018). It is therefore more appropriate to medical education, and it is the approach adopted in this project.

1.4.1 Resilience training in medical schools

It has been recognised in UK medical education that resilience training is an essential component of medical training, with the national regulator, the General Medical Council [GMC], Royal College of Physicians [RCP], Royal College of Surgeons [RCS], Royal College of Obstetricians and Gynaecologists [RCOG] explicitly emphasising resilience training (GMC, 2020; RCOG, 2020; RCP, 2017; RCS, 2015). This has been absorbed by medical schools, with a range of resilience programs incorporated in the curriculum.

The strategies for resilience training range from direct and dedicated training, to integrated training. In their case study examining an integrated, indirect training approach deployed at a UK medical school, Wright and Richmond-Mynett (2019), suggested that reliance on this approach is insufficient, and recommended the inclusion of mindfulness-based training as well. Direct training can be divided into scenario- and case-based approaches, using challenging situations within a safe-space (Howe et al., 2012; Malek, 2000; Oliver, 2017) and the use of mindfulness-based training. Although mindfulness-based resilience training has been advocated by the GMC (GMC, 2014), UK medical education has had a relative paucity of established mindfulness training programs compared to the USA, Canada and Australia (Dobkin & Hutchinson, 2013; Hassed, De Lisle, Sullivan, & Pier, 2009; Malpass et al., 2019).

The experiences of implementing mindfulness-based meditation programs in medical schools have highlighted numerous challenges. These have centred on the high demand for intensive involvement for the instructors, a time-intensive requirement to develop an individual's mindfulness skills to an adequate level, and the variability in each individual's learning curve during the training process (Dobkin & Hutchinson, 2013; Greeson, Toohey, & Pearce, 2015; Moir, Henning, Hassed, Moyes, & Elley, 2016). The combination of these challenges leads to a lack of capacity to deliver training at the scale required for medical students and practicing doctors, the limited ability for the medical students and doctors to take part due to scheduling conflicts and in cases when these are overcome, the rigidity of a mass training program enforces a pre-determined pace of progress. In this thesis, a student-led approach was utilised, allowing greater flexibility to schedule sessions on an individual basis.

1.4.2 Virtual training

When considering the challenges highlighted above, the desired criteria for resilience training can be distilled. An ideal training program would need to be accessible to the breadth of specialties and grades in medicine, broadening access as to encompass the entirety of the medical workforce. It also needs to be adaptable enough to accommodate the varied schedules that form a range of medical practice, with the associated irregular hours. A potential option for this is through the use of virtual training, delivered via a web-based platform. The advantages afforded by this platform would be that the provision of training is adaptable and flexible, offering each individual the opportunity to configure their training to their own schedule, optimised for their unique circumstances. Additionally, the use of a web-based platform has the potential to provide a greater degree of access to a larger subset of medical professionals, without increasing the cost of replication, delivering economies of scale not available in traditional face-to-face teaching strategies. The scalability of such a training medium could allow for training that extends from undergraduate medical students to the medical workforce as a whole. Developing an effective web-based program that improves the resilience of medical students and doctors can deliver the training capacity required to address the increasing problem of burnout. This novel approach would allow the gaps in the current training programs to be filled without necessarily demanding time from the busy and full medical school schedule.

In the sections above I have illustrated that the problem of burnout is widespread within the medical workforce. The approach advocated in this thesis is that mindfulness-based training can develop metacognitive skills, which can lead to enhanced levels of resilience, and thus ameliorate the spread of burnout. The desired criteria would include a high degree of flexibility for the learner, the ability to scale the program to be as inclusive as possible, and to allow each learner to proceed at their own pace with limited live instructional input. The last point is particularly important given the size of the eventual target population. For these reasons, virtual instruction, delivered via a dedicated online portal was an appropriate choice for the delivery of the training. It could be accessed asynchronously by each study participant with complete autonomy, does not come with an upper limit of participants, and could include multiple resources for each participant available prior to needing direct instructor intervention.

Rather than attempt to simply replicate the programs deployed in the offline setting using virtual instruction, it is important to consider other potential advantages that virtual instruction may offer, such as the potential for greater learner autonomy. As a working definition, learner autonomy is the capacity for each learner to schedule the time and length of each session, as well as the frequency of sessions. As greater autonomy is associated with reduced stresses and burnout, it is fitting that a program aiming to enhance resilience and reduce burnout would incorporate this into its design (Nmadu et al., 2019; Wainwright et al., 2019). This follows the principle that constructing a training program that is of a bespoke design for the means of delivery will allow for optimal outcomes (Crews, Wilkinson, & Neill, 2015; McGee & Kanter, 2011). This affords the opportunity to develop a program that intentionally capitalises on the strengths of the technology, while also acknowledging the inherent weaknesses (Olson, 2013). This may be contrasted with the difficulties in transitioning existing programs from the real-world to virtual environments, which often results in difficulties around legacy aspects that can hinder learning and worsen the experience of the learner (McDonald, Harwood, Butler, Schlumpf, Eschmann, & Drago, 2017). The research questions therefore explored the impact of learner autonomy on the training and development of each student.

1.5 Research questions

The impact of burnout on the medical workforce, and its trickle down negative effect on the health of patients has been highlighted. It has also been suggested that developing resilience via mindfulness-based metacognitive training in the medical workforce can act as a protective mechanism against burnout. However, there remain questions regarding the distribution of resilience in the medical workforce and the subsequent implications for training, the subjective and objective functionality of virtual instruction within this context, and finally the impact of the training on resilience both quantitatively and qualitatively.

While current practice in medical education has adopted mindfulness-based meditation for resilience training, this has raised ongoing challenges in implementing and disseminating this training. In contrast to existing training programs, which rely on face-to-face training, the emphasis of this project was on the use of virtual instruction alone, without any face-to-face contact with the participants in order to evaluate it in isolation, and evaluating the subjective experiences of individuals as they undergo the training program. Additionally, the four domains of resilience behaviour, namely self-belief, adaptability, emotional regulation, and support-seeking behaviour are examined (Alonso-Tapia, Garrido-Hernansaiz, Rodríguez-Rey, Ruiz Díaz, & Nieto, 2018; Collins, 2007; Glantz & Johnson, 2006; Kleiman, Chiara, Liu, Jager-Hyman, Choi, & Alloy, 2015; Rook, Smith, Johnstone, Rossato, López Sánchez, Díaz Suárez, & Roberts, 2018). In the process of this research the following questions are asked:

RQ1: What is the distribution of resilience in medical students?

RQ2: How acceptable and feasible is virtual instruction for meditation training to medical students?

RQ3: How effective is virtual meditation training on medical students of different resilience levels?

RQ4: What factors affect the change in resilience level with meditation training?

RQ5: How do medical students perceive the impact of meditation training on resilience-associated behaviours?

In considering these questions, the results are interpreted through the lens of cognitive load theory. The reasons for employing cognitive load theory as the theoretical framework stems from the hypothesis that burnout represent a state of cognitive overload, where an individual is overwhelmed by the tasks required, and is unable to function effectively. This is explored in further detail in the subsequent dedicated chapter.

1.6 Structure of the thesis

In order to serve as a guide for the thesis, and facilitate reading of the remaining chapters, a brief outline is presented here. Chapter two reviews the range of literature influencing this project and the debate on the topic, encompassing resilience, metacognition, curriculum development, and considers the evidence on virtual instruction and simulation training, evaluating physician burnout and the requirements for resilience training and finally reflects on the lessons learnt from other professions, deliberating on their translation to medical education. The literature review chapter also includes the operational definitions for metacognition, burnout and resilience. The identification of the gap in the literature serves as the foundational platform for the research questions. Chapter three explores the theoretical framework, and the role cognitive load theory played as a theoretical lens. Chapter four sets out the ontological and epistemological stances for the thesis, identifies the methodological approach, as well as the methods used to collect and analyse data.

The remainder of the thesis is concerned with the analysis and interpretation of the findings, and situating them into the wider context of medical education. Chapter five presents the quantitative and qualitative results, with the identified critical components for effective and efficient virtual instruction for resilience training. In chapter six, these findings are discussed in further detail, with exploration of the general lessons for the incorporation of simulation training in medical education explored. Finally, chapter seven provides an executive summary of the research highlighting both the original contributions, the strengths and the limitations inherent in the project, as well as the implications for medical education, and avenues for future research programs are suggested.

2 Literature Review

This research aims to provide a template for resilience training in medical education, delivered via virtual instruction, and establishing the nature of resilience, as well as reaching an operational definition of resilience. In this chapter I have divided the literature review into five sections. I therefore begin with examining the topics of resilience and metacognition, and delving into the debate on the nature of resilience, with the goal of reaching an operational definition for both concepts. Next, I consider different aspects of the process of curriculum design in medical education and how this has been affected by technological developments including simulation and virtual instruction, reflecting on how this can be applied in the context of resilience training. I have also surveyed the literature from other professions, drawing out the lessons for medical education. The gap in the literature is subsequently defined and articulated, highlighting the need to address the research questions stated in the previous chapter.

2.1 Resilience

The concept of personal resilience has been debated in the literature (Cannon, Ferreira, Buttell, & O'Connor, 2022; Capobianco, 2017; Fink-Samnick, 2009; Fletcher & Sarkar, 2013; Jackson, Firtko, & Edenborough, 2007; Pooley & Cohen, 2010; Vercio, Loo, Green, Kim, & Beck Dallaghan, 2021; Zautra, Hall, & Murray, 2010). As this is the cornerstone of the thesis, it is appropriate to begin by exploring the existing understanding of individual resilience as a concept. This section of the literature review explores the concept and reaches for an operational definition for resilience, examine the evidence of increased levels of resilience as a protective factor against burnout, and the methods developed for evaluating these levels of resilience. I then conclude by summarising the implications for this research.

2.1.1 Defining resilience

The definition of resilience is subject to several contested points, the first revolves around the level of adversity required to enable resilience to manifest. Luthar and Cicchetti (2001) suggested that within the confines of this concept, negative experiences are limited to those that have demonstrable associations, with difficulties in adjustment, with each situation being an isolated event. However, Davis, Luecken and Lemery-Chalfant (2009) and Jackson et al. (2007) rejected this narrow definition, instead taking the stance that adversity and response are an individual experience, and that separate stresses may have a cumulative impact, rather than being considered in isolation. This is supported by Neff and Broady (2011), who extended the definition of adversity to include potentially positive events that may ostensibly add to the cumulative load experienced. By implication, it is the total sum of experience of cognitive load that is of greatest consequence.

The second issue is the reactionary nature of the concept of resilience in implementing a positive adaptation. Luthar (2015) suggested that assessment of the efficacy and adequacy of the response needs to be context-specific, with the most sensitive assessments carried out by those closest to the events. This allows for comprehensive evaluation of the prior social and cultural background to be integrated into both the response and its evaluation (Clauss-Ehlers, 2008; Ungar & Liebenberg, 2011).

For the purpose of this thesis, I employ an inclusive definition of resilience, without a threshold on the level of adversity. This avoids the artificial imposition of an arbitrary level that would otherwise limit the study, without adding value. I also align with the view that the most sensitive measure of the response will lie with the individual, and therefore, adding weight to using an inclusive definition. This combination enables the capture and measure of resilience as close as possible to the individual level. The definition of resilience employed is the positive capacity to withstand stresses of any level, while maintaining an acceptable level of performance and function.

2.1.2 Skill or trait

Before a deeper exploration of resilience is embarked on, it is important to differentiate whether it is a skill, amenable to development and improvement, or an innate personality trait, which is determined by each individual's make up, and would therefore not be responsive to training (Leys, Arnal, Wollast, Rolin, Kotsou, & Fossion, 2020; Métais, Burel, Gillham, Tarquinio, & Martin-Krumm, 2022). The distinction between traits, such as eye colour, and skills such as learning foreign languages, lies at the core of this research, with resilience being assumed to be a skill.

When considering the possibility of resilience being an innate personality trait, there has been research that positively correlated it with other personality traits, such as experience, conscientiousness, and extraversion (Friborg, Barlaug, Martinussen, Rosenvinge, & Hjemdal, 2005; Riolli, Savicki, & Cepani, 2002), as well as negative correlation with neuroticism (Davey, Eaker, & Walters, 2016). Furthermore, Silk, Vanderbilt-Adriance, Shaw, Forbes, Whalen, Ryan and Dahl (2007) postulated that resilience is forged during early life, and then stabilises over the course of a lifetime; however, it is worth noting that no longitudinal empirical evidence is available to support this presumption. A meta-analysis of available research again reiterated the correlation with personality traits (Oshio, Taku, Hirano, & Saeed, 2018).

Although there is correlation with personality traits as indicated above, there has been other research indicating that resilience is a dynamic and adaptive process, which can be improved upon with directed training (Fossion, Leys, Kempenaers, Braun, Verbanck, & Linkowski, 2014; Luthar, Cicchetti, & Becker, 2003; Nilsen, Hilland, Kogstad, Heir, Hauff, Lien, & Endestad, 2016). The potential to improve resilience with training is highly suggestive of resilience being a skill.

I believe that while resilience may have innate characteristics, acting as a baseline level, there is evidence to suggest that the improvement is likely. This is analogous to sports skills, where an innate ability can be honed and vastly improved through dedicated training. As the route to improving resilience pursued here is through metacognitive training, it is also inferred that metacognition is a skill as well. The definition of metacognition is discussed in section 2.2.

2.1.3 Measuring resilience

There have been several tools developed, aiming to directly measure resilience (Ahern, Kiehl, Lou Sole, & Byers, 2006; Hoffman & Hancock, 2017; Platt, Brown, & Hughes, 2016). I examine the main available validated measures, and assess their advantages and disadvantages. I focus of the Connor-Davidson Resilience Scale [CD-RISC], Resilience Scale for Adults (RSA), Resilience scale & Brief Resilience Scale [BRS], Academic Resilience Scale [ARS-30], and the Situated Subjective Resilience Questionnaire for Adults [SSRQA] in turn.

The CD-RISC is a self-reported questionnaire developed by Connor and Davidson (2003). Since its inception, this scale has been widely deployed in multiple research projects. However, it was primarily developed to evaluate resilience levels in patients with post-traumatic stress disorder [PTSD]. While it has been validated in this population across cultures (Lee, Blackmon, Cochran, Kar, Rehner, & Gunnell, 2018; Pulido-Martos, Fernández-Sánchez, & Lopez-Zafra, 2019; Robinson, Larson, & Cahill, 2014; Yu & Zhang, 2007), research suggests that when applied to non-PTSD patients, the scale is not reliable (Arias González, Crespo Sierra, Arias Martínez, Martínez-Molina, & Ponce, 2015).

The RSA is another self-reported questionnaire, developed at the same time as CD-RISC (Friborg, Hjemdal, Rosenvinge, & Martinussen, 2003). Similarly, it has also received widespread use in research examining resilience (Dong, Ablah, Nelson, Shah, & Khan, 2013; Gonzalez, Moore, Newton, & Galli, 2016; Karaırmak, 2010; Khoshouei, 2009; Velickovic, Rahm Hallberg, Axelsson, Borrebaeck, Rydén, Johnsson, & Månsson, 2020; Yu & Zhang, 2007). Additionally, it has been validated across cultures (Basim & Cetin, 2011; Hjemdal, Friborg, Braun, Kempenaers, Linkowski, & Fossion, 2011; Hjemdal, Roazzi, Maria da Graça, & Friborg, 2015; Limonero, Tomás-Sábado, Gómez-Romero, Maté-Méndez, Sinclair, Wallston, & Gómez-Benito, 2014). While it does not focus on PTSD, it was developed and is applicable within the clinical mental health population.

The Resilience Scale is the original scale developed with the intention of measuring resilience (Wagnild & Young, 1993), focusing on the geriatric population. The BRS attempted to adapt this further and extend it to enable it to reach a wider demographic (Smith, Dalen, Wiggins, Tooley, Christopher, & Bernard, 2008). While this was achieved, it is entirely focused on the capacity to recover from adversity. As such it does not examine the functionality during adverse circumstances, and only considers the period after.

The ARS-30 has been developed in the last five years, and represents one of the newer tools examined here (Cassidy, 2016). Unlike other tools considered here that aim to measure resilience within a population, this tool attempts to correlate resilience with academic success. While it has been demonstrated to be reliable within these constraints (Cicchino, 2018; Howell, Roberts, & Mancini, 2018), it is limited by lack of validation outside of academic settings.

The final tool for measuring resilience considered was the SSRQA (Alonso-Tapia et al., 2018). It was initially developed to quantify resilience in the general population, aiming to evaluate the capacity to withstand adversity and functionality during adverse events. The research also validated it against the other measures of resilience in health and disease (Garrido-Hernansaiz & Alonso-Tapia, 2020; Rodríguez Rey, Alonso Tapia, Garrido Hernansaiz, Ruiz, & Nieto, 2019). As this aligns with the definition of resilience utilised, namely in withstanding adversity and maintaining functionality, it is the testing method used in this research.

2.1.4 Distribution of resilience

As indicated in the introductory chapter, there exists two broad views of resilience in the literature, the first viewing it as a binary concept, either present or absent; in contrast, the second views resilience as a more gradual concept, present on a gradient (Dunn et al., 2008; Dyrbye et al., 2017; Webb et al., 2010). These two views carry significant ramifications for resilience development training programs. In this section, I examined the supporting arguments for each view.

Perhaps the strongest argument for a binary distribution is the observation that some individuals appear to be able to withstand a high load and substantial pressure, without impairing their ability to function and with a 'good' mental health (Herrmann, Scherg, Verres, Von Hagens, Strowitzki, & Wischmann, 2011; Kelley, 2005; Min, Yoon, Lee, Chae, Lee, Song, & Kim, 2013). Biological evidence to support this theory has been presented, with specific neurochemical profiles that act to produce resilience and resilience associated behaviours (Charney, 2004; Dar, Osborne, Abohashem, Abbasi, Choi, Ghoneem, Naddaf, Smoller, Pitman, & Denninger, 2020; Ledford, Dixon, Luning, Martin, Miles, Beckner, Bennett, Conley, & Nindl, 2020). This provides a view of resilience as an innate property, akin to hair colour, with its presence largely dictated by the underlying personal genetic make-up. Indeed, there have been suggestions that, due to this binary distribution, attempting to develop or enhance resilience levels may at best be a fruitless endeavour, or at worst add to external stressors in the vulnerable population, causing more harm in the long run (Bonanno, Westphal, & Mancini, 2011).

This is in contrast with the distributed trait conceptualisation of resilience, which views it as following a similar spread in the population as height, centred around a common level, but also ranging above and below that level. Rather than being defined as the individuals' capacity, it is described as the process of adapting to circumstances that serve to maintain a stable and healthy level of functionality over time (Galatzer-Levy, Huang, & Bonanno, 2018; Norris, Stevens, Pfefferbaum, Wyche, & Pfefferbaum, 2008). The understanding of resilience as a response process is supported by longitudinal studies that appear to show that an individual's level of resilience is not static over their lifetime, but fluctuates with external and internal factors (Byun & Jung, 2016; Phillips, Auais, Belanger, Alvarado, & Zunzunegui, 2016; Van

Kessel, 2013). It is interesting to note that research borne out of this conceptualisation focused on enhancing resilience has also been unable to ascertain if training is effective across the range of resilience levels available at the baseline (Calhoun & Tedeschi, 2014; Gladding & Newsome, 2017; Joyce et al., 2018b).

2.1.5 Implications for this study

The evidence presented strongly suggests that resilience is a distinct entity, correlated with the capacity to face adversity, maintain adequate functionality and the ability to recover. The development of multiple tools to measure it directly makes direct measurement in this study possible. However, as only one of the available tools to measure resilience, SSRQA, has been developed for general use, rather than being confined to a specific context, it is reasonable to proceed with that tool for this research project. With respect to the question of the nature of resilience, I propose an empirical, rather than theoretical, approach to answering it conclusively, by directly measuring it after intervention, with the assumption that a change within a short period strongly implies skill development. It is therefore necessary to directly measure how resilience is distributed in the medical student population as the first step in establishing the baseline levels, and again after intervention.

2.2 Metacognition

The concept of metacognition in medical education literature is broadly defined, encompassing various aspects of the learning process. Metacognition is a term used broadly to incorporate the concepts of analysing thought processes, and deciphering the underlying logic behind decisions. The key point of consensus is that metacognition is a process of abstracting from the immediate experience, followed by self-analysis of the thought and decision-making process (Brycz, Wyszomirska-Góra, Konarski, & Wojciszke, 2018; Metcalfe & Schwartz, 2016; Norman, Pfuhl, Sæle, Svartdal, Låg, & Dahl, 2019; Rouy, de Gardelle, Reyes, Sackur, Vergnaud, Filevich, & Faivre, 2022; Wheaton, 2012). Far from being a retrospective process, metacognition presents a dynamic regulatory function over cognitive processes (Livingston, 2003; Stanton, Sebesta, & Dunlosky, 2021). There was also an appreciation of the dynamic nature of metacognition, allowing for a modulation of responses, applying specific knowledge and skills, and prioritisation information. Metacognition was also acknowledged to be an active process that requires initiation and engagement by the individual. It is additionally characterised as a skill, with potential to be enhanced through training (Rouy et al., 2022). Within the discussion of metacognition and cognitive load theory, a schema is a discreet entity that encompasses a distinct function (Paas, Renkl, & Sweller, 2004). It is worth noting that schema act to reduce the overall cognitive load, and are treated within the individual's cognitive load capacity as a single unit, but that a single schema may be highly complex without increasing the cognitive load (McVee, Dunsmore, & Gavelek, 2016; Sweller, van Merrienboer, & Paas, 1998).

Despite the assumption that clinical decisions are based purely on available evidence, prior experience and past decisions often carry more weight and dictate more of the choices, even in cases where there is a mismatch between prior experiences and current evidence (Gupta, Riva, Monti, Iannello, Pravettoni, Schulz, & Antonietti, 2014; Riva, Antonietti, & Marco, 2011). While this may be explained through the application of formed schema to current experiences, it presents a challenge for medical educators. Bernstein, Hadash, Lichtash, Tanay, Shepherd and Fresco (2015) proposed that through critical self-reflection and training of metacognitive capacity, individuals can develop their ability to evaluate the current situation and correctly apply existing knowledge, leading to an improved decision-making process. The role of metacognition to medical training is accentuated by the findings of Hong *et al.* (2015) and Burman, Boscardin and Van Schaik (2014), demonstrating increased metacognition with increasing seniority in medical students and doctors. Despite the value of metacognitive skills being acknowledged, focused training aimed at developing them is infrequent during the spectrum of medical education (Colbert, Graham, West, White, Arroliga, Myers, Ogden, Archer, Mohammad, & Clark, 2015). Multiple techniques have been described, although no reviews or meta-analyses of their efficacy exist.

The approach for this part of the literature review of metacognitive training medical education included all forms of empirical studies. Qualitative analysis was carried out using *NVivo* and meta-analysis was carried out using *Review Manager* (Cochrane, 2014; IQSR, 2018). Inclusion criteria for this review were studies involving medical students, doctors in training, doctors outside formal training programs with training completed or otherwise. Additionally, the studies were stipulated to include measurement of metacognitive skills or empirical testing of techniques to develop them. The review included all experimental and quasi-experimental study designs with or without control arms. No limitations were placed on geographical placement for the study. Articles excluded were opinion pieces, editorials or purely descriptive articles, review articles or those written in a language other than English. Review articles were evaluated for additional primary sources, but were not included in this section of the literature review. A systematic approach for a literature search was carried out using the PubMed database, aiming to assess the use of research on metacognition and metacognitive training across the breadth of medical education. Table 2.1 details the search terms used in the literature search. A total of 2166 articles were identified using these search criteria, 651 articles were included following screening of abstracts, and 104 full articles included, with 10 studies progressing to the meta-analysis stage.

Search	Query
#5	**#4 NOT #3**
#4	**#1 AND # 2**
#3	**((((((((((((((((((((((nurse) OR nurses) OR nursing) OR physiotherapy) OR physiotherapist) OR physiotherapists) OR occupational therapy) OR occupational therapist) OR occupational therapists) OR pharmacy) OR pharmacist) OR pharmacists) OR Dentistry) OR Dentist) OR Dentists) OR Dental) OR veterinary medicine) OR veterinary practice) OR veterinary surgeon) OR veterinary surgeons) OR vet))**
#2	**(((((((((((((((((((((((((((((((((((((obstetric) OR obstetrics) OR obstetrician) OR obstetricians) OR gynaecology) OR gynaecologist) OR gynaecologists) OR pediatrician) OR pediatricians) OR pediatric) OR pediatrics) OR paediatrician) OR paediatricians) OR paediatric) OR paediatrics) OR general practice) OR general practitioner) OR general practitioners) OR family practice) OR family medicine) OR GP) OR GPs) OR medicine) OR medic) OR medics) OR medical) OR physician) OR physicians) OR surgeon) OR surgeons) OR surgery) OR surgical) OR psychiatry) OR psychiatrist) OR psychiatrists) OR psychiatric))**
#1	**(metacognition) OR metacognitive Sort by: Best Match**

Table 2-1. Search terms and strategy to examine literature on metacognition and metacognitive training in medical education

2.2.1 Defining metacognition

It is invaluable to reach a consensus definition for metacognition and metacognitive skills prior to implementing strategies and programs for training. Omitting this step would lead to ill-defined programs that it would not be possible to evaluate. It has been observed that the absence of consensus in defining central concepts can lead to a hinderance in integrating research outcomes (Pierce, 2009; Tress, Tress, & Fry, 2005). It is therefore necessary to explicitly state the concepts signified by the term metacognition; this would allow more accurate interpretation of the research, as well as the potential to segment metacognition. The characteristics of metacognition as identified in this section are that active engagement of the individual, with a critical self-analysis of thought processes and actions, affording a template for improved function in the future.

In medical education literature metacognition was defined as a multifaceted concept, encompassing various aspects of the learning process (Cloude, Wiedbusch, Dever, Torre, & Azevedo, 2022; Quirk, 2006; Siqueira, Gonçalves, Mendonça, Kobayasi, Arantes-Costa, Tempski, & Martins, 2020; Soemantri & Abdullah, 2018). The key point of consensus was that metacognition is a process of abstracting from the immediate experience, followed by self-analyses of the thought and decision-making process (Brycz et al., 2018; Gonullu & Artar, 2014; Metcalfe & Schwartz, 2016; Norman et al., 2019; Quirk, 2006). There was also an appreciation of the dynamic nature of metacognition, allowing for a modulation of responses, applying specific knowledge and skills, and prioritisation information. Metacognition was also acknowledged to be an active process that requires initiation and engagement by the individual. It was additionally characterised as a skill, with potential to be enhanced through training (Downing, Kwong, Chan, Lam, & Downing, 2008; Efklides, 2006, 2008; Feyzi-Behnagh, Azevedo, Legowski, Reitmeyer, Tseytlin, & Crowley, 2013; Medina, Castleberry, & Persky, 2017).

2.2.2 Assessing metacognition

The strategies deployed for assessing metacognition and metacognitive capacity vary and can be broadly divided between direct and indirect measures. Direct methods included validated questionnaires, such as the metacognitive awareness inventory [MAI] (Schraw & Dennison, 1994), developed by Schmidt and Ford (2003), the metacognitions questionnaire-30 (Wells & Cartwright-Hatton, 2004) and the motivated strategies for learning questionnaire (Pintrich, Smith, Garcia, & McKeachie, 1993). Of these, the MAI proved to be the most widespread in medical education (Moxon, 2022; Omprakash et al., 2021; Siqueira et al., 2020; Soemantri & Abdullah, 2018). Indirect measures of metacognition compromised of expert evaluation of performance, demonstration of considerations of the wider circumstances and forward-planning, and correlation with clinical performance. In the study by Burman et al. (2014), a set framework, with Specificity, Measurability, Achievability, Relevance, and Timeliness was utilised to enable the individual trainees to demonstrate the different attributes of metacognitive capacity and their applications (Marsland & Bowman, 2010).

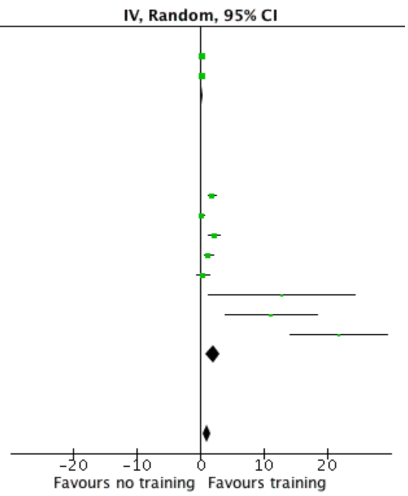
2.2.3 Training in metacognition

Two broad categories of interventions for metacognitive training were identified from the articles examined. The first of these was the use of focused increase in experiences around learning events. Examples include the deliberate practice of tasks known to be beyond current capability, followed by coaching and exploration of reasons for failure (Artino, Dong, DeZee, Gilliland, Waechter, Cruess, & Durning, 2012), or altering the orientation of the training program to be goal oriented rather than task oriented (Gardner, Jabbour, Williams, & Huerta, 2016). These serve to foster an environment centred on deep learning. The second approach for metacognitive training utilised various cognitive forcing strategies to counter inherent biases and encourage the study participants to generalise from their experiences. The nature of the cognitive forcing strategies ranged from a step-by-step checklist (Chew, Durning, & van Merrienboer, 2016) to more open-ended reflective exercises to evaluate their thought processes and encourage de-biasing (Sherbino, Yip, Dore, Siu, & Norman, 2011; Smith & Slack, 2015).

In order to provide a direct comparison of the learning gain from the two categories of training in the literature, a meta-analysis of the quantitative outcomes was carried out. While only three studies were eligible for inclusion at this point, each study evaluated the effect of metacognitive training at several timepoints. As this review focused on a single profession, deemed to be a homogeneous group for the purposes of this study, a fixed-effect model has been used for the analysis. The analysis demonstrates that training does improve metacognitive skills. Figure 2.1 provides a graphic forest plot representation of the meta-analysis. It is important to note that

Figure 2.1. Meta-analysis of the learning gain of different techniques of metacognition.

Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
1.1.1 Passive training								
Gardner et al (2016)	3.88	0.75	45	3.59	0.52	45	15.9%	0.29 [0.02, 0.56]
Gardner et al (2016)	3.96	0.75	45	3.68	0.48	45	15.9%	0.28 [0.02, 0.54]
Subtotal (95% CI)			**90**			**90**	**31.8%**	**0.28 [0.10, 0.47]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.00$, df = 1 (P = 0.96); $I^2 = 0\%$								
Test for overall effect: Z = 3.00 (P = 0.003)								
1.1.2 Active training								
Chew et al (2016)	4.07	1.16	21	2.24	0.79	19	14.2%	1.83 [1.22, 2.44]
Chew et al (2016)	2.28	0.7	21	2.08	0.51	19	15.4%	0.20 [−0.18, 0.58]
Chew et al (2016)	4.55	1.45	21	2.35	1.55	19	12.0%	2.20 [1.27, 3.13]
Chew et al (2016)	4.07	1.3	21	2.81	1.06	19	13.4%	1.26 [0.53, 1.99]
Chew et al (2016)	3.53	1.85	21	3.16	1.31	19	11.6%	0.37 [−0.62, 1.36]
Hennrikus et al (2018)	66.3	16	16	53.5	20	21	0.3%	12.80 [1.20, 24.40]
Hennrikus et al (2018)	128.4	20	57	117.3	26	101	0.7%	11.10 [3.84, 18.36]
Hennrikus et al (2018)	82.1	13	15	60.3	21	100	0.6%	21.80 [14.04, 29.56]
Subtotal (95% CI)			**193**			**317**	**68.2%**	**1.95 [0.76, 3.14]**
Heterogeneity: $Tau^2 = 1.80$; $Chi^2 = 71.14$, df = 7 (P < 0.00001); $I^2 = 90\%$								
Test for overall effect: Z = 3.22 (P = 0.001)								
Total (95% CI)			**283**			**407**	**100.0%**	**1.11 [0.48, 1.73]**
Heterogeneity: $Tau^2 = 0.62$; $Chi^2 = 84.16$, df = 9 (P < 0.00001); $I^2 = 89\%$								
Test for overall effect: Z = 3.47 (P = 0.0005)								
Test for subgroup differences: $Chi^2 = 7.36$, df = 1 (P = 0.007), $I^2 = 86.4\%$								



while following the experiential, passive training model for metacognitive training is effective, an estimated seven-fold increase in learning gain is seen with more directed training, such as the use of reflective portfolios. While the results demonstrated a statistically significant level of heterogeneity, it is judged that this does not impact the interpretation of the results of this analysis.

2.2.4 Benefits of metacognition

Medical education places unique demands on curriculum design, but does offer a cohort of students with a high metacognitive potential (Hayat, Shateri, Amini, & Shokrpour, 2020; Hong, Vadivelu, Daniel, & Sim, 2015; Siqueira et al., 2020). Fostering this potential through a dedicated design should lead to greater efficiency of learning (Hayat & Shateri, 2019; Hill, Peters, Salvaggio, Vinnedge, & Darden, 2020; Sandars, 2009). It can therefore follow that integrating metacognitive skills development and application in curricula should lead to greater learning gains in the time allotted, as well as empowering trainees to continue their development for the remainder of their career (Hayat et al., 2020; Medina et al., 2017). A higher level of metacognitive skill has been highlighted as an advantageous factor in the development of higher knowledge (Artino et al., 2012; Feyzi-Behnagh, Azevedo, Legowski, Reitmeyer, Tseytlin, & Crowley, 2014; Hennrikus, Skolka, & Hennrikus, 2018), technical skills (Bruno, Walker, & Abujudeh, 2015; Uemura, Tomikawa, Nagao, Yamashita, Kumashiro, Tsutsumi, Ohuchida, Ieiri, Ohdaira, & Hashizume, 2014), non-technical skills (Bartlett, Gay, List, & McKinley, 2015; Bond, Deitrick, Arnold, Kostenbader, Barr, Kimmel, & Worrilow, 2004; Church, Rumbold, & Sandars, 2017), as well as a correlation with the quality of clinical outcomes (Chirica & Batteson, 2021; Dunphy, Cantwell, Bourke, Fleming, Smith, Joseph, & Dunphy, 2010; Stansfield, Schwartz, O'Brien, Dekhtyar, Dunham, & Quirk, 2016).

The benefits of facilitating a metacognitive approach instruction is the production of a personalised and tailored approach to learning, which is carried out over the entire career (Hmelo-Silver, 2004; Naug, Colson, & Donner, 2011). Nelson and Narens (1994) identified that metacognition functions to continuously re-evaluate, bridging and co-ordinating the different aspects of memory function. The emphasis on specific aspects of perception and processing directly dictate the learning activity. Additionally, the executive role of metacognition in learning continues beyond the acute phase of experience, and into the construction of schema within long term memory (Nelson, Narens, & Dunlosky, 2004). Consequently, developing metacognitive skills to a higher level will give a greater ability to make decisions in real time and improved capability for developing effective schema for future function (Efklides, 2006). It is also apparent that within a medical career greater understanding of one's own thought processes will afford a greater capacity for empathy with others, a vital component for effective professional practice (Nelson, Kruglanski, & Jost, 1998).

2.2.5 Implications for this study

From the evidence presented, we can conclude that metacognitive skills allow the individual to organise and modulate their thoughts and behaviours. While direct measurement of metacognition is not practical in this study, an indirect approach was adopted. Metacognition was assessed here using the reported behaviour changes from the study participants, exploring their thoughts on the underlying causes for the changes.

2.3 Curriculum development

Medical education curricula are developed by experts in clinical and scientific fields (Carraccio, Englander, Van Melle, Ten Cate, Lockyer, Chan, Frank, Snell, & Collaborators, 2016; Hubner, Fincher, Craig, & Sweeney, 2018; Swanwick, 2013; Thomas, Kern, Hughes, & Chen, 2016). The value of such an approach to the medical education community is emphasised through the understanding of the community of academics and clinicians involved, who are interested in medical education but with expertise often lying elsewhere. However, there has been a move towards a more inclusive approach, with involvement of students in the design phases of medical curricula (Griffeth, Sawyer, Johnson, Hashmi, Gupta, Swartz, & Martin, 2017; Milles, Hitzblech, Drees, Wurl, Arends, & Peters, 2019). Indeed, there is evidence that both academic faculty and students suggest that the most effective educational programs involve near-peer teaching (Carr, Deal, Dehmer, Amos, Farrell, Meyer, & Meyers, 2012). Nevertheless, with increasing complexity in medical curriculum design and delivery, there has been an intensifying demand for dedicated educational specialists (Adirika & Okolie, 2017). The role of dedicated medical educationalist is therefore most palpably felt in curriculum development and design. This role is complicated by the comparative lack of research into the development of medical curricula compared to the plethora of existing published literature on various aspects of clinical practice. It is therefore necessary to begin the process from first principles.

2.3.1 Defining curriculum in medical education

It is perhaps the most telling aspect of the barren landscape in the literature that a consensus definition of curriculum has proved to be elusive. However, Portelli (1987) observed that a rigid definition of curriculum is unlikely to encompass all the core aspects of the concept, and so would be of limited utility. It is therefore necessary to adopt a pragmatic, flexible approach to defining curriculum, with more concrete definitions being resolved for specific cases. In purposefully beginning with a broad definition, Eisner and Vallance (1974) reached the conclusion that a curriculum may be defined as consisting of a series of questions: what skills, knowledge and practices can be taught, what should be taught, to whom should the material be taught, who should teach and how should the knowledge be delivered. This is a notion that Egan (1978) subsequently championed in defining curriculum as consisting of active choices in answering these questions. He later refined the questions in an attempt to produce a more comprehensive list (Egan, 2006). However, the difficulty in developing such a comprehensive, inclusive of all contexts, definition of curriculum led to a great deal of ambiguity, which requires further exploration.

A curriculum may therefore be conceptualised as a formalised academic plan consisting of multiple choices concerned with answering the questions as outlined by Eisner and Vallance (1974) above, with a process for evaluation and revision incorporated into the plan (Stark, Lowther, Hagerty, & Orczyk, 1986). However, each choice, whether made actively or passively, involves prioritisation of certain aspects, and collapses the potential for other avenues. This aversion to some options, the paths not taken, has been recognised as a vital component of rational decision making processes within the academic literature of economics for decades (Buchanan, 1978), with an appreciation that the balance between options is often delicate, with no clear 'best path' available (Buchanan, 1991; Wolf, 1993). Recently, this concept of opportunity cost from the perspectives of students and institutions has been ported into the complexity of educational theory (Bailey, 2009; Bajada, Trayler, Karunaratne, Breyer, & Wood, 2016; Enders, 2004; Espenshade & Chung, 2005; Falcone & Feinn, 2016; María Cubillo, Sánchez, & Cerviño, 2006). Therefore, it is imperative to include not only the benefits of a particular curriculum approach and design, but actively foresee the opportunity cost of a particular approach. This proactive approach will allow the mitigation of the greatest drawbacks.

From this line of argument, we can conclude that attempting a broad, inclusive definition of a curriculum, independent of context, is not a feasible task. While the core outline stages for general application can be stated in an abstracted manner, it is only when exploring a curriculum and its objectives within a defined context that the full complexity of the choices involved, with the associated material and immaterial costs can take shape. It is within the process of developing a curriculum with a specific and explicit goal that the route of travel from conception to finished program can be demarcated and given meaning. In order to reach a definition for this thesis, it is important to consider the contexts of professional training and the resilience training in further detail.

2.3.2 Characterising professional training

The difficulty in setting the implied boundaries of what constitutes professional education revolves on the obscurity of characterising the defining distinguishing features that make a profession unique. The problems inherent in attempting a unified definition of the defining attributes separating professions from other vocation were acknowledged by McGuire (1993), who suggested the only consistent feature between professions is the use of the professional identity. While such a definition is not always possible, it is clear that professional regulation plays a significant role for setting the educational and practice standards for each profession, and therefore, it is imperative that professional training and professionalism are defined more explicitly.

The categorical separation of professions from the remainder of the workforce in the published literature tacitly implies a qualitative difference (Abadi, Ayentimi, & Coetzer, 2020; Grotelueschen, 1985; Gutmann, Endo, & FADI, 2016; O'Keefe, Henderson, & Chick, 2017; Reed, 2018). One recognised aspect of professions is offering society assurances of competence and integrity, in exchange for localising the oversight to within the profession (Abadi et al., 2020; Adams, 2017; Freeman, 2018; Rueschemeyer, 1983). This affords each profession a degree of independence from lay supervision. However, such independence comes at the continuation of assurances supplied to society at large, and hence the prizing of professional expertise. In turn, there exists a tension between each profession and society that projects beyond the provision of assurances, particularly with the increasing reliance on professional expertise (Bourgoin & Harvey, 2018; Illich, Zola, McKnight, Caplan, & Shaiken, 1977). In educating the next generation of professionals, it is imperative to instil both the core affiliation to the professional identity, as well as an appreciation of the standards of professional behaviour and the demands placed on them.

From the perspective of curriculum design, we can therefore define a profession as a self-identifying group, with a demarcated set of knowledge and skills, capable of internal regulation to maintain high standards, with the additional criteria of being recognised externally as a distinct group (Lange, Torero, Osorio, Lobel, Maluk, Hidalgo, Johnson, Foley, & Brinson, 2021; Saks, 2012; Williams, 1998). Moreover, a profession must possess the capacity to maintain itself through the propagation and assimilation of the next generation (Aukett, 2017; Borden-King, Gamas, Hintz, & Hultz, 2020). A curriculum for training as a professional by necessity must include an inferred link between the generations of professionals, and serve to introduce the students into the profession and the professional identity. The students need to complete the training with a sense of belonging to the profession, the capacity to carry out the required role, as well as potentially serve to integrate the following generations.

2.3.3 Professional education & resilience in medical education

Within the realm of medical education it is therefore imperative to develop an ethos and culture that ingrains a collective culture of belonging to the community of healthcare practitioners, doctors and eventually, within a specific speciality (Cruess, Cruess, & Steinert, 2018; Querido, Vergouw, Wigersma, Batenburg, De Rond, & Ten Cate, 2015). This entails belonging to multiple communities of practice, which will inevitably change and evolve over the careers of individual doctors, coupled with the professional skills and competence required for clinical practice (Monrouxe, 2010). The implies a broader skill set and breadth of knowledge that makes medical education, in a manner similar to other spheres of professional education, a rather inexact science (Kennedy, 1987). The challenge of such a wide ranging educational brief is most readily apparent at the undergraduate stage, with the latent potential of medical students representing prospective clinical academic and clinical leaders, future generalists and specialists across the range of clinical practice (Maudsley & Strivens, 2000).

It may therefore be assumed that solutions and examples of medical undergraduate education may be more readily adapted to other settings than the other way around (Kennedy, 1990; Usher & Bryant, 1987). The reciprocal link between theory and medical education is itself an iterative process that initiates and develops throughout the spectrum, beginning at the undergraduate level (Hilton & Slotnick, 2005; Mann, 2011). At the same time, the primary focus of undergraduate education is to provide the critical, widely applicable training which would be suitable for most, if not all, potential career avenues. For that reason, it is logical to focus on resilience training in undergraduate medical education as a first stage of curriculum development. We can reason that developing an effective undergraduate resilience curriculum will lead to the greatest learning gain, as well as highlighting avenues for application in other medical education settings.

2.3.4 Curriculum for resilience training

From the evidence considered above, I propose that the operational definition for a resilience training curriculum is one that originates and ends with the goals of the training. Namely, the curriculum is defined as one that demonstrably improves the resilience level of medical students above the baseline. Given the high-stakes environment of medical practice, and the unique challenges of professional education, the curriculum needs to be evidence-based on strategies that have been illustrated to carry through this effect. Using a technology-enhanced learning perspective, we can attempt to make the delivery more accessible and adaptable to the learner’s circumstances. Additionally, given the size of the crisis of burnout afflicting the profession, there is also a moral duty to ensure that the availability to deliver the curriculum to as wide an audience as possible.

2.4 Simulation and virtual training in medical education

Simulation has been a part of medical education as both a method of providing situated learning in a safe environment, as well as assessment of capability and competence (Owen, 2016). Itself a broad term, simulation aims to replicate and represent a scenario in a faithful manner, with the trainee required to respond in a manner akin to real life. The attraction of simulation is the capacity to provide equal and standardised educational opportunities to all students, offer a controlled and safe environment to explore scenarios, as well as afford the opportunity for repetitive practice. For these reasons, the use of simulation for training purposes has been widespread in a variety of professions from military exercises, technical engineering operations, as well as in the training of healthcare professionals (Evans, Bae, & Roy, 2017; Frank, 2019; Magana, 2017; Owen, 2016).

In the context of medical education, the utility of simulation can be broadly divided into subcategories; the first of these is to provide a summative assessment in a standardised setting, with a view to ensure professional competence; the second setting is in the formative environment, providing an arena for deliberate practice and an opportunity to apply knowledge in a supportive environment, without exposing patients to risk. This has been recently supplemented through the use of virtual instruction and virtual training (Makransky, Bonde, Wulff, Wandall, Hood, Creed, Bache, Silahtaroglu, & Nørremølle, 2016; Nelson & Katz, 2018; Tomesko, Brody, & Touger-Decker, 2017; Winkler-Schwartz, Bissonnette, Mirchi, Ponnudurai, Yilmaz, Ledwos, Siyar, Azarnoush, Karlik, & Del Maestro, 2019), although the role and place of virtual instruction has currently not been assessed. For the purposes of avoiding repetition, I will use the more common term 'simulation' henceforth to include virtual training and instruction.

The capacity to utilise simulation for medical education is therefore a logical step. Simulation in medical education has been gaining increasing popularity over the previous three decades, with rising utilisation over time (Fincher & Lewis, 2002; Issenberg, McGaghie, Hart, Mayer, Felner, Petrusa, Waugh, Brown, Safford, & Gessner, 1999; Owen, 2016). However, one of the earliest records of simulation in medical training was by Le Boursier and Angélique-Marguerite (1759) used a model of a foetus and pelvis to teach midwives techniques for delivering babies, indicating an early realisation of the need for simulation to provide a simplified model of clinical practice to aid learning. The expectation that appropriate and comprehensive training will be undertaken before clinical practice, altered models of healthcare delivery, and coupled with a heightened focus on patient safety has led to an overall decrease in clinical exposure to direct clinical care, and thus fewer learning opportunities (Graber, Pierre, & Charlton, 2003; McManus, Richards, & Winder, 1998; Santen, Hemphill, McDonald, & Jo, 2004). Simulation is seen as a solution to all these aspects through a focused curriculum, with a demonstrable impact on patient safety and behaviour (Graber, Wyatt, Kasparek, & Xu, 2005; Joseph, Nelliyanil, Jindal, Utkarsha, Abraham, Alok, Srivastava, & Lankeshwar, 2015).

2.4.1 Types of simulation and virtual training

The value added by simulation to medical training is reliant on the ability to transfer lessons learnt in the simulation to clinical practice (Frank, 2019). Therefore, a degree of fidelity to the clinical environment is required to smooth this transition. As medical sciences have advanced and become reliant on an increasing number of technological methods for diagnosis and treatment, this has revolutionised the clinical management of patients (Reynolds, Osborne, Waggoner, Melton, Motarjemi, Schulze, & Chau, 2017). However, this had the side-effect of posing a new challenge to training, as the effective utilisation of these technologies has been shown to incur additional risks to the patient, particularly during the physician's 'learning curve' phase of practice (Murzi, Cerillo, Gilmanov, Concistrè, Farneti, Glauber, & Solinas, 2016; Reynolds et al., 2017; Whittaker, Dwyer, Howard, Huey, Lesko, Nunley, & Verdonk, 2018; Zhao, Bai, Teng, & Zhang, 2019). It has also been suggested that teaching the required skills to use these technologies requires a different approach to standard clinical education (Johnsen, Fossum, Vivekananda-Schmidt, Fruhling, & Slettebø, 2016; Shao, Yuan, Qian, Ye, Chen, le Zhuang, Jiang, Jin, & Qiang, 2020; Strandell-Laine & Salminen, 2018). This suggested that the translation from solely face-to-face teaching to technology enhanced learning requires at least some degree of redesign.

2.4.2 High and low fidelity

Technological aids to simulation have been in use for some time, with the initial use of models capable of giving physical and tactile feedback, the most famous of which is the Resusci-Anne model, a standardised manikin for practicing resuscitation, to much more technologically advanced use of virtual reality simulators for robotic assisted surgery (Grenvik & Schaefer, 2004). Other technological adjuncts to simulation methods include part-task trainers, computer-based simulators, part-body simulators, model patients and full environment simulation (Dacre, Nicol, Holroyd, & Ingram, 1996; Husken, Schuppe, Sismanidis, & Beier, 2013; Stillman, Regan, Philbin, & Haley, 1990; Takashina, Shimizu, & Katayama, 1997). The range and variety offered by different simulation technologies provides a challenging series of questions in terms of curriculum design. Bradley (2006) in considering the justifications for the implementation of simulation training within medical education, of the time, labour and financial implications concluded that careful analysis of the various impacts on different learning outcomes is needed.

In a large proportion of the medical education literature examining simulation technology in training, the question regarding fidelity is raised, examining how accurately the simulation reflects clinical practice (Alluri, Tsing, Lee, & Napolitano, 2015; Banaszek, You, Chang, Pickell, Hesse, Hopman, Borschneck, & Bardana, 2017; Issenberg, McGaghie, Petrusa, Lee Gordon, & Scalese, 2009; Kim, Park, & Shin, 2016; Lewis, Strachan, & Smith, 2012; Maran & Glavin, 2003; Owen, 2016). In contrast to the combined description and attribution of fidelity, there exist two related but distinct forms to simulation fidelity as representation of reality. The first type, which is more readily understood and most often described is fidelity of engineering, representing an accurate representation of the clinical world, requiring the reliable replication of the physical attributes with the task (Hontvedt & Øvergård, 2020; Kuipers, Terlouw, Wartena, Prins, & Pierie, 2018; Nasarwanji, Pollard, & Kocher, 2018). The second type is psychological fidelity, representing a depiction of the critical aspects of the task, without aiming to reproduce the task itself (Kuipers et al., 2018; Munshi, Lababidi, & Alyousef, 2015). In this approach, the goal is to maintain an adequate level of 'real feel' to enable effective skill transfer from the simulator to practice, through the capture of the essence of the task. This distinction is not however a new separation, but was first recognised by R. B. Miller (1954).

High fidelity simulation often requires an advanced technological level, frequently necessitating a large financial investment from the outset. Inevitably, a point of diminishing returns is reached, where further investment in increasing fidelity does not translate into significant learning gains (Maran & Glavin, 2003). Nevertheless, multiple large scale reviews have noted that high fidelity simulation training for healthcare education does lead to learning gains across technical and non-technical skill domains (Issenberg et al., 2009; Lewis et al., 2012). However, it has been also observed that the transfer of skills learned on simulators to the professional world is not a direct result of the engineering level, but is rather a factor of the psychological fidelity, in combination with prior skill level, and the task type (Druckman, 1994; Patrick, 1992). While the acquisition and development of expert technical skills may demand a high level of engineering fidelity to avoid negative skill transfer, such a high level of engineering fidelity may be detrimental to novices learning similar skills, or in non-technical domains (Dieckmann & Krage, 2013; McGaghie, 2008; Scerbo & Dawson, 2007). The focus for simulation training curricula needs to be maintained on maximising learning effectiveness, rather than maximising fidelity.

2.4.3 Advantages and benefits of simulation training

Utilising simulation training in medical education offers various tangible benefits, such as avoidance of exposing patients to the risks associated with clinicians during the early part of the learning curve, offering trainees the opportunity for repeated deliberate practice without clinical risk, and a greater responsiveness to individual training requirements. Over the recent decades there has been a progressive movement towards a technologically-enhanced simulation, which accentuates the most valuable aspects of simulation training, while aiming to minimise their limitations (Maran & Glavin, 2003; McGaghie, Issenberg, Petrusa, & Scalese, 2010). It is likely that different simulation techniques are more suited to specific learning goals. Therefore, it is important to consider the impact of simulation training over the linked but discrete domains of technical skills, non-technical skills [NoTS], and knowledge management [KM].

There is a growing recognition in medical education of the role played by NoTS over the clinical outcomes (Briggs, Raja, Joyce, Yule, Jiang, Lipsitz, & Havens, 2015; Pires, Monteiro, Pereira, Chaló, Melo, & Rodrigues, 2017; Rao, Dumon, Neylan, Morris, Riddle, Sensenig, Park, Williams, Dempsey, & Brooks, 2016). Recent studies have demonstrated that simulation training is one of the most effective modalities for NoTS training (Adib-Hajbaghery & Sharifi, 2017; Ounounou, Aydin, Brunckhorst, Khan, Dasgupta, & Ahmed, 2018; Pena, Altree, Field, Sainsbury, Babidge, Hewett, & Maddern, 2015). Interestingly, the findings echo the sentiment suggested by Maran and Glavin (2003), in that psychological fidelity is more valuable in NoTS training compared to physical or engineering fidelity. However, difficulties in design of studies has led to a large degree of heterogeneity and potential for bias in trails, making conclusions regarding the magnitude of the learning gain difficult to conclusively calculate.

The focus of technical clinical training in medical education is a two stage process; initially, the attainment of competence in the procedure, followed by acquiring proficiency. Competence was defined as performing the procedure without significant or critical errors. Proficiency was assessed using time to complete the procedure as a surrogate marker. In a previous systematic review on competence learning gain with computer based simulation, a higher level of impact on trainees was found compared with continuing medical education [CME] doctors (Iskander, 2017). In that study, it was revealed that there is a strong correlation between training with computer-based simulation [CBS] and achieving technical competence, with the overall effect being that CBS training led to a greater level of competence compared to either other simulation modalities or standardised training, although the magnitude of the impact is greater for postgraduate trainees than in the CME setting. An important observation was that the greatest benefit was for doctors with less experience (Thomsen, Bach-Holm, Kjaerbo, Hojgaard-Olsen, Subhi, Saleh, Park, la Cour, & Konge, 2017). Deliberate practice, where segments of tasks were repeatedly practiced outside of clinical settings, formed a key role in achieving the required standards, with all studies noting a learning curve associated with CBS training, and a noticeable improvement in technical skills with further simulation practice. Multiple studies demonstrated skill transfer from CBS simulation to clinical practice, and of particular note, two studies demonstrated superiority of CBS over standard simulation for the acquisition of technical competence, with Andreatta, Maslowski, Petty, Shim, Marsh, Hall, Stern and Frankel

(2010) demonstrating non-inferiority of CBS compared to standardised live simulation, and Zhao, Kennedy, Yukawa, Pyman and O'Leary (2011) demonstrating superiority over live simulation.

Technical proficiency was assessed in four randomised controlled trials [RCTs] across postgraduate training and CME settings (Cates, Lönn, & Gallagher, 2016; Clarke, Kureshi, Hong, Sadeghi, & D'Arcy, 2016; Larsen, Soerensen, Grantcharov, Dalsgaard, Schouenborg, Ottosen, Schroeder, & Ottesen, 2009; Shirai, Yoshida, Shiraishi, Okamoto, Nakamura, Harada, Nishikawa, & Sakaida, 2008). Training using CBS was associated with a statistically significant reduction in time taken to complete procedures [$p<0.00001$]. Only one RCT did not demonstrate superiority of CBS training (Shirai et al., 2008), with the result of this study being equivocal. Sub-analysis by experience level found that simulation training had a greater impact on trainees and physicians with less experience, compared to those with more procedure-specific experience (Casey, Stewart, & Vidovich, 2016). Two studies did not find a statistically significant impact of CBS training on technical proficiency (Clarke et al., 2016; Shirai et al., 2008). However, Clarke et al. (2016) suggested a role in skill retention and maintaining proficiency over time where experience is not maintained in clinical practice.

Evidence suggests that simulation training, in its broader sense including virtual instruction delivered via web-based portals, leads to significant gains in technical and non-technical skills (Iskander, 2019b, 2019c). Meta-analysis revealed an increased odds ratio of improved non-technical skills following CBS training. Qualitative analysis suggested that CBS has a positive impact on trainees' communication skills, with only one study that did not demonstrate a direct relationship between CB training and improved NOTS (Cleland, Ford, Hamilton, Nabavian, & Walker, 2007). Trainees reported increased confidence in their communication skills following CBS training (Gorrindo, Baer, Sanders, Birnbaum, Fromson, Sutton-Skinner, Romeo, & Beresin, 2011; Wilson, 2012).

2.4.4 Disadvantages and drawbacks of simulation training

The integration of simulation training in medical education is hampered and limited by the associated costs incurred (Langdalen, Abrahamsen, Sollid, Sørskår, & Abrahamsen, 2018; Sanders & Wilson, 2015). It is observed that despite the acknowledgement of costs as a key factor in medical education simulation, it has been under-represented in research (Zendejas, Wang, Brydges, Hamstra, & Cook, 2013). Ker, Hogg and Maran (2010) classified the costs incurred with simulation curriculum as hardware, infrastructure, faculty development, as well as establishing acceptance and buy in by patients and learners. This can be further split into material costs, and psychosocial costs. It is vital that strategies for meeting them are established early in the design process, as a highly acceptable simulation that proves to be excessively costly will encounter a failure in actualisation similar to an affordable simulation that is rejected by stakeholders, who are required to accept the curriculum and its potential to deliver tangible learning outcomes. Undertaking such a curriculum design program therefore places a relatively high demand from a design standpoint. Meaningful simulation training requires a wide range of perspectives, capturing both the goals of the training program, needs of staff delivering the training, the students receiving it, and ultimately the patients who will be the endpoint of medical training and education.

After the initial implementation of a simulation training program, ongoing maintenance, technical support and eventual replacement will be required. This is due to evolving technology, and the rate of progress of medical sciences, the development of a simulation curriculum must be seen as a time-limited, periodic, investment. Furthermore, these ongoing requirements are a necessary part of the resource allocation required in curriculum design, and these need to be considered in calculating the opportunity costs of such expenditures, as well as the present value of the future learning gain. As such, a commitment to the delivery of simulation training by necessity limits the future curriculum options, and therefore, an adaptable and versatile simulation platform is required.

2.4.5 Implications for this research

The approach adopted in this research is to pursue a psychological, rather than physical fidelity to the virtual instruction provided as an explicitly stated goal is to provide an adaptable platform that each participant can apply easily in their own circumstances. Fidelity, here, will be achieved via adopting a similar delivery style to meditation instruction and guidance, when this is carried out in a face to face setting (Ahlin & Kjellgren, 2016; Burke & Hassett, 2020). Additionally, several 'levels' were included, ranging from a short session to act as an introductory stage, a moderate length one and a longer session. These allowed each participant to progress as they saw fit.

2.5 Lessons in resilience from outside medicine

While medicine is undoubtedly a profession that places a large amount of prolonged stress on its practitioners, and thus demands a high degree of resilience, it is not entirely unique. In this section of the literature review, I examine the studies of three distinct professions on resilience training, attempting to draw insights on the parallels that may be drawn with medicine. It is therefore imperative to consider professions where high stakes decisions, with a real potential for mortality and responsibility for the lives of others is present, as well as the prospect of extended periods of activity without relief, while maintaining an adequate level of efficacy, allowing for a valid translation into medical education. For this reason, I will consider the civil aviation industry, the military and space agencies in turn, focusing on resilience training methods and their underlying theoretical basis.

2.5.1 Aviation industry

One of the central concepts in civil aviation is the theory of resilient systems engineering, focusing on the human component (Hollnagel, Woods, & Leveson, 2006; Patriarca, Bergström, Di Gravio, & Costantino, 2018). The driving force in resilience engineering is the purposeful movement beyond defining safety as the tight performance management, reduction in policy and protocol violation or counting of errors as the bench mark. Rather, resilience engineering defines safety as the absence of danger through deliberate design of systems that minimise or eliminate the potential for negative outcomes (Chialastri & Pozzi, 2008; Dekker, Hollnagel, Woods, & Cook, 2008). This is accepting of human function as the regulators of resilience and safety in complex systems, where the underlying assumptions may be mistaken, or the set pathways place contradictory demands. The adaptability of individuals is therefore embraced as a vital mechanism to accommodate challenges, adapt to changes in circumstances safely and effectively, even in the face of pressures. Rather than await mishaps and errors, the civil aviation profession attempts to take a proactive approach, deploying mechanisms that detect errors in embryo and preventing their progression, as well as aiming to predict the potential pathways of risk and failure before they occur (Dekker, 2007).

It has been a landmark moment in resilience design within the civil aviation industry to not only acknowledge human failure and frailty, but to purposefully incorporate them in the systems processes (Aurino, 2000). The focus of resilience engineering in aviation has thus been to equip aircrew with the generic skills vital to aircraft operations, while maintaining a high degree of flexibility to ensure an adaptive response to new experiences. Research has therefore focused on two broad sections, initially finding the gap between reality and the ideal level of practice, followed by focused training to address this gap (Deharvengt, 2007). It is noteworthy that the most efficient training regimen identified for resilience is team-based simulation

(Dekker, Dahlström, van Winsen, & Nyce, 2016), recognising that success and failure is goal-oriented and applies to the team rather than the individual. Orasanu (2010) identified that highly successful teams are those most capable of functioning more cohesively, supporting, and catalysing actions to achieve objectives. On an individual level, there has been a consistent drive to use meditation programs, with research suggesting that it bolsters personal resilience, and leads to better overall performance (Bellamy, Chambon, & van Guldener, 2018; Jha, Zanesco, Denkova, Morrison, Ramos, Chichester, Gaddy, & Rogers, 2019; Martin, 2019).

2.5.2 Military

In order to maximise operational capacity of human assets, a revolution in military training has taken place, with a focus placed on emphasising the resilience of individual soldiers, particularly over the last decade (Simmons & Yoder, 2013). Military operations place an immense pressure, both physically and mentally, on serving soldiers (Langston, Gould, & Greenberg, 2007; Sutker, Davis, Uddo, & Ditta, 1995). This effect is compounded by an ingrained culture within the military that discourages admitting that the load is becoming excessive, or requesting assistance (Bruner & Woll, 2011; Hoge, Castro, Messer, McGurk, Cotting, & Koffman, 2004). The impact of this culture is felt within the military services in behaviour that actively avoids seeking help, even when perceived as needed (Casey, 2011).

Understandably, the military has directed a great deal of effort into the development of resilience and resilience training, with the goal of reducing fatigue and burnout within the armed forces (Adler, Castro, & McGurk, 2009; Cornum, Matthews, & Seligman, 2011; Crabtree-Nelson & DeYoung, 2017). The programs of resilience training are broad-based, with the remit to address familial, personal, physical and psychological factors (Casey, 2011; Pargament & Sweeney, 2011; Pietrzak, Johnson, Goldstein, Malley, Rivers, Morgan, & Southwick, 2010). The delivery of the programs occurs through four distinct phases: assessment and identification of needs, which is subject to periodical review, followed by a universal resilience training aimed at establishing a baseline level. The third stage is a ‘top-up’ training on focused individualised program based on the individual soldier’s assessment-reassessment cycle and finally the placement of localised trainers within each unit that are capable of additional targeted training of individuals as it becomes necessary.

In considering the philosophy of these programs, it becomes evident that the initial stage involves a cycle that may be conceptualised as consisting of two parts. Initially, there is a ‘fact-finding’ and normalising part of the program, aimed at establishing a minimal acceptable baseline level of resilience. This carries many echoes and similarities of professional skills training, both within and out of the military, where a minimum standard is required. The second component involves the provision of a tailored approach to training, targeted at specific individuals and areas where the greatest impact is likely. It is important to note that this approach to resilience training has yielded positive outcomes, both objectively and subjectively (Foran, Adler, McGurk, & Bliese, 2012; Harms, Herian, Krasikova, Vanhove, & Lester, 2013). This suggests that resilience is amenable to training in a manner akin to other skills.

In this context, there have been numerous studies examining the link between meditation and resilience. There have been studies that associated increased levels of resilience with meditative practice (Mantzios, 2014; Rothschild, Kaplan, Golan, & Barak, 2017). Further studies suggest that meditation is associated with better performance under stressful conditions and is protective against negative mental health effects of experiences (Trousselard, 2009). Furthermore, the benefits of meditation have been seen beyond the period of active military service (Rice, Boykin, Jeter, Villarreal, Overby, & Alfred, 2013; Rice & Schroeder, 2019). This suggests that the effects of meditation are tangible in the moment, both in terms of performance improvement and protection, and that these effects are likely to persist.

2.5.3 Space agencies

The third context is that of space agencies, such as the European Space Agency [ESA] and the National Aeronautical Space Agency [NASA]. Space agencies have to prepare potential astronauts for entry and habitation of complex and potentially hostile environments, where external support is not forthcoming, and a high level of both effectiveness and self-sufficiency is vital (White & Averner, 2001). Space programs involved a high degree of collaboration between teams and groups of skilled and specialised individuals, aimed at accomplishing goals that surpass their individual capabilities. The study of Yi, Rykova, Feuerecker, Jäger, Ladinig, Basner, Hörl, Matzel, Kaufmann and Strewe (2014) simulated the prolonged period of spaceflight required for extra-terrestrial travel, and demonstrated that the physical and psychological resilience of teams is interrelated to other members of the group. At the heart of the design is an appreciation that preparation for known risks alone is insufficient, and fails to adapt to new challenges (Buckey, 2006; Piantadosi, 2013). It is therefore the function of the team as a broad collaborative effort that determines resilience to challenges old and new.

It follows that the key contribution of space agencies to resilience research is in the consideration of closed systems as a unit for evaluation (Boin & van Eeten, 2013). Such a system can be interpreted as resilient, provided it possesses the capacity to re-organise and adjust to evolving, dynamic situations (Boccaletti, Latora, Moreno, Chavez, & Hwang, 2006; Yates, 2012). The team's closed system can function as a reserve for individual members, and supply support as needed, thus maintaining the resilience of individual members, and enhancing the overall team resilience to beyond the sum of its parts. Through this lens, it becomes possible to view individual members not only as support for the rest of the group, but also as an intrinsic mechanism for monitoring the overall resilience of the team as a whole (Shelhamer, 2016).

Inherent in the organisational structure is a culture of unending vigilance. Nevertheless, this does not prevent disasters from occurring, such as in the cases of the *Challenger* and *Columbia* shuttle disasters. It is important to note that the approach taken for developing and ensuring resilience within the context of space agencies involves a recursive and iterative process, where a cyclical improvement is adopted to learn from experience (Dussich, 2016). There is also a capacity to divide into smaller teams and decentralise working methods, that enable innovative or unorthodox solutions to be achieved, perhaps most notably in the case of the *Apollo 13* mission (Murray & Cox, 1989). The inherent dangers of spaceflight, combined with these principles, led space agencies to adopt the concept of 'acceptable risk' (Vaughan, 1997).

Again, there is evidence suggesting benefits to meditation in this context. Pagnini, Phillips, Bercovitz and Langer (2019) suggested that meditation can carry a performance benefit for astronauts, as well as enhancing resilience to stresses. Additionally, it has been suggested that even in highly co-operative team environments such as spaceflight, individual resilience is vital, with meditation posing a possible route to improve it (Mogilever, Zuccarelli, Burles, Iaria, Strapazzon, Bessone, & Coffey, 2018; Sandal, 2018).

The core lessons from resilience training across aviation, military, and space agencies is the recognition that human adaptability is essential for maintaining safety and effectiveness in complex, high-pressure environments. Rather than merely managing errors or enforcing strict compliance, resilience training integrates human flexibility into system design, acknowledging that individuals play a crucial role in regulating performance. Training programs emphasise learning, and continuous skill development to bridge the gap between ideal and real-world performance. Across all domains, meditation has emerged as a valuable tool for enhancing personal resilience, improving performance under stress, and sustaining long-term well-being. Ultimately, the proactive identification and mitigation of risks, combined with fostering a culture of adaptability, ensure that both individuals and teams remain robust in dynamic and unpredictable conditions.

2.6 Discussion of literature

I defined resilience as the ability not only to withstand adverse events, but to maintain performance at an acceptable level. The use of the SSRQA affords the opportunity to measure resilience levels directly, and is validated for use in this population. Secondly, metacognition is defined as the cognitive skill that allows analysis and processing of experiences and information. As such, metacognition is critical to the learning process, as well as serving as a protective apparatus (Nelson & Narens, 1994; Nelson et al., 2004). Furthermore, metacognition offers potential to improve with training (Downing et al., 2008; Efklides, 2006; Medina et al., 2017).

From the experiences of the professional spheres explored, it is clear that the value of resilience training is widely acknowledged, and that resilience training is possible, with an observable impact on outcomes. Furthermore, in the high-stress, pressurised professions examined, these gains in resilience are achieved through meditation. The position required for resilience to develop must begin from a position of accepting human activity as imperfect, seeking to institute a culture of active real-time deliberation and problem solving. In cases of undesired outcomes, a considered analysis of the situation may highlight new solutions. It is invaluable to see that in these examples in high stakes professions, with prolonged periods of stress, similar to medical careers, as well as the demands of complex team working, the resilience of individuals is monitored, supported, and augmented by immediate colleagues and peers, with institutional infrastructure playing a smaller role.

Translating these lessons for medical education, it is essential to invest a dedicated part of the training program in resilience as the profession can ill-afford the current epidemic of physician burnout. Similar to the professions examined here, I advocate the introduction of resilience training into the early parts of the education pathway, situating it as a core component of the undergraduate curriculum. The incorporation of resilience training into undergraduate education will ensure that all future physicians are equipped to deal with the inevitable challenges that arise during a medical career, as well as fostering a culture that appreciates the value of high resilience skills. The mechanism for training requires a capacity to allow reflection, a dialogue with the self, as well as external review to ensure efficacy. I would therefore recommend a combination of reflective practice with individual mentoring to achieve these goals. Finally, it is important to consider how best to implement this strategy, making the best possible use of the technological means available. A technological solution, delivering virtual instruction, without an upper limit on capacity poses clear advantages and is a clear first choice.

2.7 Research Gap

The next stage for research would be to apply these aspects to metacognitive training, and develop a defined curriculum, with the goal of enhancing resilience. The current literature has thus far focused on attempting to develop resilience as a treatment, after the development of undesirable effects such as burnout. With the rising trend in physician burnout highlighted previously, it is appropriate to attempt a prevention rather than cure. The current evidence suggests that the levels experienced by physicians across all clinical environments is rising exponentially and represents a significant threat to the medical workforce (Ofri, 2013; Wilberforce et al., 2010).

Despite the skills being ultimately transferrable to a wide range of clinical experiences, it is more appropriate to utilise a defined target. It is my opinion that a primary goal of metacognitive training and stemming from the principle of "*Medice, cura te ipsum*", commonly translated as "physician, heal thyself", the topic most appropriate is that of physician burnout and post-traumatic stress disorder. A medical career is both physically and emotionally demanding, often inducing prolonged periods of stress (Persaud, 2004, 2005). From this standpoint, it is important to consider metacognitive training and the resultant enhanced resilience of doctors as a vital direction for research.

It is also appropriate to restate the research questions at this juncture

RQ1: What is the distribution of resilience in medical students?

RQ2: How acceptable and feasible is virtual instruction for meditation training to medical students?

RQ3: How effective is virtual meditation training on medical students of different resilience levels?

RQ4: What factors affect the change in resilience level with meditation training?

RQ5: How do medical students perceive the impact of meditation training on resilience-associated behaviours?

In sequential order these questions identify the baseline of resilience in medical students, establish the feasibility of virtual instruction in this context, then thoroughly evaluate the objective and subjective impact of virtual instruction and meditation training on the resilience of medical student.

3 Cognitive Load Theory, Memory and Metacognition

In this chapter I will discuss the core principles of my theoretical framework, Cognitive Load Theory [CLT], its history, and philosophical positioning, and go on to highlight the relevant aspects of memory and its application to instructional design within medical education. I will also consider how metacognition is a critical component of CLT, acting as the agency to co-ordinate memory function and modulate cognitive load. I then proceed to explore the evidence base for cognitive load, and finally its limitations.

CLT, as a theoretical framework, is based on the prerogative that efficient pedagogical techniques need to take into account the insights newly offered by neuroscience on the structure and function of the human brain. It is imperative that as we aim to equip individuals with an ever-increasing amount of complex knowledge and technical expertise, we understand, appreciate, and include the workings of the mind into the *modus operandi* of instructional design. It is through this approach that we can ease the effort of learning, and therefore relieve the workload required by the learner.

In order to understand CLT, it is useful to appreciate the circumstances and research that led to its inception, and how this has influenced the methodologies and conclusions derived from its use. These are valuable to consider, as the implications of CLT have permeated though a multitude of everyday activities, from driving to financial transactions to corporate behavioural patterns (Forlines, Schmidt-Nielsen, Raj, Wittenburg, & Wolf, 2005; Rose, Roberts, & Rose, 2004; Rowbottom & Lymer, 2009; Sweller, 1993). These examples serve to demonstrate the fundamental properties of CLT in different aspects of human activity and establish the compatibility of CLT with human activity in general and learned skills in particular.

The limits of learning as understood within the CLT framework are defined as the maximal capacity for cognitive load of the learner, but once the total load exceeds this limit learning deteriorates instruction as the learner is overwhelmed (Moreno, 2010). The ultimate goal of cognitive load theory is the construction of schema and the automation of actions, thus allowing the relief of load of working memory. The definition of expert within the sphere of CLT is an individual who possesses a high degree of automation and applicable schema in relation to a given task (Higgins & Tully, 2005; Mead, Gray, Hamer, James, Sorva, Clair, & Thomas, 2006). Moreno (2006) described the development of expertise within CLT as correlating closely with the Adaptive Control of Thought – Rational [ACT-R] framework, as originally described by Anderson, Fincham and Douglass (1997). Here, four distinct stages on the pathway to develop expertise are described, namely analogy, abstraction, proceduralisation and refinement, and finally automation.

Initially, learners attempt to solve problems through analogous interpretation of specific, previously encountered examples, and attempt to directly link these to current tasks. Subsequent to encountering a sufficient number of experiences, learners may be able to conceptualise and generalise a working model, beginning the process of schema formation. Thirdly, the initial schemas are deployed and refined through further practice, leading to the final stage of expertise where the refined schema are automated, leading to relief of cognitive load. Therefore, an expert may rely on the established schema to be able to manage more complex problems with greater ease, which involves a dynamic relationship between the different aspects of memory. As the problem is localised to a particular schema, it can be retrieved from long-term memory and applied within the working memory more effectively.

This utilisation of existing schema has been used to account for the differences in performance between experts and non-experts in practice (VanLehn, 1996). It therefore follows that the effective formation of schema is the key determinant of developing the ability to manage more complex tasks, while efficient retrieval and utilisation of schema is required to be able to function adequately under less than ideal circumstances (Iskander, 2019a; Kalyuga, Plass, Moreno, & Brunken, 2010; Kalyuga & Singh, 2015; Leppink, 2017; Jan L. Plass & Slava Kalyuga, 2019).

The application of this system to CLT has led to the adoption of a 'worked-example' model of instruction, providing learners with a practical demonstration of the steps required to solve problems (Renkl, Stark, Gruber, & Mandl, 1998). As can be predicted from the ACT-R model stages previously described, as well as directly from the principles of CTL, the use of worked examples can accelerate the initial stages of schema formation (VanLehn, 1996). This mode of instructional design has been demonstrated to enhance both problem solving skills (Kopp, Stark, Kühne-Eversmann, & Fischer, 2009; Sweller & Cooper, 1985; van Gog & Kester, 2012), as well as the transfer of these skills to new settings (Mwangi & Sweller, 1998; Renkl, 2014). This has been referred to as the 'worked example effect' (Sweller et al., 1998).

In order to appreciate and situate CLT within the wider philosophical positions of educational theory, and therefore understand the methodologies suggested and insights offered by CLT appropriately, it is important to understand its origins and the history of its development; in the following sections I will explore the key points in its history and follow this by exploring the ontological and epistemological stances.

3.1 History

The origins of CLT were first hinted at by Miller (1956), with the recognition that WM in humans is finite, with a pre-defined limit that is not subject to alteration. Recently, there have been suggestions that this limit is, in part, due to the 'thinking' language (Martin & Ellis, 2012; van den Noort, Bosch, & Hugdahl, 2006). It is through these studies that we can begin to consider cognitive load as a distinct entity, functioning as a single unit. It was Chase and Simon (1973), in a study involving set perceptual and memory tasks for chess players, who later described the process of dividing larger tasks into "chunks" to enable them to be managed and successfully negotiated within the confines of working memory. Additionally, they hypothesised that experienced players may be able to perform tasks more easily by relating them to existing knowledge schema.

The application of CLT to educational theory may be traced back to Sweller (1988). In his article, Sweller argued that problem solving may be utilised to develop novices into experts by encouraging the process of constructing schema for managing the problem. However, the effectiveness of this process is often hampered by the high demands placed on the learners in terms of cognitive processing to reach a specific resolution and there is, therefore, an apparent deficiency in cognitive capacity for the formation of more generic schema. It can then be extrapolated that the role of instructional design is to minimise the specific cognitive demands required for resolving the experienced problem or task, and to ensure sufficient overlap between the problem-solving process and the desired schema. The outcome of effective instruction is therefore to free adequate cognitive capacity to enable the acquisition of the schema without detrimentally impacting the capability to solve the immediate problems. In combination, these two facets afford each learner the opportunity to accomplish tasks, while developing a higher level of competence and expertise to facilitate the completion of future tasks with greater ease.

3.2 Ontology of CLT

At the core of CLT is a belief that there exists a set pattern that may be applied to human cognitive functions and be applied effectively across individuals and across fields. Furthermore, it is evident that learning, as contrasted to task completion, is accomplished by the development of generic schema that are applicable to a wider set of circumstances. In combination, these imply the existence of a definite reality from without the minds of the learners, with learning being the process of attempting to comprehend this reality more fully. However, as the schema are liable to the biases inherent in the teacher and the student, it follows that the understanding of the reality may converge but is unlikely to coincide completely. It is therefore important to strive to minimise the effects of these inevitable biases in research. We can therefore conclude that CLT is a post-positivist philosophical approach (Phillips, 1990).

Stemming from the positivist paradigm, post-positivism asserts the objective and observable reality, with research requiring a systematic, precise and logical approach (Schumacher & Gortner, 1992). However, post-positivism asserts that this objectively present truth can only be perceived through imperfect means, and thus can only be appreciated imperfectly (Miller, 2005). The objective reality is therefore understood but the understanding is dependent on perspective and constructs of the observer, and subject to revision through future iterations.

3.3 Epistemology of CLT

From the ontological positions outlined above, the post-positivist stance stresses a pragmatist approach to the acquisition and accumulation of knowledge. The post-positivist paradigm embraces both qualitative and quantitative approaches to enquiry, holding the belief that a numerical approach is complemented by the qualitative approach (Lindlof & Taylor, 2017; Tesch, 2013). Furthermore, in applying CLT we need to appreciate that the knowledge acquired by the student through the learning process is subject to, and actively defined by, his or her existing levels of knowledge and competence, as well as pre-existing schematic. Knowledge, as opposed to reality, may therefore be considered to be subjective, and constructed from past and present experiences. The application to educational theory and instructional design is thus dependent on the assumption that an individual's knowledge may be influenced by the learning process and guided to the 'correct' and objective truth.

Following this line of argument forward, it becomes clear that knowledge is therefore presumed rather than the absolute, with all hypotheses considered probabilistic and pending further review. It is also evident that rather than the immediate knowledge of the purely empirical, the mediated knowledge of empiricism rationally evaluated and extended offers a more comprehensive understanding. We can therefore conclude that a comprehensive theory is therefore more evidently useful in developing our knowledge than a single empirical result, whether quantitative or qualitative. The drive to seek knowledge beyond the empirical, *apriori*, leads us to conclude that this philosophy may be termed rationalist. The criteria for estimating the validity of theory may be evaluated against the criteria suggested by Kuhn (2012) of maintaining consistency both internally and with existing knowledge without giving rise to contradictions, can accurately describe and predict observable reality, avoid unnecessary complications and offer insight greater than before. The future validity of a specific theory may also be evaluated by assessing its capacity to extend beyond its original scope, and therefore avoid contradictions with other aspects of knowledge in the future.

3.4 The Structure of Human Memory

The fundamental principles of CLT are intimately related to the function of human memory, and how this is structured by the mind, with direct links to learning. The theory of memory from which CLT derives was initially described by Atkinson and Shiffrin (1968), and describes the division of human memory into three distinct functional units, each with their own operational strengths and limitations. It is important to note that we can guide memory processes through pursuing specific instructional design aspects to achieve a greater degree of learning and retention (Issa, Schuller, Santacaterina, Shapiro, Wang, Mayer, & DaRosa, 2011; Wiecha, Vanderschmidt, & Schilling, 2002). It is therefore imperative to consider human memory in more detail prior to examining the mechanisms employed by CLT to modulate them for learning. The three units of memory described are sensory memory where all inputs from the external world is received, working memory where conscious awareness and processing of sensory inputs and mapping to existing schema occurs, and finally long-term memory acting as a storage vault for information, experiences, and learned schema structures. There is also a dynamic process of communication and modulation that occurs between these units. Although functioning in unison, each section carries distinct defining characteristics.

3.4.1 Sensory Memory

In the course of human experience, we are constantly swimming in a metaphorical ocean of sensory data, encompassing all aspects of our existence across all degrees of possible perception. The data may compromise all the possible touch inputs across the skin, images seen, sounds, smells as well as any other that may be encountered. There is a distinct memory unit for each type of sensory perception, although for the purposes of learning auditory and visual senses are given prominence, reflecting both the delivery of education, as well as the overall structuring of human society. This is also apparent in medical education axioms dictating that most of the diagnostically relevant information may be gleaned from the history and close assessment of patients' appearance. In the model described by Atkinson and Shiffrin, sensory memory functions purely as a receiver and plays no role in the processing or prioritisation of data, which is a role reserved for short-term or working memory. Due to the large number of sensory memory subtypes, I will consider visual and auditory sensory inputs as exemplars.

The role of visual sensory memory, also referred to as iconic memory, has been examined before the inception of the Atkinson and Shiffrin model, with the first description of it functioning as a memory store being described by Sperling (1960). He noted that individual capacity was variable but extremely short in duration, and also documented its relationship to learning. The study also concluded that no meaning was attached to sensory stimulus, thus supporting the CLT principle that the processing of the information occurs beyond the sensory memory level. Subsequent empirical evidence suggested that the duration of visual sensory memory may be shorter than initially thought, but that processing and therefore communication to other memory units occurs just as rapidly, with attention and priming representing potential avenues to accelerate the process (Appelman, 1980; Kristjánsson & Campana, 2010). Importantly, while this effect may be utilised to enhance processing, no increase in the available amount of visual sensory memory is possible (Appelbaum, Cain, Darling, & Mitroff, 2013).

The description of phonological sensory memory, occasionally referred to as echoic memory also predated the development of the Atkinson and Shiffrin model of memory (Neisser, 1967). As the name suggests, it is primarily concerned with the sounds in the surroundings, ranging from the deliberate, such as lectures, to distracting incidentals. As with visual sensory memory, the stimulus is received, but no meaning is attributed to it at this level (Darwin, Turvey, & Crowder, 1972). Phonological sensory memory also shares the short duration characteristic, although it is observed to be of longer duration that visual sensory memory (Jaaskelainen, Hautamaki, Naatanen, & Ilmoniemi, 1999); however, the duration remains in the realm of mere seconds. This may reflect the evolution of human society and culture, with spoken word predating the development of the written language, although causality may be impossible to establish in this context.

Duration of sensory memory types are universally extremely short, estimated to be 2 seconds for visual sensory memory, but may be of slightly longer duration for other sensory memory types (Jaaskelainen et al., 1999; Mayer, 2010; Pratte, 2018). This suggests that the vast majority of sensory input never attains the level of conscious awareness. The determining factor in whether this input is elevated to consciousness or allowed to decay appears to be the level of focus and attention afforded to it. This may be a naturally-evolved mechanism to avoid overloading of the conscious mind. Viewed in combination, this suggests that the function of sensory memories universally act as a short-term record of descriptors of the sensory stimulus but do not contribute to the processing of the said stimuli, in concordance with the principles of CLT.

It is noteworthy that faults and failure in the conduction of sensory memory to the conscious mind has been noted as a key feature in multiple pathological conditions, including autistic spectrum disorders and schizophrenia, highlighting the pivotal role these memory systems play (Donkers, Schipul, Baranek, Cleary, Willoughby, Evans, Bulluck, Lovmo, & Belger, 2013; Grapel, Cicchetti, & Volkmar, 2015; Javitt & Sweet, 2015; Klintwall, Holm, Eriksson, Carlsson, Olsson, Hedvall, Gillberg, & Fernell, 2011; Strous, Cowan, Ritter, & Javitt, 1995; Tavassoli, Miller, Schoen, Nielsen, & Baron-Cohen, 2013). We can draw the conclusion that the rapid decay of sensory memory can been viewed as both a limitation, but a necessary one to avoid overload, as suggested by Bancroft, Hockley and Servos (2012) . These characteristics also lead us, by necessity, to deduce the presence of a higher level of memory systems.

3.4.2 Short-Term or Working Memory

A central principle of CLT asserts that learning is mediated via short-term, also called working memory [WM], where immediate actions and learning occurs (Cowan, 2014; Rose et al., 2004). As previously stated, a great deal of information is presented via sensory memory systems, which must be filtered to allow the distillation of the relevant information and elimination of background static noise. It has additionally been observed and documented that a further subdivision of WM into separate but synergistic components is possible, with phonological and visuospatial aspects in particular being processed in parallel, leading to a higher level of attention to a greater number of elements (Cavdaroglu & Knops, 2016; Plancher, Gyselinck, & Piolino, 2018). While this indicates that sensory memory capacity is large, it also points to a finite capacity for active attention to its contents, and to extract meaning out of the information, such as during learning, a dynamic management and prioritisation process is necessary.

WM functions by evaluating relatively small amounts of new information is incorporated and assimilated over short periods of time (Cowan, 2001b; Mogle, Lovett, Stawski, & Sliwinski, 2008; Unsworth, Redick, Heitz, Broadway, & Engle, 2009). The number of distinct components of information that may be simultaneously handled by the conscious mind (Miller, 1956). The components or elements themselves vary in definition in the literature, and there has been a move begun by Chase and Simon (1973) to utilise the term 'chunks' to describe the workings of working memory. Chunks are defined as a more inclusive 'compressed' structure, and may themselves include several elements, with existing learned schema or patterns enabling this compression (Glassman, 1999). While the process of using chunks enables the incorporation of a greater overall number of variables, the relative expansion of the individual elements leads to a smaller number of chunks than the seven suggested by Miller (1956). Cowan (2001a) distinguished the capacity of WM when considering fundamental elements compared to more complex chunks, concluding that four is a realistic limit in chunks, compared to seven elements. However, this complexity of what each chunk may entail, as well as the accumulation of combining chunks and elements simultaneously has led to variability in the empirically observed number of chunks (Gobet & Clarkson, 2004; Gobet & Simon, 1998). In analysing the available data, Mathy and Feldman (2012) concluded that the theoretical maximum is four chunks or seven elements, with some limited scope for individual variability. In practice, it is my view that this maximum is highly unlikely to apply, as human activity is more likely to require a combination of chunks and elements, potentially in rapidly changing combinations.

Certain pathological states offer insight into the key role of working memory, with attention deficit and hyperactivity disorder [ADHD], bipolar affective disorder and obesity shedding particular light on the critical necessity for this mechanism (Alarcón, Ray, & Nagel, 2015; Alderson, Kasper, Hudec, & Patros, 2013; Brown, Biederman, Valera, Lomedico, Aleardi, Makris, & Seidman, 2012; McKenna, Sutherland, Legenkaya, & Eyler, 2014; Stegmayer, Usher, Trost, Henseler, Tost, Rietschel, Falkai, & Gruber, 2014). Focusing on ADHD as a case study, Kim, Liu, Glizer, Tannock and Woltering (2014) in a cohort study compared young adults with and without a diagnosis of ADHD and found evidence of neural dysfunction of WM in those with ADHD compared to their peers. It has also been demonstrated that the neuropsychological aspect of ADHD, concerned with inattention, is far more closely associated with WM dysfunction rather than impulsivity or hyperactivity (Martinussen & Tannock, 2006). Brocki, Randall, Bohlin and Kerns (2008) demonstrated in a controlled cohort study of children with clinical diagnoses of ADHD that phonological and visual sensory information are handled jointly by working memory, indicating that the multiple streams of sensory memory become joint and cohesive at this level. The triangulation of sensory information towards a single object may serve to attribute meaning at this level.

In significant recent systematic reviews and meta-analyses concluded that attempting to enhance the capacity or function of WM in healthy individuals does not result in significant levels of improvement (Melby-Lervåg & Hulme, 2013; Melby-Lervåg, Redick, & Hulme, 2016), a finding which was mirrored in a meta-analysis by Rapport, Orban, Kofler and

Friedman (2013) in individuals with ADHD. Viewed in combination, these robust and large studies suggest that the capacity for WM is both innate, and not subject to modification. Interesting, Kofler, Alderson, Raiker, Bolden, Sarver and Rapport (2014) provided empirical evidence in a study of individuals with ADHD that deficit in WM accounts for the majority, if not all, the functional deficit in reactions. However, Alloway and Cockcroft (2012) compared matched cohorts of schoolchildren in the UK and South Africa with diagnoses of ADHD, and elicited differences in functional outcomes, suggesting that a mechanism external to WM could be utilised to maximise it function in practice. Furthermore, while the capacity in WM may not be expanded, factors such as pharmaceutical or illicit drug use may degrade it (Cousijn, Wiers, Ridderinkhof, van den Brink, Veltman, & Goudriaan, 2014; Lechner, Day, Metrik, Leventhal, & Kahler, 2015).

3.4.3 Long Term Memory

In contrast with sensory memory, long-term memory [LTM], as described in Atkinson and Shiffrin (1968), can act as both a storage for memories and experiences, as well as communicate this information back to the WM. Additionally, rather than the finite capacity of WM, LTM theoretically is in possession of limitless storage capacity. LTM also acts as a repository for previously constructed schema and automation (van Merriënboer & Sweller, 2005, 2010). However, LTM does not function beyond a consolidated, highly developed, and indexed library; no processing of the schema, knowledge or automated actions takes place at this level. It is interesting to note that Woodman, Carlisle and Reinhart (2013) in their review have also demonstrated that in occasions where schema or relevant knowledge exists in the LTM, it supersedes the working memory in setting the priorities for attention, and therefore modulating which aspects of sensory inputs are given priority and raised to the level of conscious awareness. Similarly, Kahan and Enns (2014) found that in times where clarity is lacking, individuals will attempt to fit distinct schema onto new sensory perceptions, superimposing the templates they are familiar with onto ill-defined sensory information. This can be translated into the CLT framework, explaining how schema fit into the chunks of working memory, as well as interpreting new sensory information.

Insight into how LTM function may be best gained through examining cases of dysfunction; pathologies that exhibit LTM dysfunction include Alzheimer's disease, where patients are unable to encode LTM schema and existing schema atrophy, sleep deprivation and multiple sclerosis, where vitamin D deficiency is thought to disrupt the process of LTM formation (Dermody, Hornberger, Piguet, Hodges, Irish, & Knopman, 2015; Koven, Cadden, Murali, & Ross, 2013; Prince, Wimmer, Choi, Havekes, Aton, & Abel, 2014; Souchay, 2007). These conditions demonstrate that LTM is a repository, but one that requires maintenance and upkeep in order to function effectively; additionally, the complexity of the mechanisms needed to maintain such a vital component is highlighted. In the particular study concerning sleep, Prince et al. (2014) indicated that a latency period is necessary, when no new input into LTM is placed, is required to enable optimal construction of schema. Should this period become lacking, new schema are insufficiently ingratiated into the LTM, and learning is therefore impaired.

From all these aspects it is apparent that in order for CLT to be effective, we need to effect a fourth element into the structure of human memory function to act as a manager and mediator between the various memory types and set the standards for prioritisation. This conceptual necessity is even more apparent given the findings of the review conducted by Reaves, Strunk, Phillips, Verhaeghen and Duarte (2016), which established that the modulation and attention can and does reshape the memory representation beyond the initial experience The study by Unsworth, Brewer and Spillers (2013) highlighting that retrieval from LTM is not a passive process, and is directly influenced by specific strategies employed by the individual. D'Esposito and Postle (2015) noted that this 'controller of controllers' is anatomically represented by the interplay of the prefrontal cortex via corpus striatum dopaminergic neuromodulation. The addition I propose to the Atkinson and Shiffrin (1968) model is the critical component of metacognition. Over the remainder of this chapter, I will consider CLT since its inception and describe the role of metacognition and how incorporating it into CLT contributes to the tapestry of the theory, with the effect of increasing its utility.

3.5 Forms of Cognitive Load

In CLT load is divided into three distinct subunits, with each type of cognitive load predominantly utilising a specific component of memory. As described originally by Sweller (1988), the three defined loads inherent in performance and learning are intrinsic, extrinsic and germane. Intrinsic load equates to the minimum essential information require, extraneous load is concerned with non-essential or superfluous information that may be related to the task but not to the process of learning, and germane load represents the effort involved in the cognitive strategies required to accomplish the task and develop expertise. While these forms of cognitive load are considered in separation, within CLT their impact and effects are considered cumulative. In this section, I will consider each component of cognitive load and how they may be considered within the context of medical education. I will also discuss the role of metacognition in the functioning of memory and thought processes and how this integrates into the overall framework of CLT.

3.5.1 Intrinsic Load

Implicit within the structural framework of CLT is an appreciation that each task carries an inherent level of complexity and difficulty. Intrinsic load describes the aspect of cognitive load that relates directly to the difficulty of the subject being studied (Cooper, 1998; Sweller & Chandler, 1994). More specifically, topics that depend on a larger number of separate elements represents greater difficulty to the learner, with complexity and difficulty increasing further still with the increase in interaction between these elements (Klahr & Robinson, 1981; Sweller

& Chandler, 1994; Sweller et al., 1998; van Merriënboer & Sweller, 2005). This concept is best illustrated by the example of learning a language, where the effort of learning vocabulary is less than composing phrases, and less still than appreciating the finer points of grammar and syntax. Within medical practice it is apparent that understanding cardiac valve anatomy is incrementally easier than understanding the disease symptoms and signs associated with valve dysfunction, and this is easier still than interpreting these symptoms and subsequent investigations to reach a diagnosis of aortic regurgitation causing congestive cardiac failure. As intrinsic load is essentially a dynamic relationship between the material to be learned and the learner, factors affecting the magnitude of intrinsic load can be attributed to either. An advanced learner may then be able to bring a higher level of competence and developed schema to the task, and thus minimise the associated intrinsic load (Bannert, 2002; Sweller et al., 1998).

By extension this leads us to conclude that some materials place a higher level of demand on learners' cognition than others, with this inherent difficulty being resistant to change by instructional design only (Ayres, 2006; Paas et al., 2004; Sweller et al., 1998). Nevertheless, some strategies have been developed to allow the offloading of the cognitive load in order to maximise learning efficiency. Strategies suggested to aid in reducing the magnitude of intrinsic load include scaffolding, simple to complex sequencing, 'just in time' intervention by the trainer, and attempting to simplify tasks by isolating specific elements and their interactions (Pollock, Chandler, & Sweller, 2002; van Merriënboer, Kirschner, & Kester, 2003). Within the example stated above, the trainee may be tasked to assess the patient history and examine in a specific sequence [scaffolding], progress from patients with single pathologies to comorbid patients [increasing complexity], be coached through the diagnosis [just-in-time intervention] or divide the task into history-taking, cardiac auscultation, ECG interpretation [isolation]. Nevertheless, this particular form of cognitive load represents significant challenges in instructional design.

3.5.2 Extraneous Load

Within CLT framework there is a recognition that non-optimised instructional design and techniques may inadvertently introduce a higher than necessary cognitive load. In a reflection of that a portion of the cognitive load is an inherent part of the task and forms the intrinsic load, it follows that a portion of the load does not directly relate to the task at hand and therefore constitutes the extraneous load. This form of cognitive load is defined as that component which is not necessary for learning and is therefore highly affected by instructional design (van Merriënboer & Sweller, 2005). It therefore represents a load primarily due to the learning materials, but which could have been circumvented, minimised, or eliminated entirely through utilisation of a different pedagogical methodology, and consequently extraneous load has been one a staple of CLT research. Four main mechanisms have been described which contribute to increases in the magnitude of extraneous load, and these will be evaluated in turn.

The first mechanism is split-attention and thus increasing the number of elements and interactions. Split-attention refers to distracting elements, such as questions from colleagues, telephone calls or receiving pagers, have been shown to have a detrimental impact on clinical practice and lead to a greater number of errors (Bower, Jackson, & Manning, 2015; Drew, Williams, Aldred, Heilbrun, & Minoshima, 2018; Jones, Wilkins, Caird, Kaba, Cheng, & Ma, 2017). From these studies it is also possible to conclude that with greater the task complexity, the less tolerance for split-attention effects is possible. This is congruence with the core principles of memory function and capacity discussed previously, as well as the CLT ideology of detrimental learning and function once the maximal load is exceeded. In learning environments, it is necessary to avoid overload by ensuring the integration of learning materials (Cerpa, Chandler, & Sweller, 1996; Chandler & Sweller, 1992; Kalet, Song, Sarpel, Schwartz, Brenner, Ark, & Plass, 2012). In clinical practice placing systems of practice that limit the extent of these interruptions, in combination with training to more effectively prioritise and manage interruptions may present a fruitful avenue (Campbell, Arfanis, & Smith, 2012).

Secondly, the introduction of problems and tasks without the presence of the required schema or competence may increase the extraneous load. This is of particular importance in educational practice as progression in competence requires exposure to such problems, and it is clearly not feasible to equip medical students and trainees with an exhaustive bank of knowledge for their practice. However, in the instructional design context we can introduce a high level of extraneous load when inadequate instruction and guidance is provided to learners, such as presenting them with incomplete information or lacking in ongoing guidance (Sweller, 1993). These conditions force the learner to proceed along weak lines of problem-solving techniques, such as trial and error or to search for the required information independently of that supplied in the instruction (Paas & Van Merriënboer, 1994). These techniques may lead the learner towards successful completion of the task, but they appropriate a large amount of WM to factor the increased number of elements, and therefore inhibit overall learning. Potential solutions to avoid this subtype of extraneous load include the use of initial demonstration of techniques, the use of 'worked examples' replete with complete or partially complete solutions or the use of exploratory 'goal-free' problems (Ayres, 1993; Brunckhorst, Challacombe, Abboudi, Khan, Dasgupta, & Ahmed, 2014; van Merriënboer, 2015; van Merriënboer & Sweller, 2010). All these techniques aim to supplement the capacity of the learner and provide schema to aid in task completion, thus reducing the related cognitive load.

Thirdly, the direct over-reliance and overburdening of one of the memory subtypes, exceeding the learners WM capacity and subsequently increasing the extraneous load. As the phonological and visual components of the WM function semi-independently, each with a related capacity, a greater overall total WM is available when both modalities are in use (Low

& Sweller, 2014; Sweller et al., 1998; Tindall-Ford, Chandler, & Sweller, 1997). Examples of include lower levels of engagement in telephone vs face-to-face discussions or presentation slides with large amounts of text but without a corresponding time afforded to allow the learners to read (Carpenter, Sullivan, Deshmukh, Glisson, & Gallo, 2015). However, there is evidence that utilising both WM subtypes does not lead to a doubling of an individual's capacity, rather the overall WM resource allocation is deployed flexibly, but maximal capacity is only accessible when both subtypes are employed (Morey, Cowan, Morey, & Rouder, 2010; Wahn & König, 2015). Furthermore, Morey and Cowan (2005) suggested that the level of co-operation between these subtypes can vary, even resulting in direct opposition and conflict when placing contradictory demands across WM and long-term memory.

Lastly, an increasing extraneous load may be through redundancy of information with multiple material representations of the same information, requiring the learner to utilise a greater proportion of their cognitive resources without additional benefit (Craig, Gholson, & Driscoll, 2002; Diao & Sweller, 2007; Kalyuga, Chandler, & Sweller, 2016). The most evident example of the redundancy principle is best described by the presenter who reads the presentation slides without adding further insights, leading to increased cognitive load. However, the use of complementary information in tandem has been demonstrated to increase comprehension. Fenesi and Kim (2014) provide empirical evidence to support the principles of CLT by demonstrating that presenting information using complementary data that avoids excess produces the best overall outcome.

3.5.3 Germane Load

The apex of the learning process in CLT is the development and incorporation of schema, ultimately leading to the automation of tasks, and the delegation of tasks to outside WM (Sweller et al., 1998). The schema are constructed via assessment of current situations, classifying the material comparison with existing knowledge and ensuing inferring and interpretation in order to construct a framework for future function (Mayer, 2002; Taylor & Hamdy, 2013). The load associated with these aspects, rather than the immediate problem solving is termed germane cognitive load. By necessity, if we take the maximum total cognitive load to be constant, the amount of capacity available for germane load, and the resultant learning, is highly susceptible to increases in either intrinsic or extraneous loads.

Following on from this raises a key consideration regarding germane load is whether it can be present in excess, and in itself hamper learning. Given a finite capacity, a hypothetically large amount of germane load beyond the individual learner may indeed result in a state of cognitive overload. From the study by J. J. van Merriënboer, J. G. Schuurman, M. B. de Croock and F. G. Paas (2002), where the intention was to maximise the germane load within the total cognitive load, we can infer that a real limit for germane load exists, and furthermore that this limit may be empirically determined. A demonstration of the impact of imposing greater germane load by Stull and Mayer (2007) shows that supplying schema can hasten the time to task completion compared to requiring learners to construct their own; however, the distinction of whether the increased time was purely for germane load, or if extraneous load was implicated remains unclear. A potential resolution is to define germane load as that required for learning, and classify any excess load, as Kalyuga (2007) did, to be extraneous load. This is, however, a *post-hoc* interpretation of empirical results.

The position of CLT is that instructional design should have the goal of maximising germane loads at the heart of the learning process, while accepting that this may in turn increase the overall load. The ideal schema should possess sufficient versatility to support the transfer of application across different scenarios. The utilisation of high-variability scenarios for training has been shown to enhance skill transfer across scenarios, suggesting a more comprehensive higher quality schema being developed, at a cost of higher levels of experienced cognitive load by learners (Chen, Grierson, & Norman, 2014; de Croock, van Merriënboer, & Paas, 1998; Sweller et al., 1998). It is important to note that increasing training variability by necessity dictates an increase in the surface elements, and as a result, the associated extraneous load. The impact on instructional design is therefore to balance these competing demands on learners' cognitive load, in order to optimise learning.

3.5.4 Metacognition

The role of metacognition within the realm of CLT is not as well studied as the theoretical aspects of intrinsic, extraneous and germane cognitive load (Kalyuga & Singh, 2015; Sewell, Maggio, ten Cate, van Gog, Young, & O'Sullivan, 2019; Tindall-Ford, Agostinho, & Sweller, 2019; Valcke, 2002). As sensory memory involves a large amount of data, which is not pertinent to the task or learning, the restrictive limits of WM and the complexity of retrieval of long-term memory, a mechanism for managing the overall system is required. It is metacognition that integrates the different aspects of memory, as well as directing the learning process (Kirschner, 2002a). Metacognition is therefore intimately related to schema construction, although this is largely acknowledged only implicitly within CLT (Sewell et al., 2019; Tindall-Ford et al., 2019). It is also valuable to note that while the capacity for cognitive load is predestined and finite, metacognition is more akin to a skill, and is thus may be improved with training (Scott & Schwartz, 2007; Stark, Mandl, Gruber, & Renkl, 2002).

The benefits of facilitating a metacognitive approach to CTL-led instruction is the enhancement of germane load while minimising the impact of the extraneous load, under the direct and real-time manipulation of the learner themselves, producing a personalised and tailored approach to learning. Nelson and Narens (1994) identified that metacognition functions as a method for continuously re-evaluation, bridging and co-ordinating the different aspects of memory function. The emphasis on specific aspects of perception and processing directly dictate the learning activity. Additionally, the executive role of metacognition in learning continues beyond the acute phase of experience, and into the construction of schema within the long-term memory (Nelson et al., 2004). Consequently, developing metacognitive skills to a higher level will give a greater ability to make decisions in real time and improved capability for developing effective schema for future function (Efklides, 2006). It is also apparent that a greater understanding of one's own though processes will afford a greater capacity for empathy with others, a vital component for effective professional practice (Nelson et al., 1998).

3.6 Evidence for Cognitive Load Theory

In order to establish CLT as a viable framework for study, with particular reference of educational research, it is imperative to consider the accumulated evidence for it. This section will evaluate the growing evidence from neuroscience for the different memory types discussed previously, metacognition and CLT, as well as existing evidence for how the human brain operates under the types of cognitive load, and the implications on cognitive load theory and metacognition. I will also consider the empirical background of CLT in practice, and how its application has led to significant advances in education. Finally, I will explore famous cases in medical literature and how these cases act as a practical the demonstration of CLT in health and disease.

3.6.1 Biological and Neurological Evidence

Our understanding of reality is dictated by stimuli received via our sensory organs. Sensory memory therefore serves as the critical link between the individual's mind and the external world. Using auditory memory as a case study, serving as an exemplar for sensory memory, we can evaluate the biological response to specific stimuli. The necessity to incorporate a biological approach to our understanding of CLT in application to the learning process has been underscored a growing body of evidence that indicates that the architecture of the brain dictates cognitive function, and places limitations on capacity in both healthy individuals and pathological states (Barbey, Colom, Solomon, Krueger, Forbes, & Grafman, 2012; Di Martino, Yan, Li, Denio, Castellanos, Alaerts, Anderson, Assaf, Bookheimer, & Dapretto, 2014; Funk & Gazzaniga, 2009; Murray & Spierer, 2009). Moreover, experiences, particularly during formative years can actively induce changes and mould the architecture towards specific directions (Fox, Levitt, & Nelson III, 2010). As CLT necessitates developing instructional design techniques that act in synergistic symbiosis with native functions, this is a natural starting point towards evaluating the evidence for the theory.

Neuroimaging techniques have enabled the localisation of cortical and subcortical regions that respond directly for auditory stimuli (De Santis, Spierer, Clarke, & Murray, 2007). Current evidence for persistence of auditory sensory memory suggests that it may persist for very short periods, persisting approximately 10 milliseconds, although this may be up to 10 seconds in some cases (Deouell, Parnes, Pickard, & Knight, 2006; Sams, Hari, Rif, & Knuutila, 1993). This longer persistence period is particularly evident in cases where close attention is paid to the stimuli, suggesting that it serves as a period of transfer to working memory. Neuromagnetic evidence supports this hypothesis, with recruitment of temporal integration in cases where auditory memory retains stimuli for longer periods (Loveless, Levänen, Jousmäki, Sams, & Hari, 1996). The mechanism for encouraging this persistence, effecting temporal lobe recruitment, and focusing attention can be deduced to lie outside of sensory memory.

It is primarily through the medium of functional Magnetic Resonance Imaging [fMRI] that the evidence for working memory has become evident. Investigations have revealed that working memory interprets the sensory memory inputs as interpreted on the cortex, but also recruits the parietal and prefrontal cortices (Funahashi, 2006; Ikkai & Curtis, 2011; Smith, Jonides, Marshuetz, & Koeppe, 1998; Wendelken, Bunge, & Carter, 2008). Individual differences in the capacity of working memory have been observed and demonstrated to persist across all aspects of sensory modalities (Carretti, Borella, Cornoldi, & De Beni, 2009; Daneman &

Carpenter, 1980). With regard to learning and schema formation, Seidler, Bo and Anguera (2012) found that the process of organising individual elements into chunks begins at this level; however, continued adaptation and schema finalisation did not appear to occur within working memory. Again, this suggests the presence of a mechanism that organises experiences and integrates schema into LTM but is external to the structure of memory itself.

The temporal lobes and the hippocampus play a distinct role in the consolidation of information into LTM, Of particular note, the process of establishment of schema within the LTM necessitates a sleep period (Dudai, Karni, & Born, 2015; Schönauer, Grätsch, & Gais, 2015; Simons & Spiers, 2003). Chambers (2017) identified that this process of integration and schema formation appears to be an active one, with dynamic remodelling of existing schema and reorganisation of existing knowledge. In common with other memory types, the prioritisation of data, with focusing on the relevant and selective neglect of the distractors is vital for effective function (Anderson, Green, & McCulloch, 2000; Feld & Born, 2017). This suggests that the same mechanism is active across all memory types, implying that the mechanism is not confined to a single memory type, but rather it is an independent apparatus acting across the whole of memory function.

It is interesting to note that different sections of the prefrontal cortex [PFC] are active on fMRI when individual sensory modalities are stimulated; however, novel areas are active when co-ordination of these modalities is required, indicating an external mechanism managing the co-ordination process (D'Esposito, Postle, & Rypma, 2000). The multitude of auditory stimuli is actively filtered to allow attention to be paid to specific stimuli. This filtering mechanism is not static throughout the life of an individual, with Cook and West (2012) demonstrating through electroencephalography with advancing age. Additionally, Naveh-Benjamin and Kilb (2014) demonstrated the persistence of this effect across sensory modalities, linking it capacity to associate to prior experiences, but found it unrelated to sensory acuity. These hint at the metacognitive mechanism acting outside the memory system itself, functioning in symbiosis with memory but not forming a component of it. The separation of metacognitive function from sensory memory, and the variability in its capabilities, also suggests that it may be susceptible to training and improvement, making it of particular value in educational research and practice.

The weight of the combined evidence suggests that the critical aspect of memory function, with particular reference to learning, is metacognition. This mechanism exists in parallel to all three forms of memory but acts across all types. It is here that the prioritisation, attention, as well as the essential action of neglect is initialised. Metacognition therefore functions as bridge between sensory memory and working memory, avoiding the flooding of working memory with an ocean of sensory inputs, it can also focus sensory memory on particular inputs, enhancing its retention. Metacognition also operates as a pathway between working memory and LTM, retrieving appropriate schema for interpretation of sensory inputs, chunking them as appropriate. It also continues to act to transfer new schema into the LTM, acting beyond conscious control to consolidate them.

3.6.2 Empirical Evidence

Long-term memory and schema already acquired are actively superimposed over sensory information, explaining the underlying basis of incorrect perception such as optical illusions (Fan, Hutchinson, & Turk-Browne, 2016). Another valuable insight supportive of CLT is the finding that working memory capacity functions as a shared pool for all sensory modalities (Salmela, Moisala, & Alho, 2014). Additionally, Brady, Konkle, Gill, Oliva and Alvarez (2013) suggested that the limit of function is common to working and LTM, signifying that the limit lies at the intersection of the two. These findings an external mechanism, metacognition, with its own distinct characteristics that acts as a bridge between memory types and co-ordinates function.

In view of the large volume of sensory inputs, as well as existing schema within LTM, a system for dynamically filtering the relevant from distracting information to enable the synthesis of coherent and appropriate actions. Lavie, Hirst, de Fockert and Viding (2004) explored this further and demonstrated that even in cases of high cognitive load, learners were capable of selectively neglecting distracting information and refocusing their working memory on the relevant data, and therefore avoiding cognitive overload; paradoxically, we can therefore project this to lead us to conclude that on occasions of cognitive underload distractors can play a greater role. Minamoto, Shipstead, Osaka and Engle (2015) demonstrated this effect in a series of experiments on undergraduate and postgraduate student, as well as suggesting that the modulating response lay outside the direct sphere of working memory and aimed to maintain a stable level of cognitive load. This emphasises the active role metacognition plays in the learning process when viewed through the lens of CLT.

3.6.3 Case Studies

The most famous case demonstrating the critical role of memory and its dynamic role in learning is the case of Clive Wearing [CW]. This is the case of a man who was an accomplished and successful musician, particularly renowned for being one of the foremost authorities on the works of Orlande de Lassus, who in his forties endured an episode of severe bitemporal herpes simplex encephalitis. Subsequent to several weeks unconsciousness he effected a recovery sufficient to regain consciousness, and it is at this point that the functional extent of his brain injury became apparent. Since that point, CW suffers from profound a case of amnesia and is left unable to transfer memories from his working memory to his long-term memory and as such his existence is confined to the capacity of his working memory (Wilson & Wearing, 1995). Interestingly, this antegrade amnesia did not impact his musical ability, and he retains both his talent and capacity to read musical notation, for example. However, CW is unable to learn new skills, and is not able to learn new skills. He believes that he has just woken from a state of unconsciousness, his room is strewn with notes to himself as he attempts to record new memories. However, he doubts their authenticity as he has no recollection of writing them, although he can recognise his own handwriting.

A further patient, SZ, with a similar injury reported on by Cavaco, Feinstein, van Twillert and Tranel (2012), was also a musician, although not to the same professional standard. While his functional deficit was the same, he also retained his abilities to play music. It is important to note that both individuals conserved their unique playing style, including SZ maintaining particular idiosyncratic errors. This has been noted to be in common with other cases of amnesia, where learned skills persist after the development of dense antegrade amnesia secondary to temporal lobe injury (Anderson, Rizzo, Skaar, Stierman, Cavaco, Dawson, & Damasio, 2007). This is distinct from other forms of cognitive impairment, where the acquisition of new skills and knowledge is possible.

We can therefore conclude from these cases that cognitive impairment is not equated with memory functional impairment. Furthermore, the function of the memory system as a whole, with dynamic cohesion between the different subunits is not an intrinsic part of sensory, working, or long-term memories, but is reliant on another unifying mechanism. It is this mechanism that is alluded to in the form of metacognition, where the different memory subunits interact, attention priorities are set and encoding of schema into long-term memory is initiated. The clinical cases of CW and SZ both highlight that pathology at this level is directly linked to inability to learn.

From an educators' point of view, with particular reference to instructional design, this presents both a challenge and an opportunity. The challenge presented to us is a greater degree of complexity, as we need to include the role of metacognition into teaching paradigms, both in the form of instructional design constructed to take account of the capacity of metacognitive skills and also in direct training of metacognition as a discreet skill. As already discussed above the capacity of working memory currently forms an innate bottleneck of learning, but it may be that increasing metacognitive capacity may enhance optimisation through maximising its usage. This could represent a potential prospect of developing enhanced pedagogical techniques with increased knowledge density.

3.7 Limitations

In order to gain a full appreciation of the implications of CLT in educational practice, it is important to acknowledge the boundaries of the theory. Close study of these aspects will allow for understanding how CLT may be used to develop effective instructional design methods, as well as the constraints placed on the generalisability and implementation of CLT in practice. I will consider initially the theoretical limiting factors, followed by examination of the empirical limitations encountered in CLT investigations.

3.7.1 Theoretical Conflicts and Limitations

A central tenet of CLT is that the different forms of cognitive load produce a cumulative effect, with the total load essentially equalling the sum of its parts. Initially in Sweller et al. (1998) claimed that the different types of load are directly additive and cumulative, which was later reasserted in Paas, Renkl and Sweller (2003). The addition of the different types of load is, however, dependent on the different forms being the same category, as otherwise the interaction between the different forms may not be possible. If, for example, sensory memory represents the received information of the external world, with short-term and long-term memories representing purely cognitive processes, then it would have implications regarding the different types of cognitive load. From this stance it is difficult to argue that the separate loads may be effectively added in a purely summative form. A view presented here to counter this point is that, in contrast to memory, intrinsic load, extraneous load, and germane load represent the cognitive experiences of the individual, and therefore they are intimately related and intertwined. We can then interpret them as subunits of cognitive load as a whole, with their weight and impact being cumulative.

As CLT is based on the theory of memory as described by Atkinson and Shiffrin (1968), there is an underlying assumption that working memory capacity is both finite and fixed. This was initially hinted at by the assertions made by the study by Miller (1956), where the number identified was indicated was seven discrete elements. However, as explored by Mathy and Feldman (2012), the number is modified by the using chunking to coalesce multiple elements into chunks, increasing the total capacity, at the sacrifice of being able to manage a smaller number of chunks than seven. In both these cases, the assumption that the capacity to manage chunks or elements, singularly or in combination is unalterable is retained. This is in apparent contradiction with the practical reality of progression through training, as tasks which lay beyond the individual the first time due to a high number of interacting elements will continue to remain so, which is in contradiction to experience where gradual improvements is possible, as best described by Vygotsky's zone of proximal development (1980). This may be countered through the use of schema formation in the long-term memory, allowing a greater number of elements to be evaluated simultaneously. With specific reference to the zone of proximal development concept, this is explained through the acquisition of schema by incorporation of directly related elements into a single chunk.

This is a similar criticism of CLT, regarding training and education of complex subject matters or high demand technical skills, which retain a high degree of complexity specifically due to a large number if unique and interacting elements, leading to a high potential for cognitive overload. From an educational perspective, this represents a major challenge when attempting to develop a learner to an expert stage, with the demands of more complex knowledge and tasks placing learners at a constant state of high cognitive load. Haji, Cheung, Woods, Regehr, de Ribaupierre and Dubrowski (2016) noted that one method for avoiding cognitive overload was to train in a 'stripped-down' low-fidelity environment, to aid learning early in the trainees' trajectory. Furthermore, Mills, Carter, Rudd, Claxton, Ross and Strobel (2016) noted that provided the total cognitive did not exceed the maximal individual capacity, training in a high cognitive load environment did carry the additional benefits, although adequate preparation was necessary to avoid overload. Therefore, we may conclude that complex tasks may be taught using a CLT-based instructional design, with the provision of a simplified initial model to allow the learners to develop appropriate chunks and schema. Once these are in place, escalating levels of difficulty and complexity should be within the capacity of the learners. Alternatively, Kaylor (2014) suggested that providing scaffolding and a framework prior to learners attempting a new topic or task may also present a possible solution.

A key criticism of CLT is that while it has been theoretically deployed prior to implementation of specific curricula (Kaylor, 2014; Naismith, Haji, Sibbald, Cheung, Tavares, & Cavalcanti, 2015) and multiple studies utilise it as an analytical lens (Burgess, Phelan, Workman, Hagel, Nelson, Fu, Widome, & van Ryn, 2014; Camos & Portrat, 2014; Minamoto et al., 2015), the interpretation of findings appears to be largely *post hoc* rather than empirically derived. This can lead to a situation where all items negatively impacting learning can be categorised as extraneous load and component that carry a positive impact may be labelled as germane load during the analysis. Examples include studies by Große and Renkl (2006) and van Gog, Paas and van Merriënboer (2006) a lack of positive results was interpreted as being due to higher than anticipated extraneous load. This leaves CLT in a position where it becomes unfalsifiable (de Jong, 2010), casting questions over the validity of CLT as a framework for predicting pedagogical outcomes following intervention. An answer to this criticism can be formulated by examining the initial division and design of instructional techniques, concluding that the clarity between the different forms of cognitive load are not defined in experimental design, or that their inter-individual variability produces more nuanced results than we currently measure.

In my view this criticism stems from a misinterpretation of the concepts of cognitive load rather than an inherent failure in the framework of CLT. By its very nature, cognitive load is experienced by individuals during learning, rather than a purely designed factor. Instructional and curricular designs can retain an influence over the division between the intrinsic, extraneous, and germane loads, guiding the learner towards the developing of appropriate schema. However, the learner maintains a dynamic control over the process, and is able to assign a variable amount of cognitive capacity o specific areas throughout. Arguably, this affords CLT a dual role in education research and practice; initially, we can utilise this theoretical framework to minimise the amount of extraneous load and maximise germane load, and subsequent to learning we can redeploy CLT once more, this time with the goal of *post hoc* review of the practical implications, allowing for ongoing refinement for the following iteration.

3.7.2 Empirical Conflicts and Limitations

Given the strength of CLT in defending learning through worked examples, it is surprising that it has been observed that the use of these examples alone is insufficient to lead to schema development (Renkl, 1997). This can be the result of learners being unable to locate the critical information independently, mis-understanding without insight into the mistakes, or they may not enable learners to generalise appropriately (Anderson et al., 1997; Atkinson, Renkl, & Merrill, 2003; Renkl, 1999). These insights hint that unguided worked examples alone do not lead to the formation of schema or can lead to the development of incorrect or misleading schema. It is therefore necessary to provide continued supervision and guidance through the exposure to worked examples, with the learners required to complete an increasing number of steps with increasing competence (Dyer, Hudon, Montpetit-Tourangeau, Charlin, Mamede, &

van Gog, 2015), the use of examples with errors that need to be corrected (Heitzmann, Fischer, Kühne-Eversmann, & Fischer, 2015), or requiring the development of concept maps as part of the solution (Montpetit-Tourangeau, Dyer, Hudon, Windsor, Charlin, Mamede, & van Gog, 2017). These techniques refocus the learners onto the germane load of learner and thus schema development and have been shown to markedly improve the expansion and transfer of learning to other situations.

A further aspect of CLT that necessitates discussion is the practical implications of isolating a single facet of cognitive load to facilitate study and deliver meaningful results. This is further hindered outside of experimental settings as human activity is inherently complex, and often comprises multiple simultaneous tasks (Aggarwal & Ryoo, 2011; Ryoo & Aggarwal, 2009). Coupled with the high degree of variability between individuals, it is highly likely that cognitive load is experienced on a high personalised basis, making its use for instructional design for groups, where the majority of formal education occurs, limited. This becomes most markedly apparent in the expertise-reversal effect encountered with the worked example model of instruction, where novice learners gain most until a point of expertise is reached where worked examples alone become counter-productive (Kalyuga, 2007). This has been empirically observed in multiple studies (Ayres, 2006; Kalyuga, Chandler, & Sweller, 1998; Leahy & Sweller, 2005; Rey & Buchwald, 2011). However, in these studies a 'fixed' model of worked examples was utilised for instruction, and this may represent the inherent flaw in the investigations. Schilling (2017) and van Merriënboer and Sweller (2010) indicated that successful implementation of CLT-based worked examples is contingent on an adaptable variable difficulty level, which dynamically responds to learners, allowing progression to automation level of expertise; furthermore, Kirschner, Sweller and Clark (2006) suggested that CLT-inspired instruction requires intensive instructor input, at least on an intermittent basis.

Several authors have attempted to extrapolate from experimental study findings into realistic teaching environment (Mayer, 2005; Mayer & Moreno, 2003; Sorden, 2005; Sweller et al., 1998). Nevertheless, interpretation of experimental results in the real world presupposes the validity of this translation. The contrast between the two settings may be evident by considering the core concept of cognitive overload. In experimental models the design model in CLT research is to produce a sudden form of overload; however, in real learning environments, learners utilise a variety of techniques to avoid such an instantaneous event (Bodemer & Faust, 2006; Chang & Ley, 2006). The experience of cognitive overload is therefore more likely to be a slow or subacute process. Interestingly, Fraser, Ma, Teteris, Baxter, Wright and McLaughlin (2012) in a study of medical students during simulation training found that cognitive overload presented as psychological stress and, reciprocally, addressing and removing this emotive stress led to enhanced technical performance. This is evidence that cognitive overload in the real world may appear as a psychological component, with increased stress and burnout, in contrast to the experimentally observed task-specific failure. While this is evidence that cognitive overload presents differently in experimental and non-experimental contexts, it does suggest that cognitive overload as a concept is a valid observable phenomenon. These findings also support the role of metacognition in CLT, highlighting that in practice contexts cognitive overload, as compared to failure to complete tasks successfully is related to metacognitive capability.

A related question regarding CLT theory in research is connected to the direct measurement of cognitive load. Despite the principle of CLT being that learning is hampered when the cognitive load capacity is exceeded (Sweller et al., 1998), studies have not identified the critical threshold of maximum capacity. Rather, studies such as J. J. van Merriënboer, J. Schuurman, M. de Croock and F. G. Paas (2002) and Spruit, Kleijweg, Band and Hamming (2016) tended to compare states of higher cognitive load with states of lower cognitive load, providing a comparison. In response, there have been multiple attempts to develop objective measurement techniques, with the aim of obtaining a valid, reproducible, and objective scale of cognitive load (Haji, Rojas, Childs, de Ribaupierre, & Dubrowski, 2015; Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Paas, van Merriënboer, & Adam, 2016; van Veen, Engelhard, & van den Hout, 2016). However, Naismith, Cheung, Ringsted and Cavalcanti (2015) noted that while the devised scales appear to be reliable in measuring the level of intrinsic load, they lack consistency extraneous and germane loads. A further systematic review of cognitive load measures as a major source of inconsistency in research outcomes, with a more precise measurement tool to inform CTL based instruction design.

3.8 Summary

Cognitive load theory is an attempt to apply the understanding and insight of neuroscience to educational research and practice. It ascribes certain functions to specific portions of human memory, namely sensory memory, working memory and long-term memory, combine to allow learners to acquire new knowledge and develop schema. The three core assumptions of CLT are the processing through separate channels of sensory memory, the finite capacity for cognitive processing and the assumption that learning occurs through the development of schema to allow for automation of actions in the future via co-ordinated cognitive processes (Mayer, 2005). Automated actions via the utilisation of schema require less working memory capacity to implement, leaving spare capacity for additional tasks. Expertise can therefore be defined as the possession of domain-specific schema, coupled with the capacity to apply them appropriately.

In this review of CLT, the addition of metacognition to the existing descriptions of the theory, act as the mechanisms that co-ordinates the functions of different memory systems, as well as dynamically managing the different forms of cognitive load, avoiding overload (Kirschner, 2002a). As such, metacognition is critical to the learning process, as well as serving as a protective apparatus (Nelson & Narens, 1994; Nelson et al., 2004). Furthermore, in contrast to the finite and static capabilities of the different aspects of memory, metacognition offers potential to improve with training (Efklides, 2006). Metacognition is therefore unique within CLT, as it offers us an opportunity to develop the skills of the learner, as opposed to refining the instructional design, equipping learners with the aptitudes needed for learning at both the present and future.

The role of metacognition is further highlighted when we consider that a reduced total cognitive load does not lead to dedication of redundant resources to germane load and thus effect learning without further intervention (Hessler & Henderson, 2013; van Merriënboer & Ayres, 2005). Indeed, multiple studies have focused on the need to focus on motivation and engagement of learners (Iskander, 2018; Lewis, Frank, Nagel, Turner, Ferrell, Sangvai, Donthi, & Mahan, 2014; Nagy, Zernzach, Jones, Higgs, Bowe, & Boggs, 2015; van den Berghe, Tallir, Cardon, Aelterman, & Haerens, 2015), with subsequent evidence highlighting increased engagement induces the formation of schema (Kirschner, Kester, & Corbalan, 2010; Nusbaum, Yu, Chen, Kong, Sun, & Zheng, 2014; Sewell, Boscardin, Young, ten Cate, & O'Sullivan, 2017). It is therefore appropriate and imperative to account for metacognition in CLT-based instructional design. By extension we can also conclude that in a similar manner where an excess of cognitive load may prove harmful to learning by inducing overload, insufficient cognitive load may fail to adequately engage resulting in cognitive underload, and also be detrimental to learning. Recruitment of the learners' metacognitive capacity is therefore an indispensable part of successful management of cognitive load, tailoring it to the individual need.

For the purposes of this research, I intend to focus on metacognitive aspects of CLT, with the aim of developing a simulation training program for medical students aimed at maximising their metacognitive skills, and therefore enhancing their resilience.

4 Methodology and Methods

This chapter discusses the underlying ontological and epistemological basis for the project, situating the research within the post-positivist paradigm and proceeds to justify the methodology chosen to answer the research questions. I also describe the methods deployed here, from the population and sampling, data collection tools, analysis and potential risks to the study. Following that, the justification for a mixed methods approach is stated, and ethical issues considered I will also discuss alternative methodological strategies and why they were ultimately rejected.

Studies attempting to enhance resilience have been composed of feasibility and acceptability studies, with limited attempted to evaluate the impact and behavioural change after training (Bird, Martinchek, & Pincavage, 2017; Sood, Prasad, Schroeder, & Varkey, 2011). The purposes of this study is to expand on this body of knowledge, explore and evaluate the resilience training further, assessing the gain with training and the impact on behaviour. This follows the principles of evaluation as defined by Kirkpatrick (2007), namely reaction and receptivity to training, the learning gain, behavioural changes, and end-results and outcomes of the training . The initial step required was the clarification of the baseline level of resilience in medical students. This was followed by the training intervention targeting resilience enhancement, and the subsequent re-evaluation of the level of resilience in the training group, as well as the resultant behaviour change.

4.1 Ontology and epistemology

It is important to consider the philosophical underpinnings of research and how they relate to the overall strategy employed in research. Ontology is concerned with the nature of reality and being, while epistemology is centred on the nature of knowledge (Crotty, 1998; Garner, Wagner, & Kawulich, 2016; Scotland, 2012; Stalker, 2009). Therefore, while ontology evaluates the nature of being and what can be discovered, epistemology describes the ways this may be discovered. It follows that methodological choices must be grounded in the philosophy of the researcher.

Although multiple paradigms may be described, with subtle differences dividing them on a continuum, it is best understood, and my position explained through considering the opposing extremes. These extremes are positivism and interpretivism (Cowling, 2016; Ryan, 2018). Each of these paradigms offers a different perspective on reality and the phenomenon under examination, as well as how this examination should take place. Each has distinct assumptions and demands of the research.

Positivism is grounded in the traditional scientific method, with hypotheses derived from the senses and tested empirically (Pierre, 2016; Watkins, 2018). The philosophy of positivism has four core principles, phenomenalism, deductivism and inductivism and disinterest (Comte, 2019). Phenomenalism dictates that the only knowledge regarding a phenomenon can be gained using sensory data, deductivism relates to the development of hypotheses derived from the available data, where these hypotheses are verifiable or refutable. This leads to the inductive process, where the accumulation of verified hypotheses allows for the construction of natural laws. Finally, the research must be interested in the objective findings of the research, conducted in a value-free manner.

The underlying assumptions of positivist research is that there is an independent, objective reality, with knowledge separate from the researcher and the study subjects (Comte, 2019; Watkins, 2018). The goal of research is to uncover the reality through systematic inquiry.

Knowledge can therefore be independently verified, without subjective influences (Dammak, 2015). Positivist research therefore tends to lean towards quantitative research methodologies.

At the opposite side of the continuum lies interpretivism. This paradigm begins with the declaration that the reality of human experience is socially constructed and lies on a plane separate to that of physical sciences (Capps, 2019; Williams, 2000). It would therefore not be appropriate to utilise the same research strategies as the physical sciences when examining the social sciences. Furthermore, as reality is socially constructed and individually interpreted, it is not possible to have an objective understanding of a phenomenon. Rather, it is the personal experience that attaches meaning to the subject matter. From that stance, it is easy to understand the qualitative approach adopted by the majority of interpretivist research. While this offers a rich evidence, with significant internal validity, presenting a narrative that offer justifications, it is limited by reduced generalisability (Scotland, 2012).

However, positions at the extremities are unlikely to offer the most accurate representation. Post-positivism evolved as an adaptation of the positivist paradigm, with a softening of the empirical epistemological stance (Phillips & Burbules, 2000). Post-positivism takes the stance that theories can be refuted, but they cannot be categorically proven to be correct (Ladyman, 2002; Young & Ryan, 2020). Phenomena, and reality in general, are understood through a series of closer approximations, instead of completed natural laws. Nevertheless, post-positivism in common with positivist philosophy, maintains a belief in an objective reality that is independent, tangible and measurable (Ladyman, 2002; Phillips & Burbules, 2000; Young & Ryan, 2020).

This approach dictates that theories are the best known way of organising the existing knowledge, accepting that they may be refuted or replaced by more suitable theories in the future (Kuhn & Hacking, 2012). Rather than reaching a concrete resolution to a research question, the focus is on the iterative approach of better understanding and development (Young & Ryan, 2020). Beginning from this stance, it is logical not to remain irrevocably interlocked to one methodological approach. Post-positivist research paradigms deploy quantitive, qualitative or mixed methods strategies, aiming to triangulate and approximate reality with greater fidelity.

4.2 Mixed methods research design

The research questions as stated earlier attempt to evaluate virtual instruction to deliver meditation training, define the baseline level of resilience in the medical student population, evaluate the impact of meditation training on resilience, and assess the behavioural change resulting from the training program. In order to answer these questions, it was necessary to embrace both quantitative and qualitative research methods. Adopting this approach enables the capture of a more holistic picture of resilience in medical education, triangulating the effects on resilience (Johnson & Onwuegbuzie, 2016; Onwuegbuzie & Leech, 2005). By using a mixed methods research design, I was able to capture the distribution of resilience in the target population, the magnitude of change with training, as well as the subjective experiences of the participants and their behavioural change. The combination of these aspects serves to add meaning and context to the quantitative measurements, while the quantitative measurements may augment the narrative through a degree of precision. The utilisation of a mixed methods research process adds insight that would not be available through the adoption of a solely quantitative or qualitative methodology. However, the use of a mixed methods design added a layer of complexity to the data capture process, and increased the demands of taking part in the study for participants.

While using mixed methods research design is consistent with the stated ontological and epistemological stance of post-positivism, it raises an issue regarding the integration of what are two fundamentally distinct forms of data, despite the appeal of combining methods with distinct strengths (Brannen, 2017). Rather than a simple addition of one type of data gathered to the other, mixed methods research requires a careful consideration for the underlying reason, balancing the added value of different methods with the additional challenge of integrating the results (D. Morgan, 2014). There is an additional consideration on how best to structure the research to bring together the two types of methods in a synergistic manner that informs the answers to the research questions (Creswell, 2011).

It is important to consider how the data drawn from quantitative and qualitative methods may be combined. There have been five ways of combining the findings in mixed methods research, depending on the relative strengths and respective roles each form of data plays in understanding the phenomenon under investigation (D. Morgan, 2014). The first of these combinations is where the quantitative and qualitative approaches are supplementary and may not be able to address the questions independently. The second way of combination is similar, in that the data from both approaches is also supplementary to provide a greater resolution of the phenomenon, but where one or both the approaches provide sufficient detail to address the question independently. The third approach requires investigating the same research questions using both methodologies, with the combined data providing a convergent answer. Fourthly, the methodologies are used to examine different areas, offering a distinct contribution to the overall understanding. Finally, a sequential approach where the findings from one methodology inform how the other is used. Although all of these combinations are rightly considered mixed methods research, each stipulates a different research design (D. Morgan, 2014).

The first three approaches may be combined into one under the umbrella of convergent data. Broadly speaking, data is combined in mixed methods research in three ways: convergence, accumulation and sequentially (Creswell & Plano Clark, 2011; Morse, 2010). Convergent data analysis is most suitable when the findings from one methodology need to be confirmed with the other, producing a high degree of certainty of the outcome, without any methodology taking precedence over the other. Accumulated data is added, utilising the strengths of quantitative and qualitative approaches separately to answer different aspects of the questions asked. It is possible to deploy the research methods flexibly, giving prominence to either as needed. Sequential data analysis is more appropriate where the results of one research methodology may provide a critical understanding for the other, where one technique serves as either a pilot for the main study, or as a follow up to the main study allowing greater exploration of specific findings.

However, while these distinct descriptions of mixed methods research described above provide a template for integrating quantitative and qualitative research methods, there remains the question of the order that data will be collected. While the fifth option has a clear stipulation that one method follows on from the other, the others carry a degree of ambiguity. This is because the emphasis in mixed methods research is placed on how the collected data will be interpreted, rather than focusing on when it was collected (Creswell & Plano Clark, 2011; Morgan, 2014; Morse, 2010). Data may be collected sequentially and analysed simultaneously, or collected simultaneously but analysed sequentially. Creswell and Plano Clark (2011) described embedded research design in mixed methods research. This approach involves conducting the quantitative and qualitative research simultaneously or in close temporal proximity, with the qualitative research intended to follow an intervention and analysed subsequent to quantitative data analysis. When used in combination, mixed methods allow for expansion beyond the first level in the (Kirkpatrick, 2007), which thus far dominates resilience research.

I pursued an approach beginning with a quantitative baseline followed by the intervention, then carrying out a quantitative and qualitative review. This allowed identification of a phenomenon, with appropriate statistical significance identified or refuted, followed by adding meaning and understanding through the rich narratives from individual's experiences. The data was collected in distinct steps, but the analysis of the quantitative results fed into the qualitative data analysis. Utilising this combination of approaches allowed for a more comprehensive review of the topic, with data analysis using a convergent strategy.

4.3 Population and sampling

The population chosen for this research project will be undergraduate medical students in UK medical schools, who undertook the virtual instruction meditation program, interviews and questionnaires. The rationale for choosing this group is threefold. First, this is the last truly common step for all doctors across all specialties. Secondly, the student population at this point have limited clinical experiences and are able to relate learning to the clinical environment, but have yet to undertake full-time clinical work. Resilience training at this point can, therefore, be seen as a form of ' just in time' training (Asnani et al., 2015; Houpy et al., 2017). Thirdly, targeting intervention at the medical school curriculum level will enable future dissemination of any findings to be carried out more rapidly and effectively than attempting dissemination through the much more numerous centres of clinical practice.

All UK medical schools were invited to participate, with an invitation sent to all medical education departments explaining the project, its goals and aim, with four medical schools participating in the full project. A standard post was made in participating institutions via the institutional virtual learning environment inviting volunteers to take part in the initial survey. Participants were then asked to volunteer themselves, self-selecting for the second phase of the study. As the sample will be evaluated before and after the intervention, with a relatively short time-lapse between evaluations, no independent control group was included in the study, with the baseline level acting as a natural control.

In order to determine the required number of responses for statistical analysis of the results, the sample size calculations carried out using a one-sample, one-tailed non-inferiority or superiority test, with an 80% power and a type I error of rate of 5%. The null hypothesis here represented a failure to improve the level of resilience with the training programme implemented (Chow, Shao, Wang, & Lokhnygina, 2017). Details of the power calculations are found in Appendix A. The predicted sample size to allow for the detection of change in resilience level using a one way analysis of variance [ANOVA] was seventeen.

4.4 Medical schools and student demographics

Four medical schools agreed to participate in the project, and all students in each school were invited to participate. All the schools offered five-year medical degree programs. The school size varied from approximately 300 to 1500 students, with two schools including a compulsory resilience training component in their curriculum. Table 4.1 summarises key areas of differences between the schools; the number of students is variable, with differences based on the admissions, and acceptance of offers. The number shown in the table is a representative average, using a three-year rolling average, and rounded to the nearest 50. All schools offered a proportion of their incoming places to graduates of other degrees, although exact data regarding the proportions was not available. Two medical schools required additional entrance examinations, as well as the appropriate educational attainment, whether that took the form of compulsory education or a different degree. Two schools delivered their curriculum in an integrated design, incorporating various aspects by function or region in the human body, while two utilised a problem-based learning approach, with teaching around educational cases.

Students from all four participating medical schools were invited to complete the SSRQA online. Table 4.2 summarises the number of participants by medical school. The participation appeared to vary greatly by medical school, from 1% of school B, to 13% of school A. Although direct questioning for reasons to participate was not possible at this juncture, it formed a part of the semi-structured interviews at the latter stage. There was also a widespread distribution of years, with students in earlier years of the course more likely to complete the survey. In order to avoid exerting undue pressure on the students, each participating school was asked to send out only one repeat request for volunteers. The numbers shown were the final numbers of participants after all rounds of recruitment were completed, with no differentiation based on which round of recruitment they had responded to

School	Number of Students	Existing resilience training	Course Structure	Entrance exam requirement
A	**500**	**Yes**	**Integrated**	**No**
B	**1500**	**No**	**Integrated**	**Yes**
C	**1400**	**Yes**	**Problem-based learning**	**No**
D	**300**	**No**	**Problem-based learning**	**Yes**

Table 4-1 Demographics and breakdown of participating Schools

School	Number of participants
A	**69**
B	**16**
C	**17**
D	**10**
Total responses	**112**

Table 4-2 Summary of the number of participants by medical school

4.5 Procedure and Intervention

Participants were recruited by directly approaching the heads and secretaries of all thirty-nine medical schools in England and Wales via email and telephone. Each staff member received a full explanation of the study, together with a sample consent form and a blank Student Self-Questionnaire for Responses and Attitudes (SSQRA). These gatekeepers then informed their students about the opportunity to participate; students who volunteered provided their email addresses, which were subsequently passed on to the researcher. Informed consent was obtained electronically prior to any data collection. No piloting of the study was carried out, with all participants included directly in the study.

4.5.1 Intervention

For this study, an asynchronous guided meditation program was developed and delivered via a dedicated online portal. Training was provided to introduce the process of meditation, with guided meditation being available at increasing lengths, in 5 minute, 10 minute, 15 minute, 30 minute, 45 minute and 60 minute guided sessions, although participating students were able to terminate sessions earlier. Progression to increased duration of meditation was left to the initiative of each participant. Support, both technical and instructive, was available asynchronously, either via a contact form on the portal site, or via email. Each participant had an individual log in profile, which calculate duration or time spent in meditation at each log in, and the number of separate meditations sessions. No specific limits or guidance was provided for participants, in order to give each individual full autonomy on their participation level.

4.5.2 Phase 1 (initial survey)

Subsequent to institutional recruitment, students at each participating medical school were invited to take part in the SSQRA conducted online. The invitation was via each medical school's virtual learning environment, with the approval and endorsement of the relevant medical education department and the Dean of the medical school.

4.5.3 Phase 2 (intervention)

Participants recruited into this phase were asked to undertake sessions of virtual instruction in guided meditation sessions, with each session varying between 5 to 15 minutes. Each participant was instructed to meditate a minimum of four times per week, although more frequent meditation was encouraged. They were able to select the length of time that they spent meditating on each occasion. The participants were recruited into this phase for the duration of four weeks. Each participant was able to increase or decrease the duration of the meditation sessions, and had independent control of the frequency of the meditation sessions, without external prompts.

4.5.4 Phase 3 (resurvey and interview)

All participant who undertook the intervention in phase 2 progressed to phase 3. Following the completion of the four-week meditation period, participants were asked to complete another SSQRA in order to assess any changes in their levels of resilience. They also took part in a semi-structured interview, with targeting of questions to evaluate the subjectively perceived behavioural change. During interviews, I took extensive contemporaneous notes to gauge feeling and aid the subsequent analysis. There were 26 participants resurveyed and interviewed. All interviews were conducted online via Google Meet, Microsoft Teams and Zoom. Although this was during the pandemic and with active travel restrictions, this was intended from the beginning for practical. Each participant was interviewed once, with interview duration between 35 and 85 minutes, as guided by the participant, and to allow them to fully express themselves. Interviews over 60 minutes were carried out in one sitting, but required reconnecting due to limitations of the technology at the time. All interviews were automatically recorded and transcribed using artificial intelligence tools, with the transcription checked individually by me. This process was simple and straightforward.

4.6 Data collection methods

This project combined the use of the SSRQA survey, as described in section 2.1.2, with semi-structured interviews. The SSRQA was carried out at baseline, post-intervention and followed by semi structured interviews of medical students, in order to obtain a quantitative assessment of improvement in resilience, as well as the qualitative experiences of participants, focusing on areas of perceived behavioural changes subsequent to undergoing the program. The SSRQA, which has been developed for the purpose of evaluating levels of resilience to stresses in the general adult population (Alonso-Tapia et al., 2018). The SSRQA was administered via Google Forms.

The data analysis followed the order of the research questions, beginning with the acceptability and feasibility of virtual instruction utilising the interview questions, followed by the quantitative analysis to assess the change in resilience, and what factors were predictive for improvement. Finally, the data from the interviews was also used to draw out the behavioural change and subjective perception of improvements in resilience.

In order to be able to evaluate the change in resilience, the baseline resilience of medical students was assessed via the SSRQA. This was distributed across four UK medical schools. This established the variability and range exhibited in the study population, as well as the initial baseline level of resilience in the study participants, helping answer subsequent questions. Participants were then be recruited to undertake the virtual training program as the intervention being studied. The SSRQA questionnaire was repeated at the end of the intervention, and thus supplied a quantitative assessment of the gain in resilience through the training. Finally, semi-structured interviews after the intervention were used to capture the experiences and behaviour change after the virtual training program. Due to the digital and web-based data collection planned prior to the pandemic, and implemented throughout, there was no negative impact on data collection. The increased participant familiarity with the platforms by the time of the study led to an unproblematic experience.

4.7 Data analysis

The initial research question will call for a review of the strategies used to develop resilience in the professions identified. In order to answer this question, I intend to review each of the three professions in parallel, and subsequently perform a narrative synthesis and thematic analysis of the techniques used, using a literature review methods and meta-analysis as described in Punch and Oancea (2014) and Petticrew and Roberts (2006). These findings can then be used to interrogate the role of metacognition in resilience, and how developing metacognitive skills can act to manage the demands of a clinical career and guide positive responses to work-related stresses, and supply the answer to the second research question. The interview data will be used to address answer the third question, with the hypothesis that mindfulness training is subjectively interpreted as resulting in uniformly-increased resilience across all domains. Finally, through monitoring the number of minutes each participant spends over the course of the program and correlating it with the difference in resilience scores from the questionnaire, I will be able to assess the quantitative relationship between length of time spent in metacognitive training and level of resilience.

The questionnaire uses a Likert scale, with the results presumed to be of non-parametric in nature. Therefore, I will use the Mann-Whitney U test to assess for a statistical difference before and after the training program, with $p \leq 0.05$ used as a level of statistical significance. A thematic analysis will be used to interrogate the data from the interviews.

The audio recordings of each interview were transcribed using AI software and then carefully checked against the original recordings by the researcher to correct any errors. Following Braun and Clarke's first phase of familiarisation, the researcher read and re-read the transcripts while making reflective notes, before importing the data into NVivo for line-by-line coding to capture meaningful units of text. These initial codes were examined for patterns and collated into candidate themes, which were iteratively reviewed and refined until no new themes emerged, indicating saturation. To enhance rigour, the candidate themes were shared with three fellow doctoral candidates for a plausibility check, and the researcher maintained a reflective journal throughout the process to document methodological decisions, emerging insights and personal biases. Finally, the refined themes were clearly defined, named and organised into a thematic map, which was incorporated into the write-up in accordance with the sixth phase of Braun and Clarke's framework.

During analysis, several challenges emerged that offer useful lessons for future researchers. First, relying on AI-generated transcripts introduced occasional errors in punctuation and speaker attribution, which required meticulous manual checking to ensure accuracy. Future researchers should budget sufficient time for transcript verification or consider using professional transcription services where resources allow.

Second, determining when thematic saturation was truly reached proved complex. Without formal stopping criteria, there was a risk of either prematurely closing off new insights or endlessly chasing minor variations. To address this, I combined an informal threshold—no new themes after three consecutive interviews, with a plausibility check among three doctoral peers. I recommend that researchers establish clear saturation guidelines in advance and seek external feedback to guard against both over- and under-coding.

Third, working alone on coding raised concerns about subjectivity. Although I maintained a reflective journal to record methodological decisions and personal biases, having a second coder would have strengthened reliability. Future studies should, where possible, include independent peer coders and calculate inter-rater agreement to bolster the trustworthiness of findings.

Finally, iterative theme refinement in NVivo was time-intensive and occasionally disrupted the analytic flow. Keeping a detailed audit trail of code adjustments and theme definitions helped me track evolving ideas and prevented confusion. I advise emerging researchers to document each coding round and version their code-book to ensure transparency and reproducibility.

By anticipating these dilemmas, transcription accuracy, saturation judgment, coding subjectivity and documentation burden, and adopting strategies such as external checks, clear stopping rules and rigorous audit-trail practices, future researchers can conduct more efficient and credible thematic analyses.

4.8 Ethical Considerations

As indicated previously, participants were recruited from UK medical schools. The initial approach was via a member of the medical school staff acting as a gatekeeper and liaison point of contact. This member of staff was separate to the study, and acted as an external objective advocate for students at their institution. As such, each participating institution nominated a single member of staff to act as the liaison. The project and aims of the study were explained and participation invited. The data was stored securely at Lancaster University servers, with a decryption key allowing for the deanonymisation.

The interview recordings were transcribed using transcription software, which is also encrypted, and following checking of the transcriptions for accuracy by myself the recordings were deleted. Participation was on a voluntary basis only, with the declared incentive for the participants being the opportunity to enhance their levels of resilience and undertake meditation training. No other compensation, financial of otherwise, was offered. Assurances were made that refusal to participate in the study would not impact grades or performance at the medical school. Prospective ethical approval was sought and obtained prior to the recruitment of any study participants. Beyond the participant level, full institutional anonymity for research sites in the thesis and any subsequent publications was ensured.

An unexpected ethical consideration that occurred during the study was the outbreak of the global pandemic of COVID-19. In the UK, this led to final year medical students graduating early after final examinations, in order to be able to begin clinical practice. During this particularly arduous period, it would have been unethical to increase the burden on these students by conducting interviews. Therefore, final year students were advised of the situation, and excluded from the interview stage, with the option to proceed with it at a later date, if they requested. This affected three students who had undergone the intervention stage and the post-intervention survey, but were able to undergo interviews at a later point.

4.9 Chapter summary

The mixed methods design employed in this thesis was chosen as the most appropriate research method for investigating the development and enhancement of resilience in doctors, beginning with the undergraduate training. Through the use of quantitative and qualitative approaches, I was able to evaluate the use of a technologically mobile, online learning platform for resilience training. In using this approach I was able to construct a more thorough evaluation of the training intervention than would be possible through quantitative or qualitative means alone.

5 Results and findings

The empirical data obtained in this project has been organised around the research questions stated in the introduction. I have adopted a mixed-methods approach throughout, and have presented the data strictly on the basis of how it addresses the questions raised. In order to provide a framework and make following the data easier, it is useful to briefly restate the questions here. Firstly, there is doubt as to the nature of resilience as reflected in its distribution within the target population, and the implications this carries as outlined previously. It is then appropriate to consider the acceptability and feasibility of using virtual instruction to improve resilience. Following on from this, assessing the effectiveness of virtual instruction is necessary and the factors that influence it. Next, I evaluated the effectiveness of the training. Finally, the subjectively perceived changes in resilience-associated behaviours were explored.

5.1 Differences between medical schools and between year groups

As stated in the previous chapter, participants were recruited from four medical schools, and participation was across the different year groups. As each medical school recruits independently, and delivers undergraduate medical independently, it was necessary to establish the heterogeneity of the sample groups. In order to evaluate for differences between groups, I carried out analysis of variance testing comparing the baseline scores on the SSRQA. Analysis of variance (ANOVA) demonstrated no statistically significant variance in baseline resilience between different medical schools, with $F(4, 107) = 4.19$

p=0.743. Using Pearson's correlation coefficient, no statistically significant level of correlation was seen between students from different years of study. Figure 5.1 demonstrates the results by year of study, demonstrating significant overlap. No statistically significant correlation was evident between the scores and year of study in medical school.

Table 5.1 is the Pearson's correlation coefficient between the years of study, demonstrating that no statistically significant correlation between any of the years was evident at baseline.

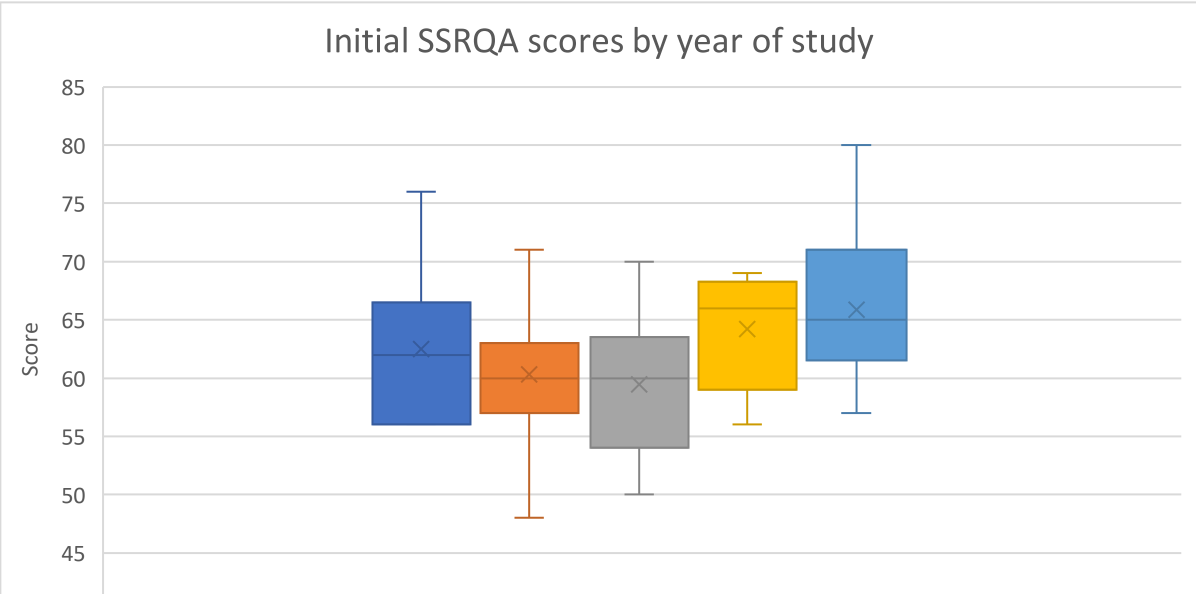


Figure 5.1 Baseline SSRQA scores by year of study

	Year 1	Year 2	Year 3	Year 4	Year 5
Year 1	**1.00**	**-0.23**	**0.16**	**0.20**	**-0.32**
Year 2	**-0.23**	**1.00**	**0.05**	**0.43**	**-0.26**
Year 3	**0.16**	**0.05**	**1.00**	**0.09**	**0.08**
Year 4	**0.20**	**0.43**	**0.09**	**1.00**	**0.00**
Year 5	**-0.32**	**-0.26**	**0.08**	**0.00**	**1.00**

Table 5-1 Pearson's correlation coefficient between years of study

Establishing that despite the range of recruitment practices at different medical schools, the different curricula and multitude of different experiences by each participant, the represent members of the same population. This is important to acknowledge at this stage of examining the results for two important reasons. Firstly, we can infer that the results of all study participants may be grouped and analysed as one population, which opens the door for statistical analysis of a larger group. Secondly, it suggests that resilience is similarly distributed in the population as a whole, and supports wider interpretations of the study findings.

5.2 Distribution of resilience in medical students

Given the homogeneity in SSRQA scores between different schools and across year groups, the grouped respondents were treated as one population. The pooled results were tested using Shapiro-Wilks and Kolmogorov-Smirnov tests, and were demonstrated to be not statistically different from the normal distribution. Figure 5.2 displays the scores from the survey, overlaid with the normal distribution. The scores were distributed between the lower limit of 48, and an upper limit of 80. The scores were centred around the mean of 61.59, and an interquartile range of 9.

As indicated at in the literature review section 2.1.4, the significance of resilience being normally distributed is the suggestion that it is a process of adapting to circumstances that serve to maintain a stable and healthy level of functionality over time, rather than a trait that is present or not (Galatzer-Levy et al., 2018; Norris et al., 2008). This intimates that there is a natural variability in the level of resilience in the population. Furthermore, as the normal distribution holds across populations, demonstrating its presence within the sample implies that it can be

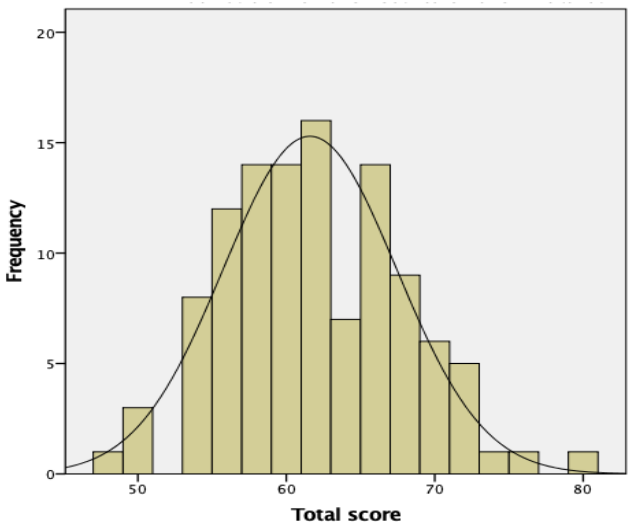


Figure 5.2 The distribution of scores in the initial survey compared to the normal

seen as representative of medical students as a whole. As a normally distributed trait, resilience training can be seen as enhancing a pre-existing facility, rather than attempting to introduce a new skill. There is an additional, subtle implication of a normal distribution to resilience, which is that the potential for improvement may not be uniform across the population. Individuals already in possession of a higher baseline level of resilience are not as likely have as much room for improvement as those with a lower baseline level.

5.3 Feasibility and acceptability

It was assumed at that the underlying motivation for students to take part in this training program would serve as a strong factor in determining their perception of the program. There is an increasing level of acknowledgement in the literature that participant motivation has a large influence on the success of training programs (Landers & Behrend, 2015; McGonagle, 2015). Therefore, exploration of each students' reasons for volunteering to take part formed a key component of evaluating the acceptability of the program. This was evaluated during the semi-structured interviews, where participants were asked about their motives, both for initially undertaking the baseline survey and continuing with the study. This was followed by examining their experience of the training program, and quantitively analysing the levels of participation, as recorded via the training portals.

The interviews commenced once participants had provided electronic consent and been sent a copy of the interview information sheet and blank SSQRA. Each participant received an invitation by email, which included a proposed schedule and a choice of video-conference or telephone format. Interviews were conducted between April and June 2025 and lasted between forty and sixty minutes, depending on the depth of participant responses. At the start of each session the researcher welcomed the participant, reiterated the study objectives and confidentiality procedures, and obtained verbal permission to record. A semi-structured interview guide was then followed, covering the core topics while allowing flexibility for participants to introduce new ideas. The researcher asked open-ended questions, used probing prompts to elicit richer detail, and paused as needed to ensure clarity and completeness of responses.

All interviews were audio-recorded using a secure digital recorder and stored on an encrypted university drive. Immediately after each session the researcher reviewed the recording to confirm audio quality and made brief reflective notes. Transcription was carried out by AI software and checked line by line by the researcher against the original recording to correct any inaccuracies. Transcripts were anonymised by replacing names and identifying details with participant codes and then imported into NVivo for thematic analysis. Throughout the process the researcher maintained a reflective journal to document emerging impressions, methodological decisions and any personal biases. A plausibility check of emerging themes was conducted with three fellow doctoral candidates, after which final themes were defined, named and organised.

5.3.1 Reasons for taking part in the study

Participants shared a range of motivations for taking part in the study, with four key themes emerging from their responses. In order to maintain a natural conversational pace to the interview, this was explored with each participant during the initial part of the interview, as an ice-breaker. Many were driven by curiosity about the topic, eager to explore an area they found intriguing. Others saw participation as an opportunity for personal development, hoping to enhance their understanding of resilience and its role in clinical practice. Some were interested in comparing their own perspectives and experiences to established norms, seeking insight into how they measured up against their peers. Additionally, a strong social influence was noted, as several participants mentioned that knowing a large group of their peers were also involved encouraged them to take part.

Beyond these themes, many participants highlighted that resilience as a crucial skill in clinical practice had been introduced to them before, either through formal teaching in medical school or informal exposure, such as reading medical journals or engaging in discussions with doctors during their clinical rotations. These prior encounters with the topic reinforced their interest and underscored its relevance to their professional development.

> *"It (resilience) kept coming up when talking to doctors on rotation. They all mentioned that there were a lot of things that knock you back, and I got told I need to find something to get me through."*
>
> *Participant Z*

> *"We had some stuff at med school that we were told was to help resilience. We were told it was important, but it's hard to see it as important as the stuff in the exams!"*
>
> *Participant S*

Two students stated that they had observed students or doctors experiencing difficulties and stress due to clinical experiences. On these occasions they had stated that they felt there was little they could offer to help. In all cases of participants offering this reason for taking part, they also stated that they wished to understand the topic of resilience in more depth and taking part in the study offered them an opportunity to explore this further.

> *"It got to me, when I walked into the coffee room to see him (a supervising doctor) in tears, with his head in his hands. He seemed so inconsolable, and I didn't know what to say. I just thought I don't want it to get to me like that."*
>
> *Participant P*

The second most prominent reason for taking part in the study followed on from the one highlighted above. After recognising that resilience is a useful skill to have, participants stated that they wished to develop this skill further and felt that there was little guidance available to them elsewhere. Participant H stated that although they regarded themselves as 'fairly good at getting over stuff', they saw the study as a potential learning chance and 'it couldn't hurt'. The two students mentioned above, who had seen colleagues overwhelmed by clinical experience, expressed a clear desire to develop themselves so they would not be placed in that situation themselves.

> *"I just thought it would be a good idea to have a chance to work on something for me. Something that would help me get through the rough and tumble."*
>
> *Participant P*

Thirdly, a desire to see how they ranked in terms of resilience compared to others was evident and expressed by a significant minority of participant as a reason for taking part of the study. While this was not presented in a competitive way, participants expressed the view that as long as they were not in a worse off position than their peers, then they were in a safe position and need not worry. Those that expressed this view tended to seek reassurance that they were indeed in possession of higher levels of resilience, and no further action on their part was needed.

> *"I think I cope better than most. I always seem to brush off things quicker than my friends, but it's always good to be prove it"*

Participant X

"Well, most people get on with it don't they? So if I'm at least average, then I should be ok too. If I'm better than that, then great!"

Participant C

Finally, a small number of participants stated that several members of their peer groups had stated that they either had already begun the study or were about to join. This made them perceive participation in the study as a normal action that they should also do in order to keep up with the rest of the group. While none stated explicitly that they were pressured into joining the study, they acknowledged that there was a degree of normalisation of the activity.

"To be honest, a few of my friends said they were going to [join the study] and I didn't want to miss out….I thought I could always drop it if it took up too much time or got boring."

Participant Q

5.3.2 Participants' experiences

As this study involved a guided meditation, delivered via an online platform in an asynchronous manner, it was important to examine how this was perceived by the participants. While all participants were familiar with online instruction and asynchronous process, their experiences were composed of recorded lectures and discussion boards. This study represented a different aspect of learning, as it required active involvement on their part. The existing familiarity with asynchronous online instruction provided the participants with a good grounding in the use of the portal. They reported that access and navigation were not problematic and facilitated being able to concentrate on the meditation. Of the 19 interviewed four had prior experience in meditation, but none practiced regularly.

While the guided meditation videos were simple to use, and enabled them to undertake the activity as needed, several expressed concerns. These involved two key areas; firstly, regarding being able to assess themselves if they are carrying out the exercises correctly, and secondly, on deciding whether to continue at the same level that they had begun or progress to longer meditation sessions. While feedback and support were available, this was not immediate, and left a number of the participants feeling frustrated at the perceived trial and error approach in the self-evaluation of the above points. One participant felt frustrated at the difficulty in judging these points while learning a new skill to the point of disengaging from the program in the latter half of the study.

> *"It [the online training portal] was easy enough to use. I liked how I could just dip in for when I had the time. It made it easier than when I used to [do] meditation classes"*
>
> *Participant H*

> *"The progression along with increasing session lengths was good. Having control of when to go for the next level when I felt ready was empowering. It gave me ownership … a sense of being in charge, made me want to keep going."*
>
> *Participant J*

Overall, the consensus was that this mode of instruction is an engaging one, offering advantages in terms of flexibility and adaptability. However, it was felt that there were disadvantages in the delay in receiving feedback, which created difficulties. There was a note that these were more pronounced at the beginning of the study, when the participants lacked familiarity with the meditation technique.

> *"The most annoying thing was when I'd send a question and it'd take a day to hear anything back. It was like trying to teach myself. I was never sure I was doing it right"*
>
> *Participant G*

> *"I didn't get it. I'd never done any meditation before. I wanted a bit more guidance. I didn't even know where to start really, so I ended up just giving up."*
>
> *Participant U*

This highlighted that a purely virtual instruction approach may not be suitable across the spectrum of the population, with a persistent role for active instruction in real time, which may need to take place.

5.3.3 Participation levels

From the data presented in Table 5.1 below, it is apparent that there was a great deal of variation in the level of participation as defined by the number of sessions, the length of each session and the total number of minutes spent in meditation. It was therefore necessary to examine the factors influencing the levels of participation. Below, I have presented the findings divided by the number of sessions and the lengths of sessions. As the total number of minutes spent in meditation is a product of these two elements, it was not examined separately. In Table 5.3 all measurements were rounded to the nearest whole minute before statistical evaluation. The participation varied per student. The mean score on the initial survey was 62.96, with a minimum score of 48 and a maximum of 74, and an interquartile range of 8. There was a considerable variation in the number of sessions, ranging from 5 to 27, a mean of 16.38 and median of 17.5 sessions over the study period. The mean length of session was 17.92 and a median of 19, with an interquartile range of 12. The mean total number of minutes was 311.04 with a median of 315, and an interquartile range of 284. Additionally, the total number of minutes was seen to be normally distributed, suggesting that there was an even dispersion in the overall level of participation around the mean, rather than the cohort being split between those who fully engaged, and those who did not.

Student	Initial SSRQWA score	Number of sessions	Mean length of session (minutes)	Total minutes
T	**67**	**27**	**28**	**756**
B	**53**	**26**	**22**	**572**
J	**50**	**22**	**25**	**550**
W	**60**	**25**	**20**	**500**
Y	**67**	**23**	**21**	**483**
F	**60**	**20**	**22**	**440**
P	**57**	**18**	**24**	**432**
A	**69**	**23**	**18**	**414**

Z	70	21	19	399
D	57	17	23	391
O	56	20	19	380
C	66	18	19	342
X	66	15	22	330
Student	**Initial SSRQWA score**	**Number of sessions**	**Mean length of session (minutes)**	**Total minutes**
E	62	20	15	300
K	48	10	24	240
N	65	14	17	238
U	70	9	22	198
Q	68	20	9	180
R	60	15	11	165
V	68	9	17	153
S	66	11	13	143
I	67	9	15	135
H	65	14	9	126
L	61	7	15	105
M	65	8	10	80
G	74	5	7	35

Mean	**62.96**	**16.38**	**17.92**	**311.04**

Table 5-2 Summary of the meditation for each student organised by total minutes in descending value

The key determining element that influenced the number of sessions across all participants was the availability of time. There was a perception that the time slot required was longer than that easily available to them. Others preferred to carry out their meditation in a more secluded setting, such as when they were at home alone. This placed external limitations on when they had opportunities to take part. Seven students undertook 10 sessions or less during the study period. In interviewing these participants, they also raised having difficulty in perceiving benefits from the meditation, which led to them participating less as the study progressed.

> *"In the end, I just didn't see the point. I didn't feel any different. If it wasn't going to make me feel any different then why go on?"*
>
> *Participant V*

> *"It was just not giving me any results. Somethings were still hard and some stuff was easy. I thought it would show some improvement sooner!"*
>
> *Participant G*

Three participants in this group stated that they had difficulties in carrying out the meditative practice itself. Having found themselves presented with this, they responded by retreating from the activity.

> *"It was just hard. Much harder than I thought it would be. There had to be an easier way."*
>
> *Participant U*

In contrast to this, there were those that managed to carry out 20 or more sessions during the 28-day study period. A total of eleven participants were in this group. There was a consistent theme that emerged in interviews around effective scheduling to incorporate the meditation into the daily routines, with eight participant opting for a timeslot either in the early morning or late evening.

> *"I thought that I could fit in a few minutes every day. But I'm always busy, always rushing. So I got the idea that I could do it in in my room before bed."*
>
> *Participant Y*

> *"The only time I reliably get is early morning, so I did it just after the morning coffee. "*
>
> *Participant W*

> *"Thing is I always forget stuff if it's not part of my routine. Only way I could keep this up for the whole time was to put it in my phone calendar, same time every day."*
>
> *Participant J*

When considering the length of meditation sessions, nine participants, including five interviewed, had mean session lengths of 15 minutes or less. This can be interpreted as indicating that they remained at the initial instruction level and did not progress further. Additionally, a mean time under 15 minutes is indicative that at least some of the sessions were terminated by the participant before the completion of the shortest guided meditation. When asked regarding this, the responses fell into two broad categories, either the interruption of sessions by outside influences frequently, or stopping the session due to not being able to meditate.

> *"I wasn't getting on with the meditation…just found it a bit too much to go for 15 minutes of nothing. I ended all the sessions early."*
>
> *Participant H*

> *"It turned out that 15 minutes is a lot longer than you'd think. Someone always walked in!"*
>
> *Participant P*

Eleven participants had mean times above 20 minutes, suggesting that they had a significant proportion of their sessions beyond the shortest session. These participants stated that as their confidence in their ability to meditate effectively increased, they felt more positive about attempting longer meditation sessions.

> *"I found the whole thing relaxing, and it got easier to focus, to do the 15 minutes. After a couple of times, I wanted to push myself, so I went for the longer sessions."*
>
> *Participant W*

> *"I really enjoyed it, at least once I got used to it. I'd originally thought I'd be able to manage the longest session without problems, but it took me a while to be able to get there. I think only got to the final stage a couple of times."*
>
> *Participant J*

Some had noticed that the meditation left them feeling calmer and less stressed, and as such they sought a higher dose in the hope of a greater effect.

> *"I don't know whether it was the meditation, or just the taking time out of everything, but I liked it. After that, I just wanted more."*
>
> *Participant A*

> *"It calmed me down. I'm always taking on a lot so setting time for this kinda made me stop and rest. I tried the longer sessions a few times. Don't think I ever actually finished a longer one though."*
>
> *Participant N*

5.4 Efficacy of virtual meditation training on resilience

After each participant completed four weeks from enrolment into the intervention phase, a repeat SSRQA survey was sent to them, with the results correlated to each participant. All participants completed the post intervention survey. There was a stipulated requirement for the interval between completion of the intervention and this survey to be within 14 days, in order to ensure the capture of short-term effect. The median length of time between completing the intervention and the post-intervention survey was 2 days, with a range between 0 and 14 days. There was a mean improvement in scores on the SSRQA post intervention by 4.88 points, with median improvement of 4 points. Figure 5.4 graphically demonstrates that improvements were not uniform, with two participants having a reduced score by 1 point, and a further two participants showing no difference and one participant had an increase on 1 point. X denotes the mean score.

The mean improvement in resilience score was 4.88 (SD = 3.70), and a paired t test demonstrated that this is statistically significant $t(25) = 4.74$, $p < 0.001$. However, as the relationship between training and improvement is not linear, additional interrogation of the data is presented below to explore this further.

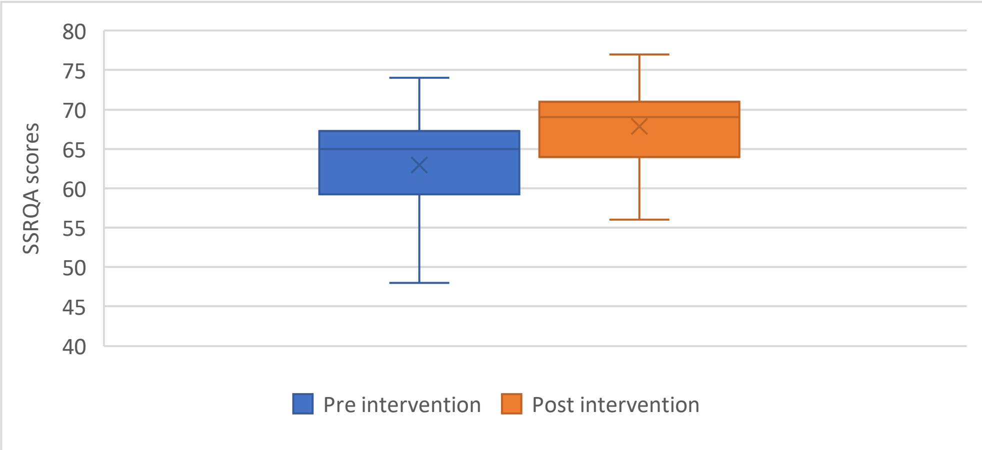


Figure 5.3 The distribution of SSRQA scores before and after the meditation course

5.5 Modelling of resilience improvement

As the resilience in the study population, illustrated in section 5.2, was observed to be normally distributed, and with a generalised linear regression model was adopted. As the goal of this resilience training program was to improve the level of resilience in the students, the target for modelling purposes was set as the difference between the pre-intervention survey and post-intervention survey, denoting the change in resilience after the training program. The factors included for analysis were the medical school, the year of study, the gender of the participants, socio-economic background of the participants, score in the pre-intervention survey, number of meditation sessions, mean length of meditation sessions, and total length of time spent in the program. This was aimed at identifying the factors that exert the greatest influence on improvement, and therefore allow for predicting training outcomes. The underlying hypothesis being that this program is effective across the spectrum represented in the medical student population, and that the benefit is proportional to engagement with the program.

Using a generalised linear regression model in a stepwise approach, two factors were found to increase the validity of the model. Through utilising the difference between the pre and post intervention scores and total number of minutes spent in meditation training, A Pearson correlation analysis revealed a significant relationship between total number of minutes and difference in scores r(25) = 0.594, p<0.05, indicating that approximately 59.4% of the variance in difference in scores can be explained by total number of minutes spent in meditation training. Modelling demonstrated that these two variables, and Figure 5.5 plots the predicted values using the model compared to the observed outcomes, with accuracy p<0.05. The Akaike information criterion for this model was 49.44 when both factors are included, whereas it is 57.84 when using the pre-intervention score only, highlighting the additive value of using pre-intervention score and total length of training as predictive factors

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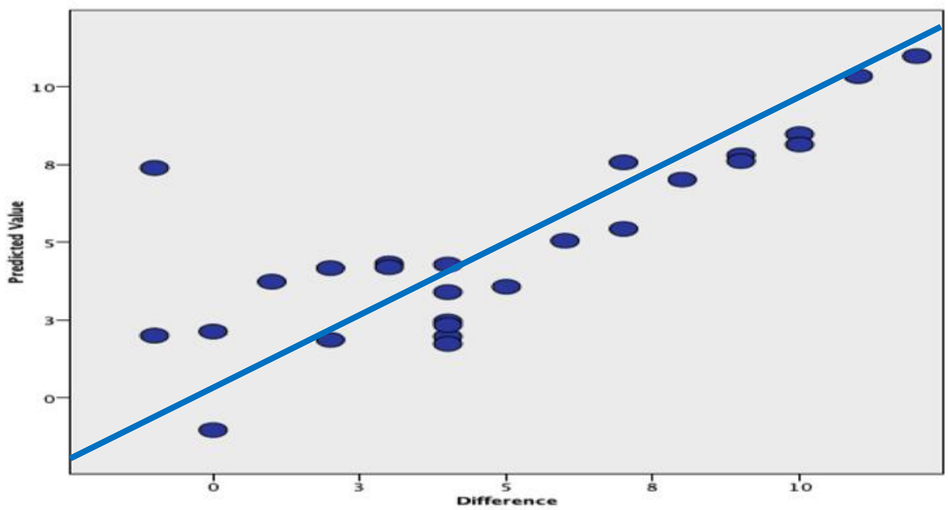

Figure 5.4 Comparison of predicted and observed values for difference pre and post intervention

5.6 Impact of programme on resilience behaviours

Semi-structured interviews examined the four constructs of resilience that have been demonstrated to be most critical in the literature (Collins, 2007; Glantz & Johnson, 2006; Kleiman et al., 2015; Rook et al., 2018). The four constructs that will be explored are self-belief, adaptability, emotional regulation, and support-seeking behaviour. The purpose of the interviews was to explore the perceptions of these domains and enable the evaluation of the program, as experienced by the students. The interviews also clarified the reasons each participant opted into the study, their experience of the platform, and their reflections on their own participation. The approach adopted here was that of a thematic analysis (TA) as described in the previous chapter (Braun, Clarke, Hayfield, & Terry, 2019; Clarke, Braun, & Hayfield, 2015). Briefly stated, the interviews, as well as any subsequent communications, were recorded and transcribed. The resilience behaviours identified above served as the main categories of behaviour explored during the interviews. Subsequent to that, each participant was coded as a separate casefile, and each event, whether interview, conversation or email was added to the case in preparation for the initial coding. From this initial coding, themes began to emerge, as characterised by their significance in relation to the topic under study,(Braun & Clarke, 2022). Coding was carried out using NVivo 12 (IQSR, 2018).

These themes were then reviewed, modified and developed further, with the resultant redefinition of the themes into the four resilience-related ones of self-belief, adaptability, emotional regulation and support seeking behaviour. The next stage involved the finalised boundaries for the themes, focusing on the narrative it offered, and how it offered insight into the research questions. The final stage, writing of the TA, is presented here.

In revisiting the interview data from a post-positivist perspective, the analysis was reframed to acknowledge both the existence of an external reality and the inherent limitations of the researcher's insights. First, I returned to the anonymised transcripts in NVivo and conducted a second round of coding expressly seeking disconfirming evidence. Rather than treating themes as definitive constructs, I treated them as provisional explanations subject to falsification. For each candidate theme, I ran coding queries to identify interview excerpts that contradicted or nuanced that theme, and I documented these tensions in my reflective journal.

Next, I introduced a layer of triangulation by comparing emerging themes with relevant quantitative findings from the Student Self-Questionnaire for Responses and Attitudes (SSQRA). Where interview accounts diverged from survey trends, I flagged these discrepancies as potential avenues for deeper interpretation rather than dismissing them as outliers. This complementary analysis helped to ground the qualitative insights in observable patterns while preserving the richness of individual voices.

Throughout this re-analysis, I maintained a reflexive stance: every methodological decision, from code refinement to theme validation, was recorded in a dedicated audit trail, alongside notes on how my prior assumptions may have shaped interpretation. By deliberately seeking to falsify emerging explanations, integrating survey data, and systematically checking coding consistency, the re-analysis aligns with post-positivist commitments to tentative knowledge claims, methodological transparency and the pursuit of a reality that can be approached, though never fully captured, by systematic inquiry.

In acknowledging the risk that participants might offer what they perceive to be the 'right' answer, several safeguards were built into the interview design and analysis. Before each interview, the researcher emphasised that there were no correct or incorrect responses and that all perspectives, whether positive, negative or ambivalent, were valuable to the study. Questions were phrased in neutral, open-ended terms and probes were used to encourage elaboration rather than confirmation. Throughout transcription and coding, the researcher kept a reflexive journal in which instances of apparent social desirability were noted and treated as analytic points rather than factual givens. Finally, during the post-positivist re-analysis phase, codes and themes were specifically checked for evidence of acquiescence; any themes heavily reliant on uniformly positive language were cross-referenced against contradictory data or survey findings to ensure that tentative conclusions did not rest solely on potentially biased accounts. These measures helped to mitigate social-desirability bias and to preserve the richness and credibility of the interview data.

All participants and the researcher were already familiar with the video-conference and electronic platforms used for the interviews, so no new technology was introduced during data collection, as evident by the choice of technique prior to the pandemic. This meant that neither participants nor the researcher needed time to learn how to use the tools, which minimised technical disruptions and allowed discussion to focus purely on the study topics. However, this shared comfort with the platforms also carried the risk of complacency: neither party questioned how the medium might shape communication, and subtle cues such as camera fatigue or connectivity hiccups may have gone unremarked. To guard against this, the researcher maintained a reflective journal in which any technical issues or moments of participant hesitation were logged and examined during analysis. By noting these occurrences and considering their potential impact on response depth and rapport, the study sought to account for, but not overstate, the influence of platform familiarity on the interview data.

Several steps were taken during analysis to mitigate bias and strengthen trustworthiness. A detailed reflective journal was kept throughout coding and theme development to record personal assumptions and moments of uncertainty. As detailed in Section 5.3, candidate themes and supporting extracts were then reviewed by three fellow doctoral candidates, who provided independent feedback on coherence and completeness. Targeted NVivo queries were also run to identify any data that contradicted prevailing themes, prompting further refinement or qualification of theme definitions. Finally, a comprehensive audit trail documented coding roundsw, theme revision and rationale for decisions. Together, these measures counteracted social-desirability, confirmation and expectancy biases and ensured that our analysis remained grounded in the data rather than pre-existing assumptions.

5.6.1 Self-Belief

The personal belief in one's own capacity to overcome obstacles has been highlighted as a key component of resilience (Collins, 2007; Ryan, Merighi, Healy, & Renouf, 2004). An optimistic outlook on the future has been suggested as a protective factor against adversity in the short-term (Snyder, 2000). The reported below self-belief characteristics were divided into positive and negative categories. During the interviews, participants were asked regarding changes during the study or since its completion. In examining this aspect, participants exhibited a range of different responses from positive or negative reactions, personal learning and development, behavioural changes and experienced subjective changes in overall demeaner.

Positive changes reported included a general acceptance of virtual instruction as a mode of learning. The majority of participants interviewed felt that taking part in the study increased their awareness of resilience and being asked directly regarding their self-belief had appreciated after reflection. The process of meditation itself had enabled them to advance this further, with the encouraging effect of learning a new skill. This was reported as morphing to an adaptive response to stresses. Additionally, some reported being able to adapt meditation into their daily encounters with adversities at work.

> *"I caught myself doing little bits of meditation through the week…. I'd have to do something or other that's a bit hard, and I'd go and run a little bit of the session in my head. (Meditation) Made me think I could get it done."*
>
> *Participant B*

However, some of the participants experienced the opposite, perceiving participating in the study as detrimental to their sense of self-belief. The trigger for this was encountering difficulty in either carrying out the meditation to their satisfaction, or in scheduling time to do it.

> *"It seemed like a small thing, but I couldn't do it. Just couldn't. No matter how hard I tried. Knocked me back a bit."*
>
> *Participant G*

> *"I got annoyed with myself. I thought I'd easily find time but something kept getting in the way. I didn't understand why I couldn't get it to fit."*

Participant Q

In both these situations, the participants stated that a feeling akin to failure led to a deterioration in their sense of self belief. This suggests that the benefits are at least partially dependent on being able to carry out meditation. Otherwise, a rebound negative effect is evident, with the difficulty in meditating acting as a further stressor. Rather than meditation offering relief or a way to alleviate stress, it increased the cognitive load on the participants.

5.6.2 Adaptability

A higher degree of resilience is associated with a greater capacity to withstand a range of situations (Rook et al., 2018). As clinical practice increases the chance of unexpected and varied conditions occurring (Allan, Magnusson, Evans, Ball, Westwood, Curtis, Horton, & Johnson, 2016; Bould & Naik, 2009; Trontell, 2004), this proved fertile ground at interviews. This was exacerbated by the international pandemic of COR-SARS-19, which exposed participants to unexpected and unanticipated situations in academic, personal and clinical settings (Carmassi, Foghi, Dell'Oste, Cordone, Bertelloni, Bui, & Dell'Osso, 2020; Kim, Shin, Hong, & Kim, 2020; Loch, Kuan, Elsalem, Schwass, Brunton, & Jum'ah, 2020). While an acute stress response can be beneficial in the immediate situation, continued exposure to stress can lead to a maladaptive psychological and physiological response (Silverman & Deuster, 2014). Therefore appropriate adaptability to longer term stress is needed for long-term physical and mental health. Below are reported the responses, which have been presented in two broad sections, reflecting the different mirrored effects meditation had on the participants.

Participants reported that being able to direct energy towards a specific task that called for personal effort allowed an opportunity to achieve goals. This served to both increase their self-belief, as well as enhance their capacity to acclimatise to the rapidly and dramatically different environments they found themselves in.

> *"I started noticing that I felt better after meditation sessions. I hadn't done anything like that before, and it was good to be able to show myself that I learned something that quickly! It gave me a boost when seeing new things."*

Participant N

There were also reports of using meditation sessions to accommodate the change in circumstances. The period of meditation was utilised by some participants as a set time to contemplate these changes and consider their options. It was described as offering time removed from the different challenges, and gave the time to plan the rest of the day. They described grouping different activities and tasks, and helped organise their progress.

> *"I tended to do the meditation at the end of the day. It fit me better that way. After the space it (meditation) gave me, I'd go over the day in my head. I could see things more clearly then."*
>
> *Participant F*

> *"After the morning meditation, I'd take a minute a come up with a plan for the day. Doesn't mean I always stuck to this, but it's a place to start. I did this more and more after we started going out on the wards and being re deployed. Seemed more important to have a plan then."*
>
> *Participant W*

However, there were a small minority of three participants representing 15.8% of those interviewed that stated that the meditation sessions became characterised as a further addition to workload, and an additional change they had to consider. This served to increase their perception of changes, and left them feeling overwhelmed.

> *"It (meditation) became another thing I suddenly had to find time to do. On top of everything going on it can get a bit much."*
>
> *Participant H*

From the evidence presented, meditation practice appeared to play an influencing role on the participants adaptability. However, the effects were not uniform across all participants. For those that were able to carry out meditation to an effective level, as judged by the participants themselves, it served as a route to alleviate their cognitive load, and afforded them a greater functional capacity. This is in contrast with those who viewed meditation as an additional task, or those who struggled to carry it out. For the participants in this second group they exhibited signs of increased cognitive loads as a result of undertaking this program.

5.6.3 Emotional regulation

The ability to regulate personal emotional responses to external stimuli, includes modulating one's emotional state, physiological responses such as heart rate or breathing, as well as emotionally-led behaviour (Burman, Green, & Shanker, 2015; Thompson, 2008). There was, again, a reported divide in how meditation impacted participants' emotional regulation, with those who were able to carry out the meditation sessions experiencing a tangible positive impact. This is in contrast to those who struggled to undertake the meditation sessions experiencing a heightened workload and an increased cognitive load, leading to a decrease in their capacity to regulate their emotions. It is worthwhile noting that the majority of participants, 68%, reported the training program as having an overall positive impact. However, the duration of this impact appeared to vary between individuals. Participants reported feeling calmer, with less agitation, anger or frustration during and after completion of the meditation program. There was a time dependent response with a significant proportion of the participants, with the greatest effect close to the time of meditation.

> *"After I'd finish a session, I'd get this feeling of being in control. I knew I could handle whatever happened without getting angry. Even my housemates said they saw me being less stressed. But by the time it was due the next session, I could feel myself getting more worked up ."*

Participant J

> *"No offense, I was a bit sceptical about this. Thought it was all a bit ….well nonsense really. But I started seeing my heartrate on my watch going down, so I stuck with it."*

Participant J

The examples presented above point to an additional aspect to resilience associated behaviours, namely being externally observed. As behaviours are the most readily available components others see, and may be externally observed, it is possible for this external recognition to act as reinforcement for the behaviour.

Negative effects were felt by those who also reported finding scheduling periods of meditation difficult, or those who found the meditation technique itself difficult to perform. This led to an increase in negative emotions and in some cases, participants sought other means to relieve these reactions.

> *"I got so angry when I couldn't make it work. Had to go for a run just to blow off some steam."*
>
> *Participant H*

The effects of the training program on emotional regulation were not homogenous across the participants. For the participants who could undertake meditation via the platform, it provided a mechanism to more effectively manage their cognitive loads and resulted in an enhanced emotional regulation. However, the opposite effect was observed with the participants who could not engage with the training program. In these participants who experienced the difficulties with the program their cognitive loads increased, leading to decreased capacity for emotional regulation.

5.6.4 Support seeking behaviour

There is evidence that support seeking behaviour is positively associated with a higher level of resilience (Li, Eschenauer, & Persaud, 2018). This has also been demonstrated to be the case for medical students, (Haglund, aan het Rot, Cooper, Nestadt, Muller, Southwick, & Charney, 2009; Howe et al., 2012). However, based on the previous studies it has not been possible to go beyond correlation, and evaluate whether the support seeking behaviour causes increased resilience, or if individuals who are more resilient incorporate it into their actions (Thompson, McBride, Hosford, & Halaas, 2016). Participants in this study were questioned at interview regarding their approach to seeking support for matters within their personal or professional lives that proved challenging or distressing. They were also asked regarding whether these had changed during or after taking part in this study, as evidence of enhanced resilience as a result of the training program.

While participants universally spoke of the value in a 'good' support system aiding their ability to debrief and discuss their experiences, few stated that they had a supportive relationship with a mentor in the academic or clinical setting.

> *"I feel quite lucky really. I became friends with one of the doctors early on, and it's always good to talk to her. She's been great at giving me tip all the way through."*

Participant E

This is despite a formal tutor assigned to provide supportive care at all medical schools where participants were enrolled. On the whole there was a reliance on friends and family for support, and seeking informal discussions from supervising clinicians where the matter of concern arose during a clinical or academic placement.

> *"I'd normally catch up with my mum on the weekend, and we'd talk about all the stuff I've seen that week. Obviously, not if I thought there was a serious problem in the hospital, I'd mention it then, but talking to mum is really how I make sense of it all."*

Participant C

Participants stated that the formal tutor relationship felt too rigid, and was interpreted as relating to academic practice only.

> *"Talking to my educational supervisor is always so formal. I pretty much need to book an appointment."*

Participant O

The pattern of behaviour did not change during or after the study, with support being sought through family and friends.

> *"We're all medics in the house. We always talked through what we did. We've been like that since the first year."*

Participant O

Participants also reported that they were not generally aware that there was an increase or decrease in the support-seeking behaviour.

5.7 Summary of results

In this chapter I have explored how participants found the process of virtual instruction for meditation, and that the delivery of a participant-led program can enhance their resilience. Undertaking meditation for short periods on a regular basis has been demonstrated to result in a statistically significant increase in participants' resilience levels on repeat administration of

SSRQA survey, using a paired-samples t-test revealed a significant difference in resilience scores, $t(25) = 4.74$, $p < 0.001$. Participants showed statistically significant a mean improvement of 4.88 (SD = 3.70), indicating. The maximum score possible in SSRQA in 200. Improvement was negatively correlated with a lower starting score, number of sessions, mean length of sessions, and total number of minutes spent in meditation during the study, with Pearson correlation analysis revealed a significant relationship between total number of minutes and difference in scores $r(25) = 0.594$, $p<0.05$.

Positive outcomes were related to the ease participants experienced in scheduling their meditation, and the ability to undertake meditation via virtual guidance, while difficulties in either of these criteria led to negative outcomes. The meditation training program was associated with an increase in self-belief, adaptability to changing circumstances, and in improved emotional regulation, but no subjective changes in support seeking behaviours were evident.

6 Discussion

This study set out to examine the use of virtual instruction to resilience training in medical students. It used a mixed-methods study set within a post-positivist paradigm. The focus on resilience arose out of the observed high levels of physician burnout (Eckleberry-Hunt et al., 2009; Riley, 2004; van den Hombergh et al., 2009). Physician burnout, where the individual concerned is overwhelmed by tasks usually within their competence, is increasing worldwide, implying that the underlying cause is not specific healthcare system or training structure, but is due to the intrinsic stresses of medical practice (Al-Dubai & Rampal, 2010; Lee et al., 2015). Burnout affects physician productivity, and has significant consequences for the function of the wider team, although these are difficult to quantify precisely (Dewa et al., 2014; Ochoa, 2018). However, several studies demonstrated that when physicians suffer from burnout, there is a direct effect on patient safety as a consequence (Dewa et al., 2017a; Dewa et al., 2017b; Lu et al., 2015). The widespread impact of burnout on both the providers and recipients of healthcare is, therefore, a critical aspect of clinical practice. Enhancing physician resilience to enable them to withstand the stresses of the profession is an invaluable tool in the arsenal of the medical workforce, with positive implications for the workforce and the patients.

The study presented in this thesis set out with the aims of answering specific questions on the distribution of resilience in the population, evaluating the feasibility and acceptability of virtual instruction of meditation for metacognitive training, assessing the impact of this training on the resilience levels of medical students, the predictive factors that affect the response to trainers and the effects of the training on medical student resilience-related behaviour. The results presented in the previous chapter provide illustration of the data captured in the course of the study. The goal of this section is to explore these results, interpreting them through the lens of cognitive load theory to deduce the meanings and the insights available from them. The significance of these points is considered.

6.1 Resilience is normally distributed

The initial challenge present in attempting to evaluate resilience in medical students was the lack of current measurements of resilience in this group, as well as conflicting conceptual implications of its distribution. Studies researching resilience within the medical profession have thus far treated resilience, and the related phenomenon of burnout, as binary concepts (Houpy et al., 2017; Lin, Lin, Lin, & Chen, 2019; McKinley, Karayiannis, Convie, Clarke, Kirk, & Campbell, 2019; McKinley et al., 2020). However, this stands in contrast with the other proposed view of resilience, which proposed a range of distribution, with individuals having more or less resilience (Fletcher & Sarkar, 2013; Grafton et al., 2010; Howe et al., 2012). Nevertheless, 'having' resilience, even if subjectively reported, to a high level has been shown to protective against burnout and stress-related disorders (Bacchi & Licinio, 2016; Beresin, Milligan, Balon, Coverdale, Louie, & Roberts, 2015; Lin et al., 2019; Park, Porter, Park, Bielick, Rooks, Mainous, Datta, & Carek, 2019).

A key finding of this study, as detailed in Section 5.1, was that resilience as an attribute is normally distributed within medical students in this study. There was also no variation observed between the levels at different medical schools, and no difference observed when evaluating by year of study. It is particularly illuminating to examine this homogeneity in the context of different medical schools, with different teaching modalities, and different sizes. The implication is that the pool of medical students represents one group and may be treated as a single entity. Furthermore, as two schools had existing programs for resilience training, the lack of observed difference was highly suggestive that the methods of enhancing resilience are not effective.

The significance of demonstrating a normal distribution of the scores from the study sample is important in two distinct ways. First, it acts as a confirmatory checkpoint in establishing the sample as representative for the target population as a whole. As resilience has been shown to be distributed normally in the general population (Lowe & Rhodes, 2013; Luthar, Cicchetti, & Becker, 2000; Tarter & Vanyukov, 2002; Vanyukov, Tarter, Conway, Kirillova, Chandler, & Daley, 2016), a sample that also demonstrates this distribution is highly likely to be representative of the population as a whole (Botha, 2014; Ødegaard, 2018). Therefore, the results presented in this study could be extrapolated to the medical student population as a whole.

Secondly, this distribution of resilience carries several other implications. As it is on a gradient, individuals may move up or down this scale. Seen in this light, training in resilience can be seen therefore a process of enhancing and developing an existing trait, rather than attempting to transplant a new ability. Furthermore, individuals with a lower starting level of resilience can also be seen as having a greater room for improvement. This suggests the potential for asymmetrical improvement with training.

6.2 Feasibility and Acceptability

The use of technology-enhanced learning, in particular the use of augmented and virtual reality has been gaining prominence over the course of the last decade, undoubtedly driven by technological advances (Gerup, Soerensen, & Dieckmann, 2020; Lopes & Jorge, 2019; Moro & Periya, 2019; Sultan, Abuznadah, Al-Jifree, Khan, Alsaywid, & Ashour, 2019). However, its use has been confined to technical skills or knowledge components of the curriculum (Clifton, Damon, Stein, Pichelmann, & Nottmeier, 2020; de Faria, Teixeira, de Moura Sousa

Júnior, Otoch, & Figueiredo, 2016; Isaacson, Green, Topp, O'Sullivan, & Kim, 2017; Jalali, Stroulia, Foster, Persad, Shi, & Forgie, 2017). The current evidence suggests that when used for these purposes virtual instruction is effective and acceptable to both faculty and students (Bracq, Michinov, Arnaldi, Caillaud, Gibaud, Gouranton, & Jannin, 2019; Kelly, O'Neill, Salaja, O'Mahony, & Dixon, 2019). Nevertheless, as previously explored, the efficacy of virtual instruction and technology-enhanced learning cannot be equated between technical skills, knowledge and non-technical skills domains (Iskander, 2019b, 2019c). In a systematic review Bracq, Michinov and Jannin (2019) found that studies within healthcare education examining technology-enhanced learning in the form of virtual or augmented reality for non-technical skills [NoTS] took place in supervised settings. However, this study afforded all participants complete autonomy to practice and learn independently with no direct supervision.

The results here demonstrated that the subjective user experience of using virtual instruction for learning how to meditate was positive, with the majority of participants reporting it as an effective means of learning a new non-technical skill. This was despite the vast majority of the participants being novices to the skill. However, the asynchronous nature of receiving feedback was frustrating, if not off-putting for a small minority. Additionally, as borne out in the interviews, the greater autonomy over their own scheduling and learning was appreciated by the students. They welcomed taking ownership of their learning process. Therefore, this study represents the first demonstration of feasibility and acceptability of asynchronous virtual instruction in medical education.

These findings are in line with the existing literature, which show that in adult learners, distance technology-enhanced learning is associated with greater autonomy (Arghode, Brieger, & McLean, 2017; Brockett & Hiemstra, 2018; Firat, 2016). The complaint from the students regarding delayed response and feedback is also consistent with findings in other studies, were rapid and adaptive responses are highly valued in technology enhanced learning settings (Vesin, Mangaroska, & Giannakos, 2018). The challenge presented in providing assistance and feedback to students during asynchronous instruction has been explored previously by Gibbons-Kunka (2017), who found benefits in incorporating synchronous elements into asynchronous instruction, thus gaining synergistic advantages between the two modalities. Advances in artificial intelligence have served to supplement asynchronous human-human interaction in governmental, service and therapeutic settings (D'Alfonso, Santesteban-Echarri, Rice, Wadley, Lederman, Miles, Gleeson, & Alvarez-Jimenez, 2017; Hill, Randolph Ford, & Farreras, 2015; Mehr, Ash, & Fellow, 2017; Reis, Santo, & Melão, 2019; Yao, Zhang, & Chen, 2015). It remains to be seen whether this would be supported through artificial intelligence may be sufficient to add the synchronous elements required in education in otherwise wholly asynchronous programs.

The implication of these findings is that while asynchronous virtual instruction is feasible for resilience training, there is a limit to its application. This limit is due to a proportion of participants finding it difficult to engage fully with the program, which leads to them either cutting short the sessions or undertaking fewer sessions over the study period. As the amount of meditation carried out is highly predictive of improved resilience during the study, this has a significant knock-on effect on those that were not able to effectively engage with the training program. This represents a potential hard limit for providing resilience training solely through asynchronous training for resilience, with an ongoing need for a synchronous, live approach. This can be understood in terms of managing cognitive load, as providing a solution and extra support can be interpreted as alleviating the required cognitive load for the participant to continue with the program, while delays in this provision may serve to increase the experienced overall load. However, the question regarding the potential to carry this out virtually, or if it needs to be carried out in person remains to be seen.

6.3 Efficacy of virtual training in meditation on resilience

The study demonstrated that in this cohort virtual training resulted in a statistically significant rise in resilience scores, averaging 2.44% increase. Modelling the results demonstrated that the improvement could be predicted by a lower starting score and total number of minutes spent in meditation during the study. There are three key inferences gleaned from these results. The first is that virtual instruction can be an effective means of delivering meditation training, and may be successfully deployed in NoTS training. Secondly, those with the lowest starting levels of resilience stand to make the greatest improvements in resilience after meditation training, suggesting that meditation is highly effective training for those whose need for resilience training is greatest. Thirdly, the improvements seen are related to the time spent meditating, whether this is through increasing the length of sessions, or increasing the number of sessions, with the key factor being the total time.

These findings suggest a likely potential adaptability to suit the needs and lifestyles of individuals, with options for a lower number of longer sessions or a higher frequency of shorter sessions. Beyond the flexibility this affords each participant, enabling a malleability to undertaking virtual training in resilience, It also grants a large degree of autonomy to each participant. The advantages of learner autonomy have been suggested in previous studies across fields (Abraham & Komattil, 2016; Lai, 2017; Lee, 2016; Neupane, 2019). Affording learners more autonomy and control over the learning process leads to greater engagement with the learning materials and the process as a whole (Gardner, Hase, Gardner, Dunn, & Carryer, 2008; Rotgans & Schmidt, 2011; Walker, 2008). The increased autonomy and sense of ownership has been shown to lead to a greater positive emotional response, with an associated improved long-term learning outcomes (Christenson, Reschly, & Wylie, 2012; Oliveira & Sarmento, 2003).

The sense of ownership and autonomy can explain the efficacy associated with higher engagement, which was predictive of greater improvement. From this we can also infer that voluntary programs that are based on self-directed and autonomous learning will result in larger gains in resilience. This particular point explains why students attending different medical schools, with different exposures to resilience training from minimal to structured programs, demonstrated no differences at baseline. A program that is delivered as compulsory component of the curriculum offers universal coverage, but may not deliver the desired outcomes. In a critical area such as resilience, this may be balanced by affording students autonomy over how and when they undertake the training, while maintaining its presence on the curriculum, similar to other core components.

These finding are consistent with existing literature. The use of meditation as a mechanism for increasing resilience has been the subject of a number of studies, which have suggested an overall beneficial effect (Betancourt & Khan, 2008; Jacobs, 2015; Rees, 2011; Rivoallan, 2018; Rogers, 2013). Hwang et al. (2017) demonstrated that meditation has this beneficial effect on resilience above and beyond that observed with relaxation, and that these effects carry on over the medium term. Epigenetic changes have been suggested to occur following meditation, serving as a biological basis for the change in response to stress, and explaining the improved resilience (McEwen, 2016). There have been further studies that have sought to establish molecular biomarkers of stress and resilience, demonstrating again that meditation serves to increase resilience and reduce stress (Averill et al., 2018; Carnevali, Koenig, Sgoifo, & Ottaviani, 2018). Additionally, functional magnetic resonance imaging [fMRI] studies have revealed that meditation induced changes in emotional regulation, at the time of meditation and afterwards (Bermudez, Krizaj, Lipschitz, Bueler, Rogowska, Yurgelun-Todd, & Nakamura, 2017; Fox, Dixon, Nijeboer, Girn, Floman, Lifshitz, Ellamil, Sedlmeier, & Christoff, 2016; Ochsner, Bunge, Gross, & Gabrieli, 2002). Changes have also been observed following meditation in the areas of perspective and self-related processing (Fox et al., 2016; Tomasino, Campanella, & Fabbro, 2016).

The degree of neuroplasticity and epigenetic modulation as a result of meditation can serve as a biological basis explaining the measured effects on resilience in this study. In the review by Fox et al. (2016), the areas of the brain related to emotional responses, autonomic responses and cognitive processing of external stimuli are activated by meditation. The results observed in this study are in concordance with these changes, suggesting that meditation serves as a stimulus inducing functional and structural neurological changes to enhance resilience. The correlation between increased meditation with increased resilience is also explained by the induction of neurological changes, which require time to occur.

Self-determination is an innate component of behaviour, and serves as a critical driver for motivation (Abraham & Komattil, 2016). In order to capitalise on this, the delivery of resilience training needs to offer enticing incentives to take part, rather than dictating a specific course to be completed at a pre-determined pace (Clark & Hoffman, 2019; Mason, Shaw, & Zhang, 2019; Stoszkowski & McCarthy, 2018). In this study each participant was granted maximum autonomy on the timing, session duration, and with regard to progression to more advanced stages. The pace of progression was therefore customised and tailored to the needs of each participant by the participant themselves. This approach maximised the self-determination component, and capitalised on the associated motivational benefits.

6.4 Impact of virtual training in meditation on resilience-related behaviour

The behavioural changes reported in this study were taken from the post-intervention interviews. As well as affording the opportunities comment on any aspect of behaviour they wished, direct exploration of the four domains of resilience behaviour, namely self-belief, adaptability, emotional regulation, and support-seeking behaviour, as defined in the literature (Alonso-Tapia et al., 2018; Collins, 2007; Glantz & Johnson, 2006; Kleiman et al., 2015; Rook et al., 2018), as referred to earlier in this thesis in sections 1.5 and 5.6 . Participants described increase self-belief and confidence, a heightened capacity to accommodate or adapt to changing circumstances and a greatly increased level of emotional regulation. These manifested themselves in a strengthened ability and willingness to attempt novel tasks, rising to the challenge of new and rapidly changing situations, and in reduced number of episodes of anger, distress or other negative emotions. However, no change was reported in the domain of support-seeking behaviour. The effects were perhaps more profound than they initially appear, having taken place during a global pandemic with rapidly escalating and restricting circumstances imposed.

Tang (2017) suggested that meditation has a direct positive impact on an individual's awareness of their self, and influences emotional patterns towards positive directions, with the hypothesised explanation being through the resulting effects on neuromodulation. Neuroplasticity induced by meditation in the anterior cingulate gyrus, fronto-temporal junction, insula and tempro-parietal junction areas of the brain have been highlighted as serving as the biological basis of these behavioural changes (Fox et al., 2016; Hölzel, Lazar, Gard, Schuman-Olivier, Vago, & Ott, 2011). The observed changes in specific areas of behaviour after the meditation are a novel finding and valuable addition to contemporary published studies, which report on generally increased resilience levels only (Galante, Dufour, Vainre, Wagner, Stochl, Benton, & Jones, 2018; Hwang et al., 2017; van der Riet, Levett-Jones, & Aquino-Russell, 2018).

It is perhaps not surprising to see changes in behaviour following periods of meditation, given the existing evidence of adaptive changes in the brain. Literature examining the effects of meditation on the resilience of study participants has thus far noted the positive impact on resilience, but did not venture further. This study extended the existing knowledge to the domains where the specific behavioural changes occur. The areas of behavioural changes were directly correlated to the areas where neurological changes were previously detected in other studies, suggesting a causative link. Therefore, we can see the results presented here as being support by the existing body of evidence, and building on this foundation. The previously shown neurological changes associated with meditation also lead to functional effects that can be externally observed in behaviour.

6.5 Development of metacognition to manage cognitive load

As defined earlier in this thesis, particularly chapters two and three, metacognition is a process of abstracting from the immediate experience, followed by self-analyses of the thought and decision-making process (Bernstein et al., 2015; Dinsmore, Alexander, & Loughlin, 2008; McCormick, 2003; Schunk, 2008; Veenman, Van Hout-Wolters, & Afflerbach, 2006). Metacognition acts as the mediating buffer for managing memory capacity and the related imposed cognitive-load across concurrent tasks (Kirschner, 2002b; Valcke, 2002), and as such is critical to the learning process, as well as serving as a protective apparatus against overload (Nelson & Narens, 1994; Nelson et al., 2004). It can therefore improve cognitive performance through optimisation of self-regulation and self-awareness (Bjork, Dunlosky, & Kornell, 2013; Follmer, 2015; Koriat, 2016). Critically, metacognition may be treated as a skill amenable to training and development, using both active and passive means (Chew et al., 2016; Gardner et al., 2016; Hennrikus et al., 2018).

As detailed previously, this study demonstrated improvement in resilience with training, where the various strategies implemented by medical schools had not, as evidenced by the lack of statistical difference at baseline. However, participants from different year groups and different medical schools were able to exhibit a statistically significant improvement in resilience with this training program over a relatively short timeframe. Therefore, it is appropriate that the results are evaluated for evidence of metacognitive development. Participants described integrating and linking the meditative practice with other aspects of their lives, describing it as enabling them to work through cognitive tasks previously deemed difficult. These greater groupings of different facets enable them to resolve difficulties and function more effectively. Furthermore, the added ability to consider a greater number of issues simultaneously increased their adaptability during a tumultuous time, with some using the meditation time to actively sort and organise the tasks and issues facing them. The combination of these led to a reduction in the cognitive overload manifesting as loss of emotional regulation (Boekaerts, 2017; Matthews, Wohleber, & Lin, 2019; Navon & Taubman–Ben-Ari, 2019; Jan L Plass & Slava Kalyuga, 2019). Thus, metacognitive development can be described as enhancing emotional regulation through modulating cognitive load by means of enabling larger chunks to be incorporated into formulated schema.

The results presented here are also supported by other studies, which demonstrate that greater autonomy and heightened motivation are correlated with greater engagement and learning gains (Iskander, 2018; Lewis et al., 2014; Nagy et al., 2015; van den Berghe et al., 2015), with subsequent evidence highlighting increased engagement induces the formation of schema with greater scope (Kirschner et al., 2010; Nusbaum et al., 2014; Sewell et al., 2017). It is therefore an appropriate extension of cognitive load theory to include metacognition as the critical mediator. We can infer from the results here that meditation is an effective mechanism for developing metacognition, enabling the construction of schema devised from larger 'chunks' (Conway-Smith, 2019; Gobet & Clarkson, 2004; Hadie, Hassan, Mohd Ismail, Ismail, Talip, & Abdul Rahim, 2018; Mathy & Feldman, 2012). Critically, as metacognition increases the relative capacity of cognitive chunks within working memory, rather than increasing their number, greater complexity may be managed more effectively, without leading to an overload of the cognitive capacity.

Perhaps the most robust evidence for meditation as a method for metacognitive development for managing cognitive loads is to be found in the participants who could not engage effectively with the training program. In these cases, participants repeatedly described a failure to be able to carry out meditation to their satisfaction as leading to increased levels of frustration, regardless whether this was due to difficulty in completing a session, delays in accessing support or in cases of not being able to grasp the concepts of meditation effectively. They then experienced increased loads, which they managed by effectively reducing their participation by undertaking fewer sessions or undertaking shorter sessions. This demonstrates that individuals are capable of monitoring their subjective cognitive load, and initiating effective methods to reduce it. However, it is notable that participants did not begin from a position of wishing to undertake a reduced level of participation. Further evidence is supplied by others who found that undertaking this training program led to them being able manage their cognitive load through an extended period through the day, while others reported carrying out shorter meditation sessions through the day to enable them to ground themselves and dynamically manage their loads more effectively.

When examining the experiences of these two groups of participants, namely those who did not meditate effectively and those who did, it is clear that in this mechanism aiming to reduce overall cognitive load takes place as an adaptive response to circumstances. This suggests that individuals have an internal balance point for their cognitive load, and actively attempt to maintain themselves at or below this level, with this mechanism being metacognition. Furthermore, this implies that the metacognitive management of cognitive load can be improved with meditation, but this improvement is contingent on first being able to meditate effectively. The gains in metacognition are evident by the enhancement of resilience for those that did manage effective meditation.

6.6 Summary of novel findings

There were several novel findings in this study, that respond directly to the research question posed in the first chapter of the thesis. In this section, I will explicitly state these finding, and explore the significance they pose for the understanding of resilience, resilience training and metacognition as a way of managing cognitive loads.

Firstly, this study is the first attempt to directly examine the distribution of resilience in medical students, with the finding of a normal distribution. In the preceding studies in the published literature, there has been an ongoing theoretical debate between a binary understanding of resilience versus a gradual distribution (Fletcher & Sarkar, 2013; Grafton et al., 2010; Houpy et al., 2017; Howe et al., 2012; Lin et al., 2019; McKinley et al., 2019; McKinley et al., 2020). This study provides empirical evidence in support of resilience being present on a gradient, with individuals possessing more or less of the trait. Furthermore, the distribution follows a normal distribution, indicating a symmetrical dispersion around the population mean.

Given the lack of differences observed between students attending different medical schools, and a lack of difference in the resilience levels between medical students in different years of their studies, the existing resilience strategies can be judged to be ineffective at the worst. This is in concordance with previous evaluations of resilience training programs (Scheepers et al., 2019). This is a precarious position, as higher levels of resilience has been repeatedly shown to act as a protective factor against burnout, with the effect demonstrated across the breadth of medical practice (Arrogante & Aparicio-Zaldivar, 2017; Dunn et al., 2008; Sands et al., 2008; Strümpfer, 2003; Taku, 2014). Therefore, a normal distribution for resilience explains that individuals at the lower resilience levels are at higher risk of burnout, presenting a target population for training. However, even though those at the lower end prior to training may stand to benefit the most, there is no set upper limit for the distribution, and training may prove to be of benefit to all. Nevertheless, when combining this understanding with the concepted of populations tending to revert to the mean with training (Yeo & Papanicolaou, 2017; Zhao, Wang, Ge, Liu, Chen, & Zhang, 2020), it is possible to infer that the greatest gains would be with those with a lower baseline. The ideal target population that stand to benefit the most from resilience training are also the individuals who should be the prime targets for resilience training due to their higher risk of burnout.

Secondly, this study presents a proof by demonstration that asynchronous virtual instruction for resilience is feasible, acceptable and effective. This carries an implication that wider implementation is a possibility. Furthermore, given the lack of distinction in the initial scores from schools that already include resilience training as part of their programs, we can hypothesise that granting autonomy and control to the participants over their own learning results in increased efficacy of the program. The autonomy granted to participants over the timing of the sessions, the length of the sessions and progression across the course may have acted as a motivator, providing a sense of control and ownership for participants over their own training.

Offering this increased ability to take control of the training, personalise it and adapt it to the individual's need, confers a greater ability to tailor the program to each individuals' needs (Clark & Hoffman, 2019; Mason et al., 2019; Stoszkowski & McCarthy, 2018). The greater autonomy leads to a greater sense of ownership and engagement with the program. When comparing the improvement in resilience with this program to the apparent lack of efficacy for the resilience training within medical schools, we can infer that learner autonomy plays a significant role in participant engagement and subsequent improvement.

The training program produced a statistically significant improvement in resilience scores on the SSRQA. Modelling the results found that lower resilience levels at the start of their training and the amount of time invested in the training are highly predictive of the improvement. This corresponds with the other study findings reported above, supporting that assertion that individuals with a low starting level of resilience have the greatest potential gain. The importance of participant engagement was also highlighted. This further emphasises the value added by the autonomous approach to training in this program.

The fourth novel finding is that the previously observed neurological changes on fMRI are related to positive changes, and likely contribute to the increase resilience following meditation. Additionally, evaluation of the impact of the program was carried out using the four stage Kirkpatrick model (Kirkpatrick, 2007). The results show that participants demonstrated impact up to level three, with positive behavioural changes in self-belief, adaptability and emotional regulation, but not in the domain of support seeking behaviours. Again, this directly correlates with the established neurological changes observed in the published literature with fMRI studies (Fox et al., 2016; Tomasino et al., 2016). Taken as a whole, these findings are consistent, and serve to provide a more holistic and complete picture of the impact of meditation for resilience training, as well as the pivotal role that technology enhanced learning is likely to play in the future of NoTS training in medical education.

Finally, this study contributes to the understanding of cognitive load theory, marrying it more effectively to neuroscience, specifically within the context of resilience and burnout. The use of meditation to develop metacognition can add greater capacity to handle complexity. This is suggested by the change in behaviour for the internal components, as presented finding section 5.6. Given the short duration of time elapsed, no fundamental change is likely to have taken place, and the difference is attributable to metacognitive change. in the This is translated in a raised threshold of resilience to stresses and burnout. In turn, this leads to a greater ability to meet the challenges of an uncertain set of circumstances, such as encountered in clinical practice. The improved capacity and resilience may be expected to manifest themselves as a protective factor against burnout.

6.7 Alternate explanations

Alternative explanations could account for the observed increase in engagement scores. For instance, participants' prior familiarity with video-conference and telephone platforms may have led to a learning-curve effect: as they became more comfortable with the medium over the course of the study, their responses grew richer irrespective of the intervention itself. It is also possible that seasonal factors, such as lighter academic workloads or impending examinations, influenced students' willingness to engage more deeply with the tasks presented. Equally, a Hawthorne-type effect cannot be discounted: participants may have altered their behaviour simply because they knew they were being observed and recorded, leading to temporarily elevated engagement that might wane once the novelty of participation wore off.

Another plausible interpretation lies in individual differences and contextual factors. Some participants reported that changes in their personal study routines or external support, such as peer study groups or enhanced access to supplementary materials, coincided with the intervention period and could have driven improvements in engagement scores. Technical issues, including intermittent connectivity problems or screen fatigue, may have selectively dampened the contribution of more critical voices, thereby skewing the data toward those most comfortable with the format. Finally, measurement artefacts in the Student Self-Questionnaire for Responses and Attitudes might have led to regression toward the mean, especially if initial scores were unusually low. These possibilities suggest that the findings are best viewed as provisional signals requiring further investigation rather than definitive proof of the intervention's efficacy. These alternative explanations are of low probability because all participants demonstrated prior proficiency with the communication platforms, making a learning-curve effect unlikely. The study period did not coincide with major academic transitions, and workload surveys showed no significant seasonal fluctuation. Furthermore, the SSQRA has established reliability and was administered under consistent conditions, reducing the likelihood of regression-to-the-mean or measurement artefacts.

6.8 Theoretical insights

This study offers several theoretical contributions to the understanding of student engagement within digitally mediated medical education. Much of the existing literature tends to conceptualise engagement as a stable, individual trait, often operationalised through quantifiable indicators such as attendance, participation metrics or time-on-task. In contrast, this research supports a more dynamic, context-dependent view. The findings suggest that engagement is not merely behavioural or motivational, but is fundamentally relational and interpretive. Students' willingness to engage was shaped not only by content but also by their familiarity in the platform, their sense of institutional alignment, and their perceptions of autonomy and psychological safety.

In this respect, the study extends current engagement theory by highlighting how students construct meaning around digital learning environments. Engagement was often described not as a fixed response to a tool, but as a reflection of how students interpreted its purpose, credibility and alignment with their learning goals. This shifts the focus beyond purely transactional models of engagement and introduces the idea that students are active interpreters of educational experiences, not passive recipients. These insights reinforce the value of interpretive elements within a post-positivist framework, emphasising that learner behaviour is filtered through both cognitive and affective lenses.

The study also challenges the assumption that digital interventions inherently foster engagement. Instead, it suggests that the perceived success of such interventions is mediated by the narratives students attach to them, such as whether they are viewed as supportive, tokenistic, compulsory or empowering. This aligns with, and deepens, sociocultural theories of engagement that place learner agency, identity and context at the centre of the educational experience.

Finally, by adopting a mixed-methods, post-positivist stance, the study contributes to methodological debates in medical education research. It illustrates how tentative inferences drawn from quantitative data can be enriched and problematised through qualitative insights. This approach offers a more holistic understanding of engagement as a multidimensional construct. It also encourages future research to look beyond surface metrics and to develop theoretical models that account for learners' lived experiences, institutional discourses, and the interpretive work students perform in response to digital tools.

In summary, this study supports a more expansive and reflexive theory of engagement in medical education. It recognises that variability, context and meaning-making are central to understanding how and why students choose to engage.

7 Conclusions

This study set out to attempt to provide a solution to the problem of burnout in the medical profession. A career in medicine has been associated with an increased risk of burnout, a state where normal tasks become more challenging, if not impossible (Eckleberry-Hunt et al., 2009; Riley, 2004; van den Hombergh et al., 2009). The study of burnout is critical, as it has been demonstrated to carry tangible negative implications for physicians and their patients (Dewa et al., 2014; Dewa et al., 2017a; Dewa et al., 2017b; Lu et al., 2015; Ochoa, 2018). Studies have shown that the rising incidence of burnout and its effects transcend cultural boundaries, healthcare systems, or specialisations (Al-Dubai & Rampal, 2010; Bohman et al., 2017; Lebares et al., 2018a; Lee et al., 2015; McCain et al., 2018; Olson et al., 2015; Wong & Olusanya, 2017). This suggests that there is a mismatch between the doctors, their training and the pressures imposed by a career in medicine, and it implies that either a new approach to medical practice is needed, or highlights an underlying need to better prepare future doctors for the realities of a medical career.

This study adopted the view that given the widespread problem of burnout, across specialties, geography, culture or healthcare system, it is more likely that physicians need specific training to protect themselves against burnout. Resilience had been shown to provide additional protection against burnout in multiple previous studies (Arrogante & Aparicio-Zaldivar, 2017; Dunn et al., 2008; Sands et al., 2008; Strümpfer, 2003; Taku, 2014). Enhancing resilience is therefore an appetising and appropriate target when attempting to address the problem of burnout. This is the path pursued in this thesis.

In this study, I examined how virtual instruction could be used to teach meditation, with the goal of improving resilience in medical students. The study demonstrated that it is possible to improve resilience levels with meditation, and that training could be conducted through a virtual instruction platform. Furthermore, there was a reported behavioural change in the participants, attributed to the training. The results reported in this study are consistent with the research already published in the fields of neuroscience and behaviour, as well as prior research into meditation. In this study, I have been able to demonstrate that the benefit is greatest for those with the lowest starting point at baseline. The role and value of voluntary participation and autonomy when taking part in resilience training was also highlighted by this study. In using cognitive load theory as an analytical lens, the results presented support the assertion that successful meditation is effective in reducing the overall cognitive load, and this leads to higher levels of resilience.

In this final chapter I explore the strengths and limitations of the study, concluding by discussing the implications for practice in medical education and the avenues of future research that carry the potential to advance this topic further.

7.1 Strengths of the study

This study had a variety of strengths. The mixed methods study design allowed for both the quantitative statistical evaluation of the sample and assessment of the gains in resilience, as well as qualitative review of the experiences of the participants and their behaviour. This study established the baseline of resilience for medical students, and demonstrated that it followed a normal distribution. Therefore, it validated both the sample of participants in the study, and the extrapolation of the results to the wider population of medical students. This is further reinforced by the inclusion of medical schools of different sizes, located in different areas of England and Wales, and following different approaches to the delivery of their curriculum. Two out of the four medical schools taking part in the study also mandated additional entrance examinations, suggesting a greater emphasis of academic skills at the point of entry to university. The uniform distribution of resilience at baseline suggests that it is independent of academic skill, and is largely uninfluenced by other aspects of curriculum delivery. This lack of effect includes the different approaches to resilience training employed by the different medical schools.

In defining burnout as an experience of cognitive overload, it became possible to define resilience as the ability to withstand difficulty and metacognition as the skill that affords the capacity to manage greater and more complex cognitive load. In reaching an operational definition of these complex and often poorly demarcated concepts, it becomes possible to research them more effectively. The study also serves as a nexus, connecting the literature from multiple fields into a single narrative. This allowed the correlation of the previously demonstrated neurological evidence of activity on fMRI with realised behaviour in the participants, placing the findings within the existing literature, and connecting the new findings with other research. In establishing consistency with the findings of these previous studies, it validates the results observed here, as well as allows for the extension of the previous ones. The value of learner autonomy in the development of resilience was highlighted by the gains during this program, where participation and progress were dictated by each individual, in contrast to the lack of measurable differences at baseline between students who had training and those who had not.

7.2 Implications for practice in medical education

There are several implications inherent in the findings of this study, and these may be used singularly or in combination to enable more effective delivery of resilience training. Firstly, it is important to consider the value of autonomy and active choice in resilience training. As previously stated, participants here volunteered to take part on multiple serial occasions. However, in the resilience programs within medical schools in the UK, where applicable, they are delivered as an inherent part of the core curriculum. However, regulatory requirements in the UK for medical education stipulate that at least a quarter of the medical school curriculum should be student-selected components. Therefore, the natural next step is making the provision for resilience training to form part of the student selected components of the undergraduate curriculum.

The challenge with this approach is how best to encourage students to undertake these resilience training options. In order to address this challenge, we can attempt to 'nudge' students to make the choice that will serve them best in the future. The nudge approach was initially pioneered in behavioural economics (Sunstein, 2014; Thaler & Sunstein, 2009), but has since been successfully implemented in encouraging academic success in university level students (Buchs, Gilles, Antonietti, & Butera, 2016; Feild, 2015; Van Amelsvoort, Isozaki, & Yoshino, 2018), with the approach termed choice architecture. By using a combination of two findings from this thesis, namely that the greatest gains in resilience were made by the students who scored lowest at baseline, and that participants were motivated by the desire to assure themselves that they do not fall below their peer group a solution presents itself. By administering a baseline SSRQA survey to the entire cohort, and revealing the individuals position along the distribution, we can encourage those who would benefit most to undertake this training. Through reminding them close to the time of choosing options, this encouragement would be reinforced. Nevertheless, this preserves each students' autonomy and avoids compulsion.

Additionally, given the proof by demonstration of the efficacy of meditation for resilience training, with the link to metacognitive skill development, it is through this approach that I would advocate future resilience training in medical schools. The additional proof of virtual instruction as a valid method for teaching resilience, and more broadly NoTS, suggested that technology-enhanced learning, and in particular virtual instruction, has a significant role to play in the medical schools of the future.

7.3 Limitations of the study

Prior to examining how the findings illustrated here may be applied to medical education, it is important to acknowledge and address the limitations, as well as consider the constraints they place on the implementation. There were four key limitations to this study, each posing specific challenges to the wider extrapolation of the results. The first limitation is the relatively low participation rate observed, in terms of both medical schools and in terms of students. This fairly small number necessarily raises the question of how far the results may be applicable to the population of medical students as a whole. Nevertheless, as previously shown, the baseline results demonstrated a normal distribution, and are therefore likely to be a representative sample of the wider medical student population. This limitation may also be addressed by the prospective power calculation, which demonstrated that sufficient numbers were recruited to allow for statistical inference.

Secondly, as all participants at each stage were volunteers from the wider pool of medical students, it remains to be seen whether those who volunteered are themselves different to the wider population examined. As those interviewed by definition volunteered at least three times to undertake the survey, once at baseline, again after the intervention for a repeat survey, and finally for the interview, it is reasonable to assume that there are inherent differences between them and those students who did not volunteer from the start. Unfortunately, given the paucity of data currently available regarding the baseline level of resilience in the general population, and specifically medical students, this is an area where a definitive resolution is unlikely as yet. However, given the statistical demonstration of normal distribution of the sample, it may be that the baseline levels of medical students can be inferred.

Thirdly, some participants raised the difficulties of delayed feedback and limited initial guidance, which led to initial frustrations. It may be that this is a result of the artificial nature of the completely asynchronous program, where, in the reality of medical student studies, the medical school provides a reassuring physical presence, as well as concentration of resources for assistance. The remedy here may be the initial induction of these meditation programmes in the real world in a face-to-face manner, prior to migration to virtual and asynchronous instruction.

Ultimately, the true measure of success for this virtual meditation training lies in its long-term impact on stress and burnout throughout the careers of these medical students. However, assessing this effect prospectively was not feasible within the scope of this study. Long-term, longitudinal research will be essential to determine whether the reported benefits endure over time. That said, the significant improvement in resilience, demonstrated through SSRQA scores, combined with existing evidence linking resilience to greater protection against burnout, strongly suggests that these benefits are likely to persist. While further research is needed, these findings provide a promising foundation for the lasting value of mindfulness-based training in medical education.

7.4 Suggestions for future research

This study established several key and novel points as highlighted above. There are three main avenues of future research that carry a potential to advance the training and understanding of the topic of resilience, and how that can be applied to medical training. These may be broadly stated as confirmatory, broadening and extension of the findings presented here. As the basis of the enhancement in resilience was underpinned by improving metacognitive skills, the implication is that there is a significant latent potential that can be tapped.

Beginning with the confirmatory studies, it is of value to ensure that the results seen here are reproducible. While the distribution seen in the results suggests validity, it is necessary to ensure that the feasibility of virtual instruction and the gains in resilience seen here can be repeatedly observed by other researchers. As there were no statistically significant differences between different medical schools, it may be possible that future studies could be located at single sites, and extrapolated more broadly. It would also be useful to examine the use of virtual instruction, and compare how it fares when directly compared to face-to-face instruction.

This study was focused entirely on medical students in the UK, and therefore it leaves two options for seeking a broader outlook. These may be through the repetition of similar studies in other healthcare professions, or expansion to other high-risk professions. Additionally, examining the effects of virtual instruction in meditation across different countries with different cultural backgrounds also carries the promise of possibly extending the reach of this technique. Should it prove to be as effective to deliver meditation training for resilience across professional boundaries, or across cultural boundaries and given that virtual instruction has an effectively unlimited capacity, there are clear economies of scale to be gained.

Finally, the study findings may be extended in several ways. A longitudinal approach could inform whether the gains demonstrated by participants persist over the longer term, and whether these gains require continuous training to be maintained. Indeed, it is worth examining whether continued training may serve to improve levels of resilience beyond what was seen over the course of this study. Of critical importance, it is invaluable to bring the study of resilience to the point of evaluating its effect on burnout. This, however, would necessitate follow up of participants over the duration of their careers, and may represent a goal to converge to, rather than pursue directly.

In summary, addressing the problem of burnout in medicine is an urgent and sizeable problem. In the longer term, it is likely that a rethink of how medicine is practiced is indicated, coupled with improved training for resilience. The training program presented here illustrated a route to enhance resilience in medical students, with improved behavioural changes. This presents a potential route that can be deployed flexibly to suit individuals, and offers greater gains for individuals who stand to benefit the most. Therefore, deploying asynchronous virtual instruction for resilience training in medical education and training is strongly recommended. The use of technology to deliver the personalised training program, as illustrated here, is a process whose time has come.

7.5 Growth and Learning as a Researcher

At the outset of this doctoral project, I approached research through a largely positivist lens. I viewed the researcher as an objective and detached observer, working systematically to reveal measurable truths. My understanding of rigour was closely tied to control, neutrality and replicability. In hindsight, this reflected my early academic training, which tilted heavily towards ‘hard’ sciences and a general perception that validity in research depended on the degree to which the researcher could distance themselves from the subject. Over the course of this PhD, however, that position shifted substantially. I have come to appreciate the complexity, subtlety and contingency of educational research, especially within clinical and professional learning contexts. I now recognise that credibility often stems not from detachment, but from reflexivity, transparency and thoughtful engagement with context.

One of the first surprises I encountered was the degree of flexibility required during the research process. While the structure of academic research is often presented as linear, moving from literature review to question refinement, data collection and analysis, my actual experience was far more iterative. Timelines were shaped as much by institutional cycles, participant availability and ethical processes as they were by any research plan. I learned that while rigour is essential, so too is adaptability. Designing and conducting research during a global pandemic, even when the topic was not directly pandemic-related, brought into view the ethical responsibilities involved in conducting research in a healthcare-linked setting. Although my study required minimal adjustments, I was nonetheless required to think carefully about burden, access and the evolving demands placed on participants. Navigating this ethical terrain reinforced the centrality of care and responsiveness in applied research.

The most challenging aspect of the process was securing ethical approval. Not because the study raised major ethical concerns, but because it forced me to articulate my project not simply as an academic exercise but as an intervention in a live context, with real people in real institutional settings. I had to think beyond compliance and consider how my study would be received, interpreted and perhaps even acted upon by participants and gatekeepers. It brought into focus the broader role of the researcher in shaping expectations, relationships and potential outcomes.

Analytically, I found the study unfolded much as I expected. My working assumption was that the existing programmes and platforms under investigation would offer some benefit, however modest, and this expectation was largely confirmed by the data. What was more revealing, however, was the variation in how those benefits were experienced, framed and articulated by students. The data did not simply speak for itself. It required interpretation, contextualisation and reflection. This was where my stance began to evolve. Although the quantitative elements of the study were important, I found increasing value in the qualitative insights and in the moments of contradiction, ambiguity or divergence. These were not flaws to be corrected, but rather signals that richer explanations were needed.

In terms of my development as a researcher, one of the most significant shifts has been in how I make decisions. I have become more deliberative and more reflective. I am more inclined to consider the assumptions behind each methodological choice and to revisit those choices in the light of new data or perspectives. I have also grown more comfortable with uncertainty. At the start of the PhD, I tended to view inconclusive findings as a weakness. Now, I see them as invitations to probe further, to revisit theory, or to refine the scope of inquiry. This change has not only improved the quality of my research but has also made the process more intellectually satisfying.

If I were to offer advice to myself at the start of this journey, it would be this: perseverance is one of the greatest predictors of success. There were points in the research process when delays, revisions and competing demands made progress feel incremental at best. But each small step built towards something meaningful. Research, I have learned, is less about sudden breakthroughs and more about sustained, thoughtful effort. It is about returning repeatedly to a problem with patience, curiosity and care.

Perhaps the most important realisation I have come to is that research does not end with the completion of a thesis. While academic rigour remains crucial, the value of research lies increasingly in its ability to inform, influence and adapt to the settings it seeks to understand. In the context of medical education, this means that findings must be more than publishable.

They must be communicable, applicable and open to revision based on feedback from those working on the ground. As a researcher, I now see my role as part of a broader ecosystem of learning, where inquiry is continuous, collaborative and responsive. This includes acknowledging the limits of my own interpretations and remaining open to how others, including students, educators and policymakers, may see things differently.

In conclusion, this doctoral study has marked a significant period of personal and professional growth. It has deepened my understanding of research not only as a technical process but as an ethical and relational one. I have moved from a view of research as objective observation to one that recognises knowledge as provisional, situated and shaped by interaction. I have developed a greater capacity for critical thought, a stronger sense of methodological responsibility, and a renewed commitment to research that is both rigorous and responsive. These are lessons I carry forward not just into future academic work, but into practice, leadership and contribution across the field of education and healthcare.

8 Appendices

Appendix A – Sample size calculation

Formula for sample size calculation

$$n = 2(\sigma \frac{z - \frac{\alpha}{2\tau} + z - \beta}{\mu A - \mu B})^2$$

Where:

n = sample size

σ = standard deviation

β = Type II error, therefore 1−β= power

τ = number of comparisons

μ = mean

$$z = \frac{\mu A - \mu B}{\sigma \sqrt{\frac{2}{n}}}$$

Appendix B: : Situated Subjective Resilience Questionnaire for Adults (SSRQA)

Please complete the following 20 questions about yourself. When completing the questionnaire, please think about your domestic and work experiences as they have been over the past year, and do not dwell too long on each question.

Circle the number most closely reflecting your feelings today. 1 = No never and 5 = Yes always. 2 3 and 4 are shades in between.

Question	Score				
When I have had problems at work that made me feel very upset, the distress lasted a long time	**1**	**2**	**2**	**4**	**5**
When I have had problems with close people (such as arguments with family or friends) that affected me deeply, I have quickly recovered	**1**	**2**	**2**	**4**	**5**
I have found it difficult to stop feeling bad when I have had important problems (such as arguments) with close people (family or friends).	**1**	**2**	**2**	**4**	**5**
When I have had a health issue that I was badly affected by, I easily recovered from that distress	**1**	**2**	**2**	**4**	**5**
When a family member or another close person has suffered from a serious health problem, I have had a hard time recovering from the distress	**1**	**2**	**2**	**4**	**5**
When I have had financial problems that were a real worry for me, it did not take me long to over-come the stress	**1**	**2**	**2**	**4**	**5**
When I have had important problems at work, the distress went away quickly	**1**	**2**	**2**	**4**	**5**

When I have had problems (such as arguments, etc.) with close people (family or friends), it took me a long time to stop feeling bad	**1**	**2**	**2**	**4**	**5**
When I have had important problems with close people (family, friends, etc.), for instance when we have had an argument, I have easily recovered from the distress	**1**	**2**	**2**	**4**	**5**
When I have had an important health issue, I had a hard time overcoming the distress that it caused me	**1**	**2**	**2**	**4**	**5**
When a family member or a close person has had a serious health issue, I have quickly recovered from the upset caused by that situation	**1**	**2**	**2**	**4**	**5**
When I have had a financial difficulty that was a real problem for me, it was difficult to stop feeling bad	**1**	**2**	**2**	**4**	**5**
It took me a long time to recover when I have had problems at work which affected me deeply	**1**	**2**	**2**	**4**	**5**
When I have had a health issue that has psychologically affected me, I felt better quickly	**1**	**2**	**2**	**4**	**5**
It has taken me a long time to overcome the dis- tress when a family member or a close person has had a serious health issue that caused me great stress	**1**	**2**	**2**	**4**	**5**
When I have had a financial difficulty that was a serious problem for me, it was not hard for me to overcome the stress	**1**	**2**	**2**	**4**	**5**
When I have had work difficulties that caused me great stress, I have easily recovered	**1**	**2**	**2**	**4**	**5**
When I have had serious health problems that deeply affected me, I have felt bad until the health issue was gone	**1**	**2**	**2**	**4**	**5**

I have been able to recover quickly when a family member or a close person has had an important health issue that disturbed me	**1**	**2**	**2**	**4**	**5**
When I have had an important financial difficulty that caused me great distress, I have felt bad until the financial situation was resolved	**1**	**2**	**2**	**4**	**5**

Appendix C: Semi-structured interview outline

Self Belief:

- How well do you feel you generally cope with very challenging situations? How often do you face these sorts of situations?
- Are there certain types of challenging situations that you feel more comfortable dealing with? Why is this? Describe a recent example.
- What types of challenging situations do you feel less comfortable with? What is it about these situations which make you less comfortable? How well do you think you have dealt with these situations in the past?

Adaptability:

- How difficult do you find it to adapt when situations change rapidly? Is there anything about changing your behaviour or approach that you find particularly challenging? Why do you think this is?
- Do you get frustrated when plans change? How does this affect other people you work or study with? Describe a recent example.
- Have there ever been times when you have stuck to the same approach when dealing with a task when it would have been better to change what you were doing? Why did you choose to keep doing what you were doing? What was the impact?

Emotional Regulation:

- Generally, how well do you feel you keep control of your emotions when faced with stressful and demanding situations? How often do you have to deal with these kinds of situations?
- Under what circumstances do you find it most difficult to stay calm at work or university? Why do you think this is?
- In what situations do you find it easier to keep calm, even when things are stressful? What strategies do you use in order to do this?

Support-seeking behaviour:

- Do you have a person or group of people at work or university that you can discuss problems or issues with? If you encounter a problem, would you typically consult these people or try to work through the problem by yourself?
- In which kinds of situations do you typically find it easier to ask for support? Describe an example. Why do you think asking for support is easier in these situations than others?
- Are there any circumstances under which you find it more difficult to seek support from others? If so, what types of circumstances are more challenging in this regard?
- Interviewer notes:

Participant Code: Pre-intervention☐ Post-intervention☐

Positive behavioural indicators	Negative behavioural indicators

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