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Seeing is Believing

Using Visualisations of Medical Disease and Treatment to Improve Patient Adherence

Annie Selina Kozlowski Jones

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Health Psychology, the University of Auckland, 2018.
Abstract

The effective understanding of health information is essential to inform adaptive patient health behaviours, such as adherence to treatment. Despite developments in our understanding of pathological processes and innovative treatments, patient comprehension and health literacy remains problematic. The format and delivery of health information can influence the accurate comprehension, retention, and implementation of medical advice. Visualisation is a type of visual health information which represents internal bodily processes of disease and treatments. Visual health information has increased salience and encoding within memory, and can break down barriers imposed by literacy and unfamiliar terminology. Initial work demonstrates that visualisation can improve perceptions, understanding, and subsequent health behaviours, although significant gaps in understanding are evident.

This thesis intended to extend the current literature by addressing several aims. The research aimed to establish the efficacy of different formats of visualisation across different healthcare trajectories. These studies also aimed to provide an understanding of which populations may find visualisation most effective. More broadly, this thesis aimed to provide further understanding of visualisation as an intervention technique to improve health behaviours. Specifically, this thesis investigated whether visualisation interventions could improve objective health outcomes in patients with both acute and chronic conditions.

Four studies were conducted to address these aims. The first two studies provided insight into assessment and methodological considerations for visualisation. The first study (described in Chapter Three) developed and examined a new measure, the Health Visual Information Preference Scale (Health VIPS), for identifying individuals who prefer visual supplementary health information. This scale had good psychometric properties and could effectively identify individuals with greater preferences for visual health information. Study Two (described in Chapter Four) investigated whether virtual or physical visualisation mediums have differences in their impact upon perceptions of illness and treatment motivations. Women at-risk of developing osteoporosis were shown either animations presented on a computer tablet or 3-D printed bone models. This study concluded that both forms of visualisation were equally effective in improving perceptions of illness and treatment from before to after seeing these tools.
The second portion of this thesis included two randomised controlled trials (RCTs) investigating the efficacy of visualisation interventions in two distinct populations. Study Three (described in Chapter Six) examined the utility of an active visualisation device in improving adherence to antiretroviral therapy in non-adherent patients living with HIV infection in South Africa. This device was a physical demonstration depicting the effects of consistent adherence versus non-adherence upon viral load and treatment efficacy. This study found that participants who saw this visualisation device had a clinically significant decrease in plasma viral load at follow-up compared to those who received standard care only.

Study Four (described in Chapter Seven) was another RCT examining whether a visualisation intervention could improve adherence to a health behaviour other than medication adherence. This study examined the efficacy of an animated visualisation intervention in improving adherence to post-operative mobilisation following colorectal and gynaecological oncology surgery. Participants saw animations depicting the purpose of mobility in enhancing recovery from surgery. This study found that participants who saw the visualisation intervention had significantly greater average step count post-surgery to one week following discharge as compared to control participants. This study also included an active control group who received the same verbal information but with no animations. The intervention group had a significantly greater understanding of the purpose of early mobilisation as compared to the active control group and two-fold greater average step count, although this did not reach significance.

The results of the studies included in this thesis provide evidence for the efficacy of visualisation interventions in improving perceptions of illness and treatment beliefs, but also in improving health behaviours. Furthermore, these interventions demonstrated improvements in objective health behaviours and clinically relevant markers of self-management in both chronic disease and surgical recovery. This research also contributes to current understanding of visualisation by providing evidence for how visualisation tools can be designed to increase efficacy. There are clear clinical implications for these findings. Visualisation devices have high applicability to be incorporated into healthcare to improve the delivery of health information and subsequently improve patient health behaviours. Future research could investigate the potential mechanisms of visualisation in improving objective health behaviours to better inform visualisation design. Future research could also further explore applications for visualisation tools in other conditions, to improve self-management and treatment outcomes across health promotion and healthcare.
Acknowledgements

This journey has been a masterclass in the fruition of hard-work and perseverance. Firstly, research is about giving back – I extend my gratitude to all the patients who selflessly volunteered time during their illness journey and made this research possible.

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I dedicate this thesis to my late Granddad Jan Kozlowski - a symbol of perseverance through adversity, whose memory provides an ever-present source of light during tempestuous times.
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5. **Active Visualisation: A New Intervention Approach**


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6. Using Active Visualisation to Improve Medication Adherence in Chronic Illness

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7. Using Active Visualisation to Improve Adherence to a Health Behaviour Following an Acute Medical Procedure


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Chapter One

Topic Introduction and Thesis Overview

Introduction of Thesis Topic

The exchange of health information between healthcare providers and patients is fundamental for the effective translation of medical advice into health behaviours. Accordingly, enhancing the delivery of health information to patients is a key strategy for improving patient self-management. Visualisation is an intervention technique which uses visual health information to explain processes occurring inside the body, in terms of disease progression and treatment purposes. Therefore exposure to visualisation can increase patient understanding and motivate adherence to behaviours which are in accordance with medical recommendations. While there is substantial research exploring the effects of showing patients their diagnostic medical imaging, evidence for this imaging improving health behaviours is limited. Visualisation provides a more comprehensive demonstration of illness and treatment processes, yet more evidence regarding the efficacy of these interventions is needed. This thesis aims to build upon current understanding by examining the clinical utility of visualisations of medical disease and treatment, particularly with regard to improving patient adherence and health behaviours.

Research Aims

The broad aim of this thesis is to provide a greater understanding of the efficacy of visualisation as a clinical intervention to improve health behaviours in patients. Specifically, this thesis examines the efficacy of different formats of visualisation (e.g. physical versus virtual visualisation, standard versus active visualisation) across diverse illness groups, to provide a broad understanding of when, how, and for which patient populations visualisation may be most useful. This thesis also aims to provide further evidence for the utilisation of visualisation techniques to improve objective clinical outcomes for specific patient groups, including patients with acute and chronic conditions.

Thesis Outline

Given the dearth of literature within this field, the focus of this thesis is to extend current knowledge about the utility of visualisation interventions by demonstrating the applicability of visualisation to a diverse range of medical settings and patient populations. This is achieved by using different visualisation modalities within different patient populations and treatment settings. This broad approach was selected as a more narrow focus on a specific form of visualisation within a single patient group, would not provide the same depth in understanding regarding different applications of visualisation.
To investigate the above aims, Chapter Two first provides a theoretical overview of the current literature relating to visual health information, and explores evidence that suggests visualisation could be a novel intervention strategy to improve health behaviours. This chapter provides a working definition for visualisation as used within this thesis, and outlines the few empirical studies which are classified as visualisation interventions. This chapter also highlights gaps within the current literature that this thesis attempts to address.

The subsequent chapters of the thesis can be considered in two sections. Chapters Three and Four describe studies investigating methodological and assessment strategies for utilising visualisation. Chapter Three presents the results of a study investigating the psychometric properties of a newly-designed measure, the Health Visual Information Preference Scale (Health VIPS). This measure assesses preferences for receiving visual health information in contrast to standard written health information alone, thereby highlighting those individuals who may respond best to visualisation interventions. This manuscript reports data collected from two studies and three independent samples. Chapter Four presents the first piece of empirical research within this thesis. This manuscript reports the results of a study investigating whether different visualisation modalities have different effects upon illness perceptions and treatment motivations. This study was conducted with a sample of older women at-risk for developing osteoporosis.

The second part of the thesis encompasses results from two randomised clinical intervention studies assessing the use of different forms of visualisation, in different patient populations of both acute and chronic conditions. Chapter Five includes an editorial piece describing a sub-concept of visualisation, ‘active visualisation’. This manuscript also describes the methodology of a newly created active visualisation device to improve adherence to antiretroviral therapy (ART) in the context of HIV infection. The manuscript in Chapter Six reports the results from a randomised controlled trial (RCT) using this device to improve adherence to ART in non-adherent patients in the Western Cape of South Africa. This trial also aimed to establish whether a visualisation intervention could improve an objective marker of adherence (HIV viral load).

Chapter Seven includes the results of a second intervention study. This RCT investigated the efficacy of an animated visualisation intervention for improving adherence to early mobilisation following surgery in colorectal and gynaecological surgery patients. This trial aimed to establish whether the improved outcomes from exposure to visualisation could be generalised to improve
adherence to a health behaviour other than medication adherence (post-operative mobilisation). The primary outcome measure was post-operative mobilisation, measured objectively using step count.

Chapter Eight is a general discussion which draws conclusions across the work presented within this thesis. This includes integrating the main findings from this research into the literature, discussing the strengths and limitations of the research presented, considering the clinical implications for using visualisation within healthcare, and suggested directions for future research.

**Research Questions**

The research questions for the following chapters included in this thesis are provided below:

Chapter Two: Does evidence support the efficacy of visualisation in improving health behaviours?

Chapter Three: Can preferences for visual health information be measured?

Chapter Four: Do physical and virtual visualisation models influence illness perceptions and treatment motivations differently?

Chapter Five: Could an active visualisation intervention be designed to portray the purpose of antiretroviral therapy for HIV?

Chapter Six: Can an active visualisation intervention improve objectively-measured adherence to antiretroviral therapy within a large randomised controlled trial?

Chapter Seven: Can active visualisation objectively improve adherence to a health behaviour other than medication adherence, in the form of post-surgery mobilisation?
Chapter Two

Visualisation: Background, Theory, and Relevant Literature

The following chapter examines the current theoretical and empirical evidence for the utility of visualisation within healthcare. This chapter begins by providing a definition of visualisation as utilised within this thesis. Issues which can arise when delivering and receiving health information are then discussed, followed by a theoretical justification of how visual information may overcome these to promote greater understanding and memory for health advice. Related literature examining the utility of visual imagery to change motivations and behaviour is discussed, including limitations within these previous research paradigms. The chapter then returns to the concept of visualisation to examine the current literature using visualisation interventions within patient populations. Finally, gaps within current empirical evidence are evaluated and points for future research are highlighted.

Defining Visualisation

Visualisation involves the use of visual health information to promote understanding, motivation, and ultimately, greater adherence to health behaviours. In the research described in this thesis, visualisation is defined as the use of visual imagery to represent internal bodily processes of both disease and treatment. In more simple terms, visualisations demonstrate to patients the processes occurring inside their body, both in terms of how their illness may have developed, but also how their treatment works to try and control their disease progression or improve symptoms. Visualisations may be abstract representations of a bodily process (such as animations, demonstrations, or illustrations), or created using real patient data (such as 3-dimensional (3-D) printed models or anatomical computer modelling). These types of visualisations are distinct from the use of diagnostic medical imaging or personalised health-related feedback imaging (DiClemente, Marinilli, Singh, & Bellino, 2001), as visualisations are specifically designed as patient-friendly education tools. Visualisations may also be created using different modalities, such as physical (e.g. 3-D models, live, physical demonstrations) or virtual formats (e.g. animations).

Under the term visualisation, this thesis also defines a sub-concept of ‘active visualisation’. Active visualisation refers specifically to visual representations that are dynamic in nature, such as physical demonstrations or virtual animations. Active visualisation is therefore distinct from
visualisation, which more generally can also include other formats such as static images or 3-D printed models. This concept is discussed further in Chapter Five.

**Issues with the Communication of Health Information**

The transaction of health information between healthcare provider and patient is an integral component of modern healthcare. The medical consultation is a dyadic encounter, within which the clinician listens to and interprets the patient’s presenting problems, and, if possible, provides them with a medical explanation for this presentation (Mabeck & Olesen, 1997). During this interaction, the clinician may provide the patient with information regarding their presenting symptoms, illness self-management, or a treatment plan. Being able to understand medical advice, and recall that information when needed, is fundamental to the patient being able to implement these instructions (Jackson, 1992; Martin, Williams, Haskard, & Dimatteo, 2005; Watson & McKinstry, 2009). There are contextual and patient-specific factors that can greatly impair the effective transaction of health information. This is problematic as inadequate patient recall and comprehension of medical advice may lead to valuable and viable treatments becoming ineffective.

**Contextual Factors**

Factors within the clinical context which can interfere with the successful transaction of health information include time-restricted consultations and the overuse of medical terminology. The strict time pressures that clinical staff are often working under when interacting with their patients can affect information delivery (Selic, Svab, Repolusk, & Gucek, 2011). During a minimal amount of time, clinicians are tasked with delivering large amounts of information that may be overwhelming for the patient to process quickly (Houts, Doak, Doak, & Loscalzo, 2006; Selic et al., 2011). A linear association exists between the amount of information given to the patient and the amount of information forgotten (Safeer & Keenan, 2005). An early study suggested that patients can forget half of the instructions that are given during an appointment shortly after leaving (Ley & Spelman, 1965). Further evidence suggests that even when patients can recall content, nearly half of this information may be inaccurate (Anderson, Dodman, Kopelman, & Fleming, 1979). This is problematic considering that vital information about health, such as precise treatment instructions, may be communicated by the clinician but not accurately retained by the patient. The structure and time pressures of the clinical consultation therefore present an opportunity for inaccurate or incomplete information retention by the patient, which may result in compromised self-management.
A second contextual factor of the healthcare setting which affects the delivery of health information is the overuse of medical terminology by clinicians. Health professionals have a tendency to utilise and rely upon medical jargon in their verbal explanations (Houts et al., 2006). From the view of a health professional, these terms are familiar and provide a precise explanation of the presenting condition (Houts et al., 2006). Additionally, there may be an absence of suitable, equivalent, non-technical words that can be substituted to accurately communicate the same ideas to the patient (Houts et al., 2006).

The overuse of technical jargon can impede understanding and the ability to retain and recall health information (Jackson, 1992; Watson & McKinstry, 2009). Health literacy remains a substantial issue worldwide (World Health Organization, 2013b) and within New Zealand (Ministry of Health, 2010). The general population can have difficulty understanding medical terminology in written health materials, even with terms that are commonly used in the medical setting such as ‘screening’ or ‘symptoms’ (Smith, Trevena, Nutbeam, Barratt, & McCaffery, 2008). Generally, the lay public has a limited understanding of bodily structure and biology. Patients too can have an inadequate understanding and poor health literacy in regard to their own medical illnesses and treatments (Braddock III, Edwards, Hasenberg, Laidley, & Levinson, 1999; M. Williams et al., 1995), with some patients even demonstrating difficulty in identifying the location of their affected organ (Weinman, Yusuf, Berks, Rayner, & Petrie, 2009). The overuse of technical terminology may become even more problematic when medical staff unintentionally mismatch the complexity of information presented with the patient’s learning ability (Osborne, 2006). Contextual factors of the healthcare setting may therefore result in the patient attempting to make sense of an overwhelming amount of information, explained using unfamiliar and technical language.

**Patient-Specific Factors**

Patients can also experience factors within the medical consultation that limit their ability to successfully retain health information, such as problems with comprehension and the experience of psychological or physical symptoms. Verbal communication is the most commonly used method for delivering health information. When supplementary materials are provided these tend to be in a written format (Ngoh & Shepherd, 1997). Written materials cannot convey all types of health information, such as physiological movements or dynamic processes (Wilson et al., 2012). Written materials may also be difficult for patients to attend to (M. Williams, Baker, Parker, & Nurss, 1998), particularly those with reduced abilities regarding comprehension and literacy (Kessels, 2003). Importantly, this group is often
the population who are most in need of health advice (Michielutte, Bahnson, Dignan, & Schroeder, 1992). Individuals with limited literacy typically demonstrate decreased understanding of their illness, poor self-management, and reduced involvement in medical decision making (Dewalt, Berkman, Sheridan, Lohr, & Pignone, 2004). For these patients, the initial barrier to understanding is the delivery of health information using an unapproachable learning medium (Brotherstone, Miles, Robb, Atkin, & Wardle, 2006), even before an attempt to understand information content is made. Moreover, conveying information about disease aetiology or treatment efficacy through verbal or written formats may be especially difficult, due to the complex thinking required to understand intangible and invisible bodily processes.

The experience of illness may also impede patient comprehension of health information. The nature of seeking medical care means that patients are likely burdened by the experience of unpleasant physical symptoms, such as pain and discomfort. Additionally, when faced with a new illness diagnosis or health threat, it is also likely that patients will experience anxiety in conjunction with their physical symptoms. The intrusive experience of physical symptoms and anxiety may preoccupy the patient, impairing their ability to concentrate and subsequently compromising their ability to retain relevant medical advice (Houts et al., 2006). Therefore, even patients with sufficient language and comprehension skills may have difficulties in understanding information if they are concurrently burdened by symptoms (Houts et al., 2006). Experiencing high levels of anxiety and distress not only impact comprehension, but also memory for medical information (Kessels, 2003). Evidently, providing information to patients is not a straightforward process. Therefore, before a change in health behaviour can even be considered, the most important step in ensuring patient acceptance of a treatment is facilitating effective comprehension of health information.

Effects of Poor Communication on Health Outcomes

Given that these patient-specific factors are likely to occur during a medical consultation, it is important to consider the resulting effects of poor communication upon health. Misunderstanding may lead to the development of faulty perceptions of illness and treatment efficacy beliefs. Treatment advice generally includes specific detail in regard to dosing regimens, but can also include information regarding the purpose of treatment and efficacy. Poor understanding can result in unhelpful beliefs regarding the nature of illness and the necessity of treatment, which are consistently linked with poor outcomes across a range of illness groups (Broadbent et al., 2015; Cooper, Jackson, Weinman, & Horne, 2002; Hagger & Orbell, 2003; Horne et al., 2013). Misunderstandings of health information could also result
in problematic decisions that subsequently affect patient health. Both low health literacy and poor understanding have been associated with greater non-adherence across a number of illness populations (Kripalani, Gatti, & Jacobson, 2010; M. Williams et al., 1995). Importantly, even when language is not a barrier, patients can still fail to comprehend medical instructions (M. Williams et al., 1995). Failure to attend to health information may therefore result in misunderstandings of health and treatment necessity, which in turn may influence treatment intentions and adherence behaviour.

Finding alternate methods of communication that enhance and support patient understanding, despite the existence of these barriers, is therefore an important avenue of research for health psychology. Health information should be delivered using a format that promotes coherence and retention to increase the likelihood of better health outcomes for patients.

**Theory Supporting the Use of Visual Health Information**

An alternate method for delivering health information to patients is to present information using a visual format. Visual health information has several advantages over traditional delivery formats. Firstly, visual information may improve comprehension, particularly for individuals with reduced comprehension skills or low health literacy (Entwistle & Williams, 2008). For these patients, visual information removes barriers imposed by written or verbal communication (Brotherstone et al., 2006). Visual illustration can significantly improve comprehension when compared to traditional text formats alone (Michielutte et al., 1992). Evidence suggests that both patients with high and low literacy gain improvements in understanding when images representing anatomical processes are incorporated into medical information (Smith et al., 2008). Medical processes, that are usually described using scientific terminology, can be transformed into recognisable visual depictions of internal bodily processes and functions. Importantly, in comparison to written materials, animations about colorectal cancer screening accompanied with verbal information have been found to result in the same level of information recall for both high health literacy and low health literacy individuals (Meppelink, van Weert, Haven, & Smit, 2015). This suggests that visual information can support understanding in lower health literacy populations, and effectively deliver complex health information to individuals from all educational backgrounds.

Risk communication research also highlights the efficacy of visual aids in improving understanding of health risk information, particularly within vulnerable groups (e.g. low literacy, language barriers, high-risk patients, older adults) (Garcia-Retamero & Cokely, 2013). Patients value the way that images increase their understanding of the ‘invisible’ processes occurring inside the body.
(Carlin, Smith, & Henwood, 2014; Vilallonga et al., 2012), and find visual imagery an appealing learning medium (Michielutte et al., 1992). Images may even increase trust and understanding at the point of diagnosis (Phelps, Wellings, Griffiths, Hutchinson, & Kunar, 2017), which presents a crucial opportunity to promote adaptive behaviours for long-term illness management.

In addition to being a more appealing and understandable learning medium, evidence suggests that visual images are also more memorable than verbal or written information (Gardner & Houston, 1986). Different information formats such as written, auditory, and imagery-based information are each processed and stored distinctively within memory (Mayer, 2008). Theories suggest that visual information is subject to enhanced cognitive processing. Paivio’s Dual Coding Theory (1971) suggests that information is processed through two mental pathways, the verbal and imaginal systems (for non-verbal stimuli). These systems activate different sensory systems within the brain. Visual information is encoded using dual processes of both verbal and image traces, whereas verbal information is processed sequentially by each of these systems. The dual processing of visual stimuli therefore leads to the 'picture superiority effect' and an enhanced response within memory for encoding and retrieval (Paivio & Csapo, 1973).

Similarly, Yuille & Catchpole’s (1977) information processing theory suggests that the processing of visual stimuli includes the use of both perceptual and sensory memory systems within the working memory. In contrast, the discursive processing used for verbal retrieval and encoding is not related to these same internal sensory experiences (MacInnis & Price, 1987; Yuille & Catchpole, 1977). Distinctiveness models of image encoding also determine that pictures are easier to remember than text due to their distinct visual-sensory aspects (Mintzer & Snodgrass, 1999). Each picture has distinct sensory and semantic features that make it highly discriminable from others and ensure that each picture is uniquely encoded within memory (Brotherstone et al., 2006; Mintzer & Snodgrass, 1999).

Therefore, in comparison to linguistic information, visual stimuli are encoded more rapidly and are more accessible within memory, making them easier to recognise and recall (Paivio, Walsh, & Bons, 1994). Indeed, presenting 3-D or 2-dimensional (2-D) images alongside a diagnosis can boost recall of information pertaining to the medical condition and symptoms within a simulated medical consultation (Phelps et al., 2017). A review by Houts and colleagues (2006) also noted that the inclusion of pictures alongside written and spoken language increases recipients’ attention, recall,
comprehension, and adherence to that information. Importantly, this effect was most pronounced for individuals with lower literacy levels.

The Elaboration Likelihood Model (ELM) is another processing model that suggests a potential mechanism by which visual information can influence health behaviour change (Petty, Barden, & Wheeler, 2009). This model proposes that when information is elaborated at a higher level (using a greater level of thought), lasting changes in behaviour are more likely to occur. As visual information is more salient, this could cause higher elaboration of that information. Information elaborated at a higher level is processed via the central route, which can modify attitudes that become part of the individual’s belief system. These attitudes are considered more accessible within memory, are maintained long term, are more resistant to change, and predictive of behaviour.

ELM theory also suggests that there are two determinants of how information will be processed; motivation and ability. The motivation of elaboration is influenced by the personal relevance of the information (Petty & Cacioppo, 1979). It is likely that visual health information would elicit high motivation through depictions of risk regarding pathology and disease progression relevant to the patient. Second, visual formats may increase the ability to understand health information compared to other traditional formats. Ability can be impaired by distractions within the learning context (Petty, Wells, & Brock, 1976). The healthcare environment can include many distractions affecting information processing and cognitive resources, such as the experience of symptoms and distress. Visual health information, in comparison to written information, may therefore heighten the ability to process information within the healthcare system by removing additional barriers related to literacy. Visual information should therefore increase motivation for information processing, while simultaneously compensating for a potential reduction in ability (which is likely overlooked by more traditional forms of health information).

Visual health information may also align with patients’ cognitive models of their illness. The lay public often describe having ‘pictures’ of information within their mind (MacInnis & Price, 1987). In regards to illness, these pictures could be thought of as cognitive representations of disease and treatment. There is increasing evidence that patients perceive their illness visually, and develop mental images or metaphors of their illness beliefs, anatomy, and disease processes (Harrow, Wells, Humphris, Taylor, & Williams, 2008; Mabeck & Olesen, 1997). Numerous drawing studies, where patients are asked to draw a picture of their affected organ, demonstrate the visual perceptions of health and disease that patients hold (Broadbent, Niederhoffer, Hague, Corter, & Reynolds, 2009;
Figure 1. Examples of patient drawings representing perceptions of cardiovascular damage from before and after myocardial infarction (Broadbent et al., 2004).

Formal models of illness cognitions suggest that illness representations exist upon a continuum, ranging from abstract and conceptual, to concrete and experiential (Leventhal, Meyer, & Nerenz, 1980). Visual imagery may have the capacity to turn abstract ideas about illness (i.e. internal, non-tangible ideas of disease) into more concrete representations (Devcich, Ellis, Waltham, Broadbent, & Petrie, 2014; B. Williams, Anderson, Barton, & McGhee, 2012). Patients also acknowledge the value of being able to 'see' what is going on inside their body (Carlin et al., 2014; Devcich et al., 2014). Moreover, when clinicians communicate using medical imaging or metaphors, this has been found to influence the patient’s mental image of their illness, as well as their beliefs, fears, and perceptions of treatment efficacy (Harrow et al., 2008). Presenting health information using concrete, visual demonstrations may therefore influence patient understanding of physiological disease processes and mechanisms of treatment action within the body.
How Might Visual Information Improve Adherence?

Visual information may have the capacity to increase adherence to health behaviours by improving understanding and recall of information, and behavioural motivation. Ley’s model of patient communication (1988) suggests that adherence is influenced by understanding, recall, and satisfaction. The easier that information about health behaviours is to understand and recall, the more likely that information is to influence adherence to those behaviours. Visual health information may therefore motivate adherence to health behaviours by a) increasing the saliency of health risks, b) establishing concordance between the patient’s understanding of the problem and treatment necessity, and c) by eliciting an emotional response to health information.

First, visual health information may motivate change in patient behaviour by increasing the salience of health risks. It is well established that patients hold cognitive representations of health threats (Leventhal et al., 1980). These mental representations develop as a function of information derived from health professionals, as well as the patient’s own understanding, fears, and concerns about their health and body (Harrow et al., 2008). Health behaviour theories posit that imagery can impact motivation by increasing perceptions of risk, and negating beliefs of being impervious to illness (Rees et al., 2013). Models of illness cognitions (Leventhal et al., 1997) and treatment adherence (Horne, 1997) suggest that a patient’s perception of the ‘problem’ (their condition) will influence how appropriate they believe a treatment is. Therefore, if no accurate perception of a problem or health risk exists in the first instance, health behaviours are unlikely to change.

Visual imagery may also be effective in increasing motivation by creating alignment between the patient’s understanding of the problem (their disease or illness) and the necessity of treatment (Karamanidou, Weinman, & Horne, 2008), through conveying clear, concrete representations of health and illness threats. Effective motivations to change health behaviour arise from perceiving the link between a concrete illness threat and behaviour change (Petrie, Broadbent, & Meechan, 2003; Hall, Weinman, & Marteau, 2004). The more concrete that illness representation is, the greater potential it has to influence health behaviour (Hollands & Marteau, 2013; B. Williams et al., 2012). Indeed, empirical evidence suggests that providing imagery of a health threat is more effective in influencing health behaviour intentions compared to written text alone (Vardavas, Connolly, Karamanolis, & Kafatos, 2009). Furthermore, visual health information may be particularly efficacious in increasing illness understanding and treatment motivation for asymptomatic conditions (with an absence of physical, motivational cues for treatment), or for treatments where consistent adherence does not
result in noticeable symptom reduction for patients. Visual, biological depictions of health information may therefore increase information salience, perceived risk, and subsequently motivate change in health behaviours.

Imagery may also increase information salience by evoking a heightened emotive response. Viewing an image of a stimulus can evoke the same response from the brain as interacting with that stimulus in a real life encounter (Paivio et al., 1994). Therefore, the ability of visual information to convey a real, personal health threat is likely to be confronting and elicit fear within the individual. Fear arousal activates visual-spatial regions of the brain resulting in enhanced memory for visual-spatial information (Putman, Van Honk, Kessels, Mulder, & Koppeschaar, 2004). The resulting anxiety can increase the encoding of that information within memory. Individuals may therefore have heightened focus upon and greater recall for anatomical diagrams or mental images of illness developed during consultations (Cameron & Chan, 2008). Depicting a personal illness threat can therefore increase anxiety, enhance attention towards the information, heighten information encoding, and allow easier access to and recall of that information via the availability heuristic (Joffe, 2008; Tversky & Kahneman, 1974). Imagery may therefore be a powerful tool to increase the likelihood that patients accurately attend to information delivered by health professionals.

Importantly, a fear message which elicits anxiety alone may not be successful in promoting health behaviour change (Leventhal, Brissette, & Leventhal, 2003). Just as too little anxiety is counterproductive to attention and memory, so too is the experience of excessive anxiety (Kessels, 2003; Ley, 1979). Emotions theory suggests that heightened anxiety can either motivate behaviour in an attempt to decrease the unpleasant feeling of anxiety created by the stimuli, or conversely, promote defensive avoidance as an adaptive response to escape these feelings (Janis & Feshbach, 1953). Exposing patients to the reality of a health threat in the face of an unhealthy behaviour could cause conflicting feelings and elicit cognitive dissonance (Festinger, 1957), which may be managed through escapist behaviours. To successfully change behaviour, information depicting a health threat should be coupled with a behavioural plan suggesting how the threat can be decreased (Leventhal et al., 2003).

Visual health information should therefore both expose patients to a health threat and provide imagery that explains response efficacy (how to lessen the threat) (Cameron & Chan, 2008). For example, simply showing a patient an image depicting high levels of arterial cholesterol may not be an effective intervention. However, coupling this image of a health threat with an explanation of how statin works to prevent cholesterol deposition in the arteries may be more likely to motivate increased
adherence. Efficacious adherence interventions should utilise methods which provide patients with a complete understanding of how treatment aligns with illness (Petrie & Weinman, 2012), by establishing a clear link between the threat posed by an illness and how treatment can mitigate that threat. The dual presentation of both a health threat and treatment efficacy information should therefore elicit effective behaviour change.

**Using Visual Information to Modify Perceptions and Improve Understanding**

Visual imagery has been used in research to increase patient understanding with regard to a wide range of diseases, procedures, and treatments. Computer-based, 2-D animations have been used to enhance patient understanding of heart failure (Strömberg, Dahlström, & Fridlund, 2006), and to prepare patients for cardiovascular and gastroenterological procedures (Enzenhofer et al., 2004). Both 2-D and 3-D animations have also been found to improve recall of colorectal cancer information and improve understanding of prostate health respectively in populations with low literacy levels (Meppelink et al., 2015; Wang et al., 2015).

3-D animations have been utilised to educate patients undergoing thyroid surgery regarding basic anatomy, the surgical procedure, and possible complications (Hermann, 2002). In this randomised controlled trial, seeing the animations in comparison to text alone decreased anxiety and additionally increased understanding of the procedure, trust in the treatment, and self-reported readiness for the operation. Dental research has also utilised 3-D animations to educate patients with periodontitis. Animations explaining the aetiology, symptoms, physiology, and treatment of periodontitis can increase recall of knowledge pertaining to the condition up to three weeks following the intervention, above receiving narration and sketch drawings only (Cleeren, Quirynen, Ozcelik, & Teughels, 2014). Among individuals with rheumatoid arthritis, ultrasound imaging has also been used to educate patients about the necessity of their medication (El Miedany, El Gaafary, & Palmer, 2012).

Qualitative research suggests that patients can gain value from ‘seeing’ their personal medical imaging. Showing obese patients a CT scan of their fat and body composition as part of a weight reduction programme has been found to increase interest about related disease, feelings of involvement in the medical consultation, and behavioural motivation (Bergelin & Lundgren, 2014). Participants completed scans prior to commencing the weight reduction programme and six months later. Participants whose follow-up images revealed reduced fat storage in the liver were increasingly motivated to continue their behaviour change. Another qualitative study with cardiac patients also revealed the value that patients draw from being able to see the reality of disease inside their body.
from coronary imaging scans (Devcich et al., 2014). Images also appeared to reinforce messages given during consultations, provide participants with a more concrete understanding of their heart condition, and helped establish links between lifestyle changes and disease. Showing patients biological evidence of behaviour change results through imaging may therefore help maintain and promote consistent adherence.

Visual imagery has also been used in research to improve understanding and beliefs regarding cancer screening behaviour. In contrast to standard written information, simple 2-D visual images have been found to increase understanding of the purpose of colorectal cancer screening in a sample of eligible older adults (Brotherstone et al., 2006). A more sophisticated 3-D multimedia animated intervention has also been found to improve understanding of colon cancer in patients undergoing diagnostic colonoscopy (Hassinger et al., 2010). Understanding of colon cancer significantly improved after seeing the intervention, with the greatest increases in individuals who had the lowest levels of understanding at baseline. However, these results were limited by the lack of a control group for comparison, and the use of a pre-test which may have primed attentional focus.

Another study has demonstrated the preventative use of visual health information. Viewing a 3-D heart model of cardiac pathology has been found to improve risk perceptions in sedentary, healthy, young adults (T. Lee, Cameron, Wünsche, & Stevens, 2011). The model depicted heart rate and cholesterol build-up modified to match the likely heart status of each participant, and displayed ‘future’ depictions of how healthy or unhealthy behaviour would affect this. Seeing the imagery improved understanding of cardiac risk, resulted in greater worry about heart disease, and increased healthy diet and exercise intentions. Although these results provide insight into how visual health information could be utilised preventatively to improve motivations, the use of a healthy, young population limits the generalisability of these results to the wider, at-risk population.

**Using Visual Information to Change Health Behaviours**

Despite a strong theoretical relationship between visual health information and improved behaviour change, limited empirical evidence exists to demonstrate this association. One large area of research has utilised personalised medical imaging. This method is commonly used in studies of smoking cessation behaviour, where smokers are shown pictures of their atherosclerotic plaques or arteries from imaging such as ultrasonography. Some studies find increases in intentions for smoking cessation (Shahab, Hall, & Marteau, 2007), while others additionally describe increased quitting behaviour. Bovet and colleagues (2002) showed smokers high-resolution ultrasonography arterial images revealing the
development of peripheral atherosclerosis, to determine if this exposure (in addition to quit counselling) would motivate smoking cessation. Those whose imaging revealed a plaque had a significantly greater self-reported rate of quitting at six month follow-up (22%), in comparison to those whose image showed no plaque (5%), or those who received quit counselling only (6.3%). It was hypothesised that exposure to imaging increased motivation by translating smoking from a perceived hypothetical threat to a current health problem (Bovet et al., 2002). This supports the ability of visual imagery to increase the saliency of health risk information.

A Cochrane review article on the use of medical imaging to change health behaviours suggested an overall relationship between imaging and smoking cessation (Hollands, Hankins, & Marteau, 2010). In the three reviewed smoking cessation trials (Bovet et al., 2002; O’Malley, Feuerstein, & Taylor, 2003; Shahab et al., 2007), the pooled effect of viewing imaging was an increase in smoking cessation behaviour of 2.81 times that of individuals in the control conditions (Hollands et al., 2010). Although these studies suggest evidence for using diagnostic imaging to promote behaviour change, multiple component interventions such as these prevent an understanding of the specific benefits gained from the use of visual imagery.

Medical imaging from diagnostic procedures has also been used in research with cardiac patients to increase motivation, awareness, and behaviours associated with reducing cardiovascular disease risk. Mols and colleagues (2015) showed patients with newly-diagnosed coronary artery disease their angiogram images in an attempt to motivate health behaviours to decrease cholesterol levels. The intervention group saw these images in addition to receiving information and a follow-up consultation with their GP as part of standard care. The intervention condition reported greater adherence to statin medication, increased uptake of healthy dietary behaviours, and higher smoking cessation levels, when compared to the control group. There was also a significant decrease in total cholesterol levels among participants in the intervention group who were still continuing statin therapy at follow-up.

Importantly, studies using personalised medical imaging have found effects to be greater for patients whose imaging depicts a more severe condition. Both Bovet and colleagues (2002) and Rodondi and colleagues (2008) found that when showing smokers pictures of their plaques (in addition to receiving counselling and nicotine replacement therapy), smoking abstinence is greatest for those whose imaging reveals a visible plaque. Similarly, Devcich and colleagues (2012) found that cardiac patients whose angiogram imaging revealed diseased arteries had greater intentions for medication
adherence and exercise than patients with normal results. These patients also reported greater exercise levels at six week follow-up.

This association between increased severity of imaging and greater positive health behaviour change has been established in other cardiac populations (Orakzai et al., 2008), even at long-term follow-up (Schwartz, Allison, & Wright, 2011). Level of severity as depicted by coronary imaging has also been associated with increased adherence to cardiac medication such as statin therapy and aspirin via self-report (Kalia et al., 2006), and more objective adherence measures (Labounty, Devereux, Lin, Weinsaft, & Min, 2009; Taylor et al., 2008). These interventions can even have long-term benefits, with one study finding this association between the presence of coronary artery calcification and adherence up to six years after viewing the cardiac imaging (Taylor et al., 2008). Kalia and colleagues (2006) hypothesised that seeing personal risk for asymptomatic conditions like atherosclerosis may motivate engagement with treatment. Visual information may therefore trigger behaviour change in the absence of biological cues.

A small pilot study utilising a different form of personal medical imaging showed promising change in a clinical outcome. In this study, patients with diabetic retinopathy were randomly allocated to receive either their personal retinal images, or to control group receiving standard care (Rees et al., 2013). Participants’ retinal images were classified as either mild, moderate, or severe retinopathy. Example images demonstrating varying levels of severity were also displayed for reference. Participants received the images alongside information about the retina, the impact of suboptimal blood glucose control, and other disease-related information. At three month follow-up, the intervention group were significantly more motivated to control their blood glucose, and demonstrated a statistically and clinically significant decrease in HbA1c compared to the control group. Although limited by a small sample size (n=25), this study found a clinical improvement within the intervention group who received their personal imaging. It may be that comparing images of personal disease severity to other classifications of morbidity increases the salience and emotional impact of information, and therefore motivates behaviour change.

Although the use of personalised medical imaging is straightforward and cost-effective, it is important to note that research findings are not homogenous. One study found that intensive case management was a better intervention for improving cardiac risk factors than coronary calcification imaging, which produced no changes in outcomes (O’Malley et al., 2003). In a study of patients undergoing diagnostic laparoscopy for pelvic pain, participants randomised to view a polaroid photo of
their pelvis taken during surgery were not found to have any changes in reported levels of pain, understanding, or satisfaction with their consultation (Onwude et al., 2004). Furthermore, a study in patients with lower back pain found that showing participants an MRI of their lumbar spine resulted in no improvements in clinical or subjective outcomes, with the imaging group actually having a significant decrease in a general health measure at follow-up (Ash et al., 2008). Visual evidence suggesting a lack of pathology could conflict with a patient’s pain experience and result in negative effects on mood and anxiety. Furthermore, personalised medical imaging may only be helpful when moderate disease risk is depicted, as one study aiming to increase preventative cardiac behaviours found that imaging that reflected low risk adversely encouraged abstinence from behaviour change (Lederman, Ballard, Njike, Margolies, & Katz, 2007).

In conclusion, while many studies have used visual imagery as part of interventions to improve health, there are important considerations regarding this evidence. First, the majority of literature is limited by the use of 2-D diagnostic imaging. The impacts of other forms of visual imagery are largely unknown. Second, the use of personalised risk imaging alone may only be powerful for patients with severe levels of disease, as patients whose imaging reveals mild pathology may be reassured that behaviour change is not an urgent requirement for their health. Third, these studies are inconsistent in terms of producing positive changes in health behaviours, and therefore provide only limited conclusions about the effectiveness of visual imagery as a form of intervention. Studies utilising personal diagnostic imaging also have a methodological flaw that may account for these inconsistencies. These studies present patients with a static image of a health threat. As theorised above, exposure to a health threat in isolation may result in an incomplete picture regarding the relationship between illness and treatment. Although some studies also provide additional counselling or information, it is likely that the visual imagery is what remains salient in memory, due to the unique encoding processes described earlier. This visual health threat may be the literal ‘image’ that the patient retains once they leave a consultation. When considering how to motivate behaviour change, it may be more useful to provide holistic visual depictions that represent both disease processes and explanations of how changing behaviour can prevent illness progression. Therefore, it is important to provide more visual information than a single picture, and to instead consider the best method for delivering visual information to increase understanding of illness and treatment.
Visualisation Intervention Studies

As defined at the beginning of this chapter, visualisation is a more holistic method of portraying visual information, which attempts to provide patients with a context for understanding a disease or treatment process. For this reason, visualisation interventions may be more effective and comprehensive in improving patient health behaviours. Few studies have developed novel visualisation interventions to change health behaviours and adherence, which provide this comprehensive level of detail about disease and treatment processes.

A seminal visualisation intervention study conducted by Karamanidou and colleagues (2008) used a physical demonstration to explain the mode-of-action of phosphate-binding medication to patients with end-stage renal disease. Participants were shown a plastic container and asked to imagine that this represented their stomach. The researcher poured a phosphate solution into the container which symbolised the ingestion of high-phosphate food. A second solution was then added representing the phosphate-binding medication. This physical demonstration allowed participants to see how their medication works and the purpose of the treatment. After viewing the intervention, participants reported significant improvements in treatment understanding, and greater beliefs about medication necessity and treatment efficacy. These improvements remained present one month post-intervention. Changes in perceived treatment understanding and efficacy, however, did not translate into increased treatment adherence. Although this intervention demonstrated the purpose of treatment, creating a link between treatment and general disease management may have further motivated adherence. Importantly, participants in the study acknowledged the value of the visual demonstration, claiming that “a picture is worth a thousand words” and the “picture has stuck in my mind” (p. 209).

Stephens and colleagues (2016) used a different physical visualisation technique to investigate how effective bone models could be in motivating treatment initiation among patients newly-diagnosed with osteoporosis. In this study, participants received either a standard consultation or an enhanced consultation using two 3-D bone models depicting osteoporotic and healthy bone (see Figure 2). The models were 3-D printed in plastic using data from CT scans of the iliac crest of the hip from an osteoporotic patient and a healthy patient. Participants who saw the bone models reported a greater emotional response associated with their osteoporosis after their consultation, and greater levels of understanding of osteoporosis at follow-up. A greater proportion of the intervention group were also more likely to initiate oral bisphosphonate medication, although this difference did not reach statistical significance. This study therefore revealed that visualisation can enhance understanding and the
saliency of health information, as evidenced by the greater emotional response in the visualisation group.

Figure 2. 3-D printed bone models used in Stephens et al. (2016) depicting osteoporotic (left) and healthy (right) bone.

Visualisation interventions can also utilise technology for delivery in a portable, easy to disseminate format. An innovative, smartphone application was used in a trial attempting to improve adherence to antiretroviral therapy (ART) in patients living with HIV infection (Perera, Thomas, Moore, Faaske, & Petrie, 2014). Participants in this study received one of two versions of a smartphone application. The first group received a standard application which included a medication clock reminder. The second group received an augmented version which included an animated simulation estimating the participant’s current plasma concentration of medication, and consequent level of immune protection (see Figure 3). Participants could therefore see in real-time how their adherence behaviour affected the immune and viral activity within their body. At three month follow-up, participants who received the augmented application reported greater adherence to medication and had decreased viral load, in comparison to those receiving the standard application. Although limited by a small sample size (n=28), this study revealed how visualisation can utilise technology to increase portability, and how such tools can be used to improve adherence.
Figure 3. Screenshot of the simulation animation of CD4 cell and viral activity in the smartphone application used in Perera et al. (2014).

Technology was also utilised in another visualisation intervention to improve illness perceptions and recovery in patients following an acute coronary event (Jones, Ellis, Nash, Stanfield, & Broadbent, 2016). In this study, following a myocardial infarction, participants were exposed to animations and computer modelling of the heart on an iPad at their bedside during hospitalisation. The heart model depicted their estimated level of heart damage (mild, moderate, or severe, as based on their Troponin-I level), while subsequent animations and illustrations demonstrated the mode-of-action of their statin and aspirin medications in preventing future cardiac events (see Figure 4). At seven week follow-up, participants who saw this intervention reported increased treatment control beliefs, reduced cardiac anxiety, faster return to normal activity times, and greater levels of exercise, as compared to those randomised to standard care only. This study provides another example of how visualisation could be easily incorporated into clinical practice to improve patients’ perceptions of illness and treatment, and influence changes in health behaviour.

Figure 4. Screenshot of animation depicting efficacy of statin medication from Jones et al. (2016), with added labels.
Gaps within the Literature

Although empirical work exists within the realm of visual health information, there are some important gaps in understanding the efficacy of this intervention technique. Firstly, there is a clear lack of homogenous evidence for the efficacy of visual health information in improving patient outcomes, and in particular objective health outcomes. The studies that do show changes in clinical outcomes are limited by small sample sizes (Perera et al., 2014; Rees et al., 2013), provide only partial evidence (Stephens et al., 2016), or highlight changes in self-reported outcomes only (Jones et al., 2016). This limits understanding regarding the efficacy of visual imagery beyond use as purely an educational tool.

The lack of concordant results in previous studies could be associated with methodological limitations in study designs. Studies utilising visual health information often fail to include adequate comparison groups, such as standard care or other control groups. This diminishes the ability to understand the specific additive effects of visualisation as an intervention technique. It is therefore important to consider how to best design visualisation studies so that findings suggest additional efficacy to receiving that same information in a standard verbal format.

Second, as described above, the majority of research using visual imagery has relied upon the use of personalised medical imaging. Although diagnostic imaging is easily accessible and can increase motivation, many of the studies discussed have methodological flaws, including a lack of randomised-controlled designs, the absence of comparison groups, and a reliance on self-reported measures of behaviour change. Showing diagnostic imaging alone may provide patients with an incomplete picture regarding how behaviour change can result in the reduction of a health threat. Furthermore, unfamiliar medicalised images may be difficult for patients to interpret, understand, and relate to their health.

Interventions which utilise specifically-designed visualisations may enhance understanding and prove more powerful in changing patient outcomes. However, work in this area is limited. We are yet to understand whether certain formats of visualisation are more effective than others, for example physical (e.g. demonstrations, 3-D printed models) versus virtual (e.g. animated) visualisations. Future research should also focus on creating well-designed, randomised trials to allow more rigorous testing of the effects of visualisation upon health behaviours. Lastly, we are yet to understand the potential of visualisation to impact upon behaviours other than medication adherence. There is a need for trials which comprehensively develop and test the components of visualisation using different
methodological techniques. These studies will provide a more thorough understanding of the potential and limitations for incorporating visualisation into clinical care to communicate health information.

Summary

The effective delivery of health information to patients is essential for optimal healthcare. Despite this, both clinician and patient enter this exchange with pre-existing factors that can greatly impede the transaction of information. Visual health information presents an alternative communication method. Theoretical and empirical evidence demonstrates how visual imagery may enhance understanding and utilisation of health information. The majority of empirical evidence examining the use of visual imagery in healthcare has utilised existing personal medical imaging, rather than creating visual imagery that depicts both illness aetiology and treatment mode-of-action. Furthermore, this diagnostic imagery may only be effective for patients with severe levels of risk. Visualisation presents a new intervention technique that provides initial evidence for improving health behaviours, by providing a more complete explanation of the illness problem and purpose of treatment. The current visualisation literature is minimal, contains clear gaps, and limited evidence for change in objective health outcomes. The following chapters of this thesis will address these gaps to broaden understanding of how visualisation interventions can improve health outcomes for patients.
Chapter Three

Assessing Preferences for Visual Health Information

Preface

Within healthcare consultations, information is delivered verbally from the clinician to the patient. This verbal information can be supplemented with additional relevant material. Traditionally, the most common format of supplementary material is written health information (Ngoh & Shepherd, 1997), such as brochures or information sheets describing procedures and treatments. It is likely, however, that idiosyncrasies exist regarding how individuals would prefer to learn about health, including the format of the information they receive. While some individuals are content with written information, others may benefit from receiving visual health information instead. Furthermore, a mismatch between format preference and information delivery could create an additional barrier to understanding and effectively utilising health information.

Chapter Two established that visual formats can increase the comprehension, motivation, and encoding of health information. It is probable, however, that there are individual differences in the extent to which visual health information is beneficial in improving the understanding of illnesses and treatments. Some individuals may require a visual explanation of their illness to comprehensively understand disease pathology and the link between disease and treatment. Some patients find that visual information increases their understanding of the 'invisible' processes of illness (Carlin et al., 2014; Devcich et al., 2014). It is therefore important to identify patients who would prefer the inclusion of additional visual health materials in explanations of illness and treatment processes.

Highlighting individuals who would benefit most from visualisation tools can allow preference to be matched with information delivery, which could increase understanding and subsequent health behaviours. Matching preference and information delivery may additionally improve patient satisfaction with health information and with their healthcare in general. Health professionals could also use patient preferences to customise and personalise information delivery during consultations, which may increase patient feelings of involvement. Understanding these individual differences is therefore important for enhancing the effectiveness of supplementary health information, and in particular the potency of visual health information.

To date, there is no way of measuring the extent to which individuals prefer visual health information. The following manuscript describes the development and psychometric properties of a
new measure, the Health Visualisation Information Preference Scale (Health VIPS). The Health VIPS is a brief, 9-item scale that measures preferences for receiving additional visual health information in hypothetical healthcare scenarios. The Health VIPS includes items regarding whether being shown scans, images, visual demonstrations, and animations would help improve understanding of illness, treatments, and procedures. Reverse-coded items measure the extent to which patients are satisfied with written information and do not require additional visual information. This measure therefore aims to address this gap and to identify those who prefer the addition of visual health tools.

Two studies are included in the following manuscript. These studies demonstrate the utility of the Health VIPS in three independent samples, including healthy young adults, clinical outpatients, and patients undergoing surgery. These diverse samples provide insight regarding how this measure could be utilised across different healthcare settings to match information delivery with individual preferences.
Citation
Abstract

Objective. Patients are likely to have individual preferences for learning about health, which may influence their comprehension and utilisation of health information. Some patients may prefer visual health information, which can make complex health information easier to understand. Aligning health information presentation with preferences may increase understanding and improve health outcomes, yet no scale measures preferences for visual health information. Design. Two studies examined the psychometric properties of the Health Visual Information Preference Scale (Health VIPS), a new measure designed to assess preferences for visual health information. Methods. In Study 1, 103 undergraduate students and 97 patients undergoing colorectal and gynaecological oncology surgery completed the Health VIPS. Exploratory factor analyses (EFA) were conducted for both samples. Internal consistency, test re-test reliability, and validity were assessed in the student sample. In Study 2, 196 outpatients completed the Health VIPS. Confirmatory factor analysis (CFA) was performed on this sample, in addition to measures of reliability and validity. Results. In Study 1, EFA analysis revealed a one-factor structure. The Health VIPS demonstrated good internal consistency in both the student sample (α=.70-.80) and patient sample (α=.80), and good test-retest reliability in the student sample (r=.63, p<.001). Convergent and discriminant validity were also established. In Study 2, the CFA confirmed a one-factor structure. The Health VIPS also demonstrated discriminant and convergent validity. Scale item means in all samples were positively skewed, suggesting a general preference for visual health information. Conclusions. Initial evidence suggests the Health VIPS has good psychometric properties. This scale could identify patients who would benefit from additional visual aids when receiving health information.
Introduction

Delivering health information effectively to patients is an integral component of health care utilisation. The effective translation of health information from provider to patient should improve the likelihood that treatment recommendations evolve into adherence. Effective comprehension, however, can be difficult to achieve for many reasons, including factors of the clinical environment such as short consultation times and the intrusion of psychological and physical symptoms (Houts et al., 2006). Furthermore, physicians often overestimate patients’ abilities to comprehend the information they conveyed during a consultation (Kelly & Haidet, 2007). This becomes problematic as misunderstandings of health information impair the ability of the patient to apply recommended treatment and lifestyle changes to promote health.

One approach that may increase the comprehension and utility of health information could be matching information delivery with the patient's preferred information format. It is likely that idiosyncrasies exist regarding how patients would prefer health information to be delivered, which could influence their health behaviours. Evidence from health risk evaluation and decision-making research indicates that different methods of presenting risk result in differing evaluations and use of that information (Peters, Dieckmann, Dixon, Hibbard, & Mertz, 2007; Schapira, Nattinger, & McAuliffe, 2006). Indeed, the framing and packaging of information, particularly when unfamiliar and complex, can influence how that information informs choice (Peters et al., 2007). The medical encounter constitutes an unfamiliar and often complex scenario for most patients, meaning the ‘packaging’ and format of health information may influence understanding and subsequent behaviour.

In the healthcare setting, standard verbal explanations are generally supplemented with written materials such as pamphlets, medication inserts, and other printed instructions (Ngoh & Shepherd, 1997). Written health information may be helpful for patients with the capacity to read, understand, and remember that information (Hoffmann & Worrall, 2004). However, not all patients attend well to written health materials (Webster, Weinman, & Rubin, 2017; M. Williams et al., 1998), especially those with lower comprehension and literacy skills (Brotherstone et al., 2006; Kessels, 2003). Poor health literacy is common. The lay public also demonstrates difficulties in understanding medical terminology, even with terms that are commonly used within the healthcare context (Smith et al., 2008). Furthermore, research shows that patients often have only rudimentary knowledge of their anatomy and bodily processes (Weinman et al., 2009). Considering these widespread issues with health literacy, it is likely
that for some patients written health information is a barrier to understanding and utilising health information and advice.

Patients may prefer to receive visual information about illnesses and treatments, particularly those who struggle with health literacy or who are cognitively aligned to best understand visual representations of information (Houts et al., 2006; Peregrin, 2010). Visual depictions of health risk material are often preferred by patients (Edwards, 2002; Goodyear-Smith et al., 2008), and can increase both understanding and health risk perceptions (Galesic, Garcia-Retamero, & Gigerenzer, 2009; Lipkus & Hollands, 1999). Patients with both high and low literacy value the inclusion of anatomical images in health materials (Smith et al., 2008), and the ability of visual images to explain ‘invisible’ anatomical processes (Carlin et al., 2014; Devcich et al., 2014; Vilallonga et al., 2012). Visual tools and interventions have become increasingly popular methods for communicating health information to patients (Jones, et al., 2018a; Jones et al., 2016; Jones, Fernandez, Grey, & Petrie, 2017; Perera et al., 2014; Phelps et al., 2017; Rees et al., 2013; Stephens et al., 2016). However, it is yet unclear how many patients prefer this style of information, and whether all, or only certain, individuals respond better to information delivered this way.

Despite the likely existence of distinct preferences for health communication, to our knowledge, no measure exists to assess preference for supplementary visual health information. There is considerable research on learning styles and identifying ‘visual learners’ (Childers, Houston, & Heckler, 1985; Fleming & Mills, 1992; Kirby, Moore, & Schofield, 1988; Richardson, 1977), however, there is an important distinction to be made. Measures of learning style abilities do not assess information preferences. These measures are concerned with identifying where the responder sits in regards to different cognitive styles (e.g. visual versus verbal learner). There is no scale to identify patients with heightened preferences for receiving health information visually. Being able to identify patients with a visual health preference could ensure that additional information is provided in this format, which may increase comprehension and adherence to recommendations.

In this paper, we report on the development of a measure identifying preferences for receiving visual health information. This measure may help to identify patients who prefer and additionally respond better to visual explanations of health material in clinical settings. We report on the psychometric properties of the Health Visual Information Preference Scale (Health VIPS). Study 1 reports the results of exploratory factor analyses (EFA) conducted with both healthy and clinical
samples, and Study 2 reports the results of a confirmatory factor analysis (CFA) completed with a sample of outpatients attending hospital medical clinics.

**Study 1 Method**

*Participants*

Two independent samples completed the Health VIPS. The healthy sample comprised 103 undergraduate students from the Faculty of Medical and Health Sciences at the University of Auckland, studying between October and December 2017. The clinical sample consisted of 97 patients undergoing elective colorectal and gynaecological oncology surgery at Auckland City Hospital between July 2017 and July 2018, who completed the Health VIPS in a questionnaire battery as part of another clinical trial. Included participants spoke English, were over 18 years of age, and had no known mobility issues (as relevant to the clinical trial).

*Procedure*

The student sample were recruited by either a cohort email sent to a stage one health psychology course, or by Facebook invite in a medical student group. Participants received no compensation for taking part in the research. Respondents completed the questionnaire electronically by following a link to the website SurveyMonkey (2017), and provided informed consent before beginning the questionnaire. Participants answered demographic questions (age, gender, highest level of education), followed by the Health VIPS and other validation measures (reported below). Participants were emailed two weeks later and asked to re-complete the questionnaire for test re-test reliability assessment. Test re-test reliability was conducted in the student sample only, as the clinical sample were undergoing surgery and this intervention could have influenced test re-test reliability in this sample. The study was approved by the University of Auckland Human Participants Ethics Committee.

The clinical sample completed the Health VIPS as part of a baseline battery of measures collected at their surgical pre-admission appointment. Ethics approval was gained for this study from the Health and Disability Ethics Committee and the Auckland District Health Board.

*Health Visual Information Preference Scale items*

To create the initial Health VIPS item pool, the authors (AJ, MK, LM, KP) reviewed the literature for existing scales attempting to assess visual learning preferences. Items were developed using a mixture of methods, including expert consultation from study authors to generate items, and reviewing two learning preference scales (Fleming & Mills, 1992; Kirby et al., 1988) for examples that could be used
as a style guide for item wording. Each author was instructed to develop 5 to 6 items that considered
the use of different types of visual health information (e.g. diagrams, illustrations, scans) in different
medical settings where information is commonly provided (e.g. surgical preparation, treatment
initiation, consultations). These items comprised a raw pool of 22 items. The authors consulted and
removed items from this list that had obvious overlap and addressed similar content from a face validity
perspective, which resulted in an initial 12-item scale used for pilot testing.

This 12-item initial version was piloted with 45 postgraduate health psychology students at the
University of Auckland, as well as undergraduate psychology students from La Sierra University,
California and Philipps-University of Marburg, Germany. Following basic provisional reliability analyses
from the pilot data and open feedback from the students, 3 items that were repeatedly highlighted as
confusing were removed from the scale. This resulted in the final 9-item measure.

The Health VIPS asks respondents to rate the degree to which they agree or disagree with
each item (full item list can be found in Table 1) on a Likert scale ranging from 1 (“strongly disagree”) to
5 (“strongly agree”), with three reverse-coded items. Total scores are calculated by averaging the
items. The tool measures a single dimension where lower scores indicate less preference and higher
scores indicate stronger preference for visually presented health information. Items compare receiving
visual information with written information, as this is the standard form of supplementary material used
in healthcare.

Validation Measures

Style of Processing – Picture subscale. The Style of Processing picture subscale (SOP-P)
(Childers et al., 1985) was used to assess convergent validity of the Health VIPS. The SOP scale aims
to assess preference for imaginal processing. We used the 11-item picture subscale only, as the verbal
subscale items were irrelevant. The response scale for the SOP-P consists of four anchored response
points ranging from 1 (“always true”) to 4 (“always false”), with one reverse-coded item. Example items
include “When I’m trying to learn something new, I’d rather watch a demonstration than read how to do
it” and “My thinking often consists of mental ‘pictures’ or ‘images’”. Higher scores reflect less
preference for visual processing, therefore we would expect a negative correlation with the Health
VIPS.

BRIEF health literacy screening tool. The BRIEF health literacy screening tool (BRIEF)
(Haun, Luther, Dodd, & Donaldson, 2012) was used to assess discriminant validity. The BRIEF health
literacy screening tool is a 4-item measure of health literacy which asks respondents four questions
about health comprehension, and their confidence in understanding health information and completing tasks. Items 1 to 3 are answered using anchored responses from "always" to "never", and anchors "not at all" to "extremely" are used for item 4. Higher scores represent greater health literacy. We expected no correlation between the BRIEF and Health VIPS, indicating two distinct measurement constructs.

**Statistical Analyses**

Analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 25.0. To verify the appropriateness of the sample for performing a factor analysis, we used an anti-image correlation matrix. According to Kaiser and Rice (1974), items with a measure of sampling adequacy less than 0.50 should be excluded from the questionnaire and further analyses; none of the items were eliminated based on this criterion. In addition, we calculated the Kaiser–Meyer–Olkin coefficient and performed a Bartlett test of sphericity to assure that the data set was suitable for factor analysis. Due to the fact that principal components analysis with Kaiser criterion is an error-prone extraction method, where the number of extracted factors may be overestimated (Costello & Osborne, 2005), Horn’s parallel analysis (1965) for factor extraction was used. Parallel analysis is based on the assumption that significant factors or components from observed study data have larger eigenvalues than those obtained from a random data set with the same sample size and number of variables (Crawford et al., 2010). As recommended by Costello and Osborne (2005), the principal axis factoring method was applied for the parallel analysis as well as EFA. EFA was calculated without applying any rotation method. Reliability analysis was used to test internal consistency of the scale, with satisfactory target values set at .70 (Bland & Altman, 1997; Nunnally, 1978), although scales with fewer items tend to have smaller values (Tavakol & Dennick, 2011). The strength of correlations were used to assess test re-test reliability, and convergent and discriminant validity.

**Study 1 Results**

*Undergraduate Student sample*

**Sample characteristics.** 106 students opened the questionnaire link and began responding. Of those, 103 fully completed the Health VIPS and were retained in the sample (97.2% completion rate). Participants ranged from 18 to 50 years of age (M= 20.99, SD= 5.09), were mostly female (78.6%, 81/103), and reported having completed at least secondary level education (59.2%, 61/103), with some also having completed tertiary (35%, 36/103) or postgraduate study (5.8%, 6/103).

**EFA.** The anti-image correlation matrix showed no item with a measure of sampling adequacy coefficient less than 0.50. A Kaiser–Meyer–Olkin coefficient of 0.67 indicated that the items were
amenable to factor analysis. The Bartlett test of sphericity also affirmed that the factor model was appropriate for this data set ($\chi^2(36, N= 103) = 167.60, p< .001$). Parallel analysis indicated a one-factor solution. An argument could be made for a second factor based on the parallel analysis, as the raw data and percentile scores were the same (0.61), but the authors decided to extract one factor only, as parallel analyses run in other samples (the follow-up data and the patient sample data discussed below) clearly demonstrated only one factor. The EFA under application of the principal axis factoring method resulted in factor loadings of ≥ .321 and communalities $h^2 ≥ .103$ (see Table 1). The factor explained 22.39% of the total variance. Items with less than satisfactory item-total correlations were retained to ensure comprehensive scale content.

We repeated the EFA with data collected at follow-up. This EFA yielded similar results. The anti-image correlation matrix showed no item with a sampling adequacy coefficient less than 0.50. A Kaiser–Meyer–Olkin coefficient of 0.81 indicated very good applicability of the residual sample of items for factor analysis, and again the Bartlett test of sphericity affirmed the factor model was appropriate for this data set ($\chi^2(36, N= 83) = 191.26, p< .001$). The EFA under application of the principal axis factoring method (with a single factor extracted again) resulted in factor loadings of ≥ .319 and communalities $h^2 ≥ .102$ (see Table 1). The factor explained 33.28% of the total variance.

**Reliability and validity.** Descriptive statistics revealed a positive skew in scale item responses (see Table 2), and the average mean score of scale items was 3.82 (SD= 0.52). The Health VIPS demonstrated good internal consistency at baseline ($\alpha= .70$) and follow-up ($\alpha= .80$). At follow-up, 83 of the 103 students completed the Health VIPS (80.6% retention rate), between 14 and 34 days after the initial assessment ($M= 17.84, SD= 5.44$). The Health VIPS demonstrated moderate test-re-test reliability, reflected by a significant, positive correlation ($r= .63, p< .001$). As predicted, the Health VIPS correlated negatively with the SOP-P both at baseline ($r= -.32, p= .001$) and follow-up ($r= -.41, p< .001$), demonstrating convergent validity. No significant correlation was found between the BRIEF health literacy scale and Health VIPS at both baseline ($r= -.06, p= .541$) or follow-up ($r= -.18, p= .121$), demonstrating good discriminant validity.

**Clinical sample**

**Sample characteristics.** Of 123 patients approached, 97 completed the baseline questionnaire for the trial. Patients were excluded for not meeting the larger trial inclusion criteria (n= 4) or for declining participation (n=22). Of those 97 participants, 94 completed the Health VIPS as part of the baseline questionnaire. The majority of the clinical sample was female (62.9%, 61/97) and New
Zealand European or European (71.1%, 69/97), ranging in age from 18 to 91 years old (M= 58.60, SD= 16.39).

**EFA.** The anti-image correlation matrix showed no item with a measure of sampling adequacy coefficient less than 0.50. A Kaiser–Meyer–Olkin coefficient of 0.78 indicated very good applicability of the residual sample of items for factor analysis. Bartlett’s test of sphericity was again highly significant and confirmed that the factor model was appropriate for this data set (χ²(36, N= 94) = 274.61, p< .001). As described above, parallel analysis again confirmed a single factor structure within the patient sample. The EFA under application of the principal axis factoring method resulted in factor loadings of ≥ .292 and communalities h² ≥ .085. The descriptives for this sample revealed a positive skew in responses to each item (see Table 2), and the average mean scale score was 3.66 (SD= 0.69). The patient sample demonstrated good internal consistency (α= .80). The factor explained 33.55% of the total variance.
Table 1. Factor loadings, communalities and item-total corrections for Health VIPS items in the student sample (N= 103).

<table>
<thead>
<tr>
<th></th>
<th>Factor loadings**</th>
<th>(h^2)</th>
<th>(r_{itc})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Being shown a scan or an image of the inside of my body would help my understanding of a medical condition.</td>
<td>0.40</td>
<td>0.16</td>
</tr>
<tr>
<td>2.</td>
<td>I often find that medical information that uses words, but no pictures, is harder to follow.</td>
<td>0.55</td>
<td>0.30</td>
</tr>
<tr>
<td>3.</td>
<td>When it comes to understanding health information, I find an image is worth a thousand words.</td>
<td>0.68</td>
<td>0.47</td>
</tr>
<tr>
<td>4.</td>
<td>I am the sort of person who doesn’t need visual aids (e.g. pictures, diagrams) to understand medical information.*</td>
<td>0.35</td>
<td>0.12</td>
</tr>
<tr>
<td>5.</td>
<td>If I were newly diagnosed with an illness, seeing animations or images would help me to create a picture of what the illness “looks like”.</td>
<td>0.32</td>
<td>0.10</td>
</tr>
<tr>
<td>6.</td>
<td>If I needed to have surgery, a visual illustration of the operation would help me to better understand the procedure.</td>
<td>0.41</td>
<td>0.17</td>
</tr>
<tr>
<td>7.</td>
<td>I prefer a straightforward verbal or written explanation of an illness to one that includes illustrations.*</td>
<td>0.55</td>
<td>0.30</td>
</tr>
<tr>
<td>8.</td>
<td>If I was prescribed a new medicine, being shown a visual demonstration of how the medicine worked inside the body would be helpful for my understanding.</td>
<td>0.45</td>
<td>0.20</td>
</tr>
<tr>
<td>9.</td>
<td>When my doctor gives me health information, I prefer a simply-written document rather than one with added pictures or diagrams.*</td>
<td>0.44</td>
<td>0.20</td>
</tr>
</tbody>
</table>

* Reverse-coded items ** Extraction method: Principal axis factoring. \(h^2\), individual item communality; \(r_{itc}\), corrected item-total correlation.
Table 2. *Mean and standard deviations of each Health VIPS item across the study samples.*

<table>
<thead>
<tr>
<th>Study 1 (EFA samples)</th>
<th>Study 2 (CFA sample)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student sample (N= 103)</td>
<td>Patient sample (N= 94)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>1. Being shown a scan or an image of the inside of my body would help my understanding of a medical condition.</th>
<th>2. I often find that medical information that uses words, but no pictures, is harder to follow.</th>
<th>3. When it comes to understanding health information, I find an image is worth a thousand words.</th>
<th>4. I am the sort of person who doesn’t need visual aids (e.g. pictures, diagrams) to understand medical information.</th>
<th>5. If I were newly diagnosed with an illness, seeing animations or images would help me to create a picture of what the illness “looks like”.</th>
<th>6. If I needed to have surgery, a visual illustration of the operation would help me to better understand the procedure.</th>
<th>7. I prefer a straightforward verbal or written explanation of an illness to one that includes illustrations.</th>
<th>8. If I was prescribed a new medicine, being shown a visual demonstration of how the medicine worked inside the body would be helpful for my understanding.</th>
<th>9. When my doctor gives me health information, I prefer a simply-written document rather than one with added pictures or diagrams.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
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<td>M (SD)</td>
<td>M (SD)</td>
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<tr>
<td>1.</td>
<td>4.30 (0.79)</td>
<td>4.46 (0.80)</td>
<td>4.44 (0.87)</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>2.</td>
<td>3.78 (0.91)</td>
<td>3.43 (1.11)</td>
<td>3.41 (1.12)</td>
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<tr>
<td>3.</td>
<td>3.79 (0.88)</td>
<td>4.05 (1.05)</td>
<td>3.86 (1.03)</td>
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<tr>
<td>4.</td>
<td>3.37 (1.03)</td>
<td>3.49 (1.05)</td>
<td>3.31 (1.12)</td>
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<tr>
<td>5.</td>
<td>4.27 (0.78)</td>
<td>4.09 (0.95)</td>
<td>4.07 (0.90)</td>
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<tr>
<td>6.</td>
<td>4.35 (0.87)</td>
<td>3.97 (1.05)</td>
<td>4.13 (1.00)</td>
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<td></td>
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<td></td>
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<tr>
<td>7.</td>
<td>3.38 (1.13)</td>
<td>3.27 (1.28)</td>
<td>3.01 (1.14)</td>
<td></td>
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<td></td>
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<tr>
<td>8.</td>
<td>3.54 (1.22)</td>
<td>3.34 (1.22)</td>
<td>3.51 (1.10)</td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>9.</td>
<td>3.64 (0.96)</td>
<td>3.21 (1.10)</td>
<td>3.09 (1.11)</td>
<td></td>
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<td></td>
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</table>

**Study 2 Method**

*Participants and Procedure*

The questionnaire was completed by 204 outpatients who were attending specialist services at Greenlane Clinical Centre, the main outpatient centre for Auckland City Hospital, New Zealand.
Patients in the waiting room were consecutively approached by the research assistant who invited them to complete an anonymous questionnaire assessing preferences for health information. Patients were excluded if they did not speak English or were not interested in participating. Patients completed the questionnaire in the waiting room and returned the completed questionnaire to the research assistant before leaving. Ethical approval for the study was received from the Auckland Health Research Ethics Committee and the Auckland District Health Board Research Office.

Measures
In addition to the Health VIPS and demographic items (age, gender, ethnicity, level of education, and outpatient service), participants also answered additional measures to assess validity.

Preference test. To test preferences for health information using an example, participants saw a single page divided into two depictions of the same information in both picture and text format. This information was adapted from an instruction leaflet for self-injecting insulin. Patients ticked a box indicating their preference for either the written or pictorial information option (see Appendix B). This item assessed convergent validity of the Health VIPS for establishing health information preference.

Self-rated health. A one item self-rated health question assessed discriminant validity of the Health VIPS. This item asks participants to rate their health compared to other people their age on a 10-point scale ranging from poor to excellent.

Health confidence. A two-item health confidence tool (Wasson & Coleman, 2014), measuring patients’ confidence with managing their health and with health information, was used to assess convergent validity. Each item asks patients to rate their response from 0 to 10, with higher scores reflecting more confidence.

Satisfaction with health care. One item from the General Satisfaction subscale of the Patient Satisfaction Questionnaire (PSQ-18) (Marshall & Hays, 1994) was used to assess convergent validity. Responses to the statement “The medical care I have been receiving is just about perfect” are rated on a 5-point scale (strongly agree to strongly disagree).

Experience with health information. One item asked patients to select whether the majority of supplementary health information they have received in the past had been given in either a written or visual format. This item was used to assess convergent validity. A variable was created reflecting match between preference and experience, and the relationship between this and health confidence and satisfaction with health care was assessed.
All tests were conducted using SPSS and SPSS AMOS versions 25.0. In accordance with recommendations for scale development (Byrne, 2016), a CFA within the structural equation framework was also applied to test the underlying factor structure of the Health VIPS in the outpatient sample. The analysis was based on comparisons of covariance matrices with maximum likelihood estimation. The CFA was first run with a one-factor structure, not allowing for any covariance of error terms. To indicate goodness-of-fit for the model we used the RMSEA, CFI, TLI, and Chi-square to degrees of freedom ratio indices. Good fit is indicated by values under .06 for RMSEA, values above .90 for CFI, and values close to .95 for TLI (Hu & Bentler, 1999). The ratio of the Chi-square value to degrees of freedom should be under 2:1 or at least 3:1 (Byrne, 2016). Modification indices were also inspected to understand the nature of error covariances between each item. The standardised regression coefficient is reported for each item. Reliability analysis assessed internal consistency of the scale, and assumptions of convergent and discriminant validity were made by assessing the strength of correlations, or significance of independent samples t-tests.

Study 2 Results

CFA

First, we ran a one-factor CFA model including the 9 items of the Health VIPS without allowing for any covariance between error terms. This model did not demonstrate an acceptable fit. The $\chi^2$ test was highly significant, ($\chi^2(27, N= 196) = 146.23$, $p < .001$), and the goodness-of-fit indices did not reach appropriate values (RMSEA= .150, CFI= .687, and TLI= .583). Modification indices (MIs) were inspected, and the highest MIs were evident for items 7 and 9 (MI= 44.69), 2 and 3 (MI= 17.14), 4 and 7 (MI= 28.51), and 4 and 9 (MI= 22.39).

We therefore ran separate models, where each step allowed for an additional modification based on each covariance from the MIs reported above (see Table 3). The final one-factor model allowing for all four error covariances indicated the best fit (see Figure 5). For this model, the $\chi^2$ test was significant, ($\chi^2(23, N= 196) = 37.45$, $p < .001$), and the goodness-of-fit indices reached appropriate values (RMSEA = .057, CFI= .962, and TLI= .941).
### Table 3. Model steps and indices for CFA analysis.

<table>
<thead>
<tr>
<th>Structural Equation Model</th>
<th>Model Indices</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>RMSEA</td>
</tr>
<tr>
<td>1st model</td>
<td>.150</td>
</tr>
<tr>
<td>2nd model</td>
<td>.117</td>
</tr>
<tr>
<td>3rd model</td>
<td>.102</td>
</tr>
<tr>
<td>4th model</td>
<td>.089</td>
</tr>
<tr>
<td>5th model</td>
<td>.057</td>
</tr>
</tbody>
</table>

*Note.* Allowed error covariances: Model 1: none, Model 2: between items 7 & 9; Model 3: between items 7 & 9, 2 & 3; Model 4: between items 7 & 9, 2 & 3, 4 & 7; Model 5: between items 7 & 9, 2 & 3, 4 & 7 & 9.

### Reliability and Validity

Mean scores of the Health VIPS items again suggested an overall positive skew (see Table 2), and the average of items was 3.63 (SD= 0.57). The Health VIPS demonstrated good internal consistency ($\alpha= .70$). The preference test demonstrated good convergent validity, whereby those who selected the pictorial information had significantly higher scores on the Health VIPS ($M=34.07, SD= 4.83$) compared to those who selected the text option ($M= 31.43, SD= 5.20; t_{(160)}= -3.33, p=.001$). To assess convergent validity we calculated, for participants in the upper and lower quartiles of the Health VIPS, a binary variable indicating (mis)match of experience with health information and preference for modality of health information. Differences between these groups in scores on the health confidence and health satisfaction measures were then assessed. Individuals with a mismatch had significantly lower health confidence ($M= 6.18, SD= 2.02$), compared to those with a match ($M= 7.14, SD= 2.04; t_{(99)}= 2.33, p=.022$). Those with a mismatch also trended toward being more dissatisfied with their medical care ($M= 2.21, SD= 0.99$), than those with a match ($M= 1.90, SD= 1.07$), although this again did not reach significance ($t_{(99)}= -1.50, p=.137$). A weak, negative relationship was found between the Health VIPS and self-rated health ($r= -.14, p=.043$), thus demonstrating discriminant validity.
General Discussion

These studies assessed a new measure of patients’ preferences for receiving supplementary visual health information. Overall, the results suggest that the Health VIPS is a brief, reliable, and informative instrument for assessing visual health information preferences. The tool demonstrated good psychometric properties, including internal consistency across samples. The Health VIPS also demonstrated good test-retest reliability, discriminant validity to measures of health literacy and self-rated health, and convergent validity with a non-health-related measure of visual processing style and a measure of health information preference. These results suggest that the Health VIPS is assessing a distinct construct, specific to the health context. The EFA revealed that the measure taps into a single factor that theoretically aligns with the stated purpose of the scale.

The CFA confirmed the one-factor structure of the Health VIPS. Although some factor loadings and communalities of scale items were lower than would be desired across the studies, these tended to be for the reverse-coded items. This suggests a statistical artefact, as from a construct validity point of view these items do not make sense as a second factor. Furthermore, although these reverse-coded items share variance, when this variance was allowed for in the model the fit of the single factor structure substantially improved. The importance of considering both conceptual and empirical evidence when extracting factors has been highlighted (Hair, Black, Babin, & Anderson, 2014). In this
instance, these reverse-coded items serve an important purpose in preventing acquiescent responding, and allowing the potential for different levels of preferences to be identified by the Health VIPS. This is important when considering that most people would like the addition of visual information, which would likely diminish variance in this construct. The authors therefore believe that these items should be retained for greater content validity and to minimise the acquiescent response bias. Future users of the scale should treat these items with caution but the authors believe the inclusion of these items promotes content validity of this construct of visual health information preferences.

It is reasonable that the Health VIPS performed differently in the three independent samples across the two studies. Participants in each sample had different experiences and histories with health information. The student sample likely had limited experiences with health information as patients. The two patient samples were also distinct. The patient sample in Study 1 were currently undergoing a medical procedure (surgery), whereas the Study 2 outpatient sample were undergoing diagnostic investigations or regular check-ups. Preferences and scores on the Health VIPS are likely to be distinct between those with differing levels of exposure to health information.

This study is limited by several factors. First, the student samples used for initial scale piloting, the EFA, and to assess test re-test reliability were relatively homogenous samples of undergraduate and postgraduate students studying medical and health sciences. This sample is not representative of the general population or patients, and medical and health science students specifically may have a different understanding and approach to learning about biological processes in comparison to the lay public. Including patients in scale development may have provided more representative feedback of scale items and appropriateness of wording. The EFA conducted in the patient sample, however, did yield similar results. Second, we assessed convergent but not predictive validity for the Health VIPS. It would be interesting to see if Health VIPS scores also predict health information preferences assessed at a later point in time. Third, it is significant to note that the amount of variance explained by the single factor of the Health VIPS in the EFAs performed in Study 1 could be considered low (between 22.3% to 33.5%). This could be the result of smaller sample sizes, however, it has been noted that in social science research it is not uncommon to consider lower amounts of variance explained satisfactory (Hair, Black, Babin, & Anderson, 2014). In this instance, decisions regarding factors to retain should also include considerations of theoretical content.

Despite these limitations, there are clinical implications for this scale. Firstly, delivering visual health information to those with increased preferences, could improve patient understanding and
subsequent health behaviours. Research on health risk information suggests that the format of information may influence actual medical decision making by influencing patients' knowledge attainment (Hawley et al., 2008). Visual information can increase patient attention, comprehension, and retention (Brotherstone et al., 2006; Mintzer & Snodgrass, 1999), making patients more likely to adhere correctly to physician recommendations. These effects could be heightened further if patients prefer receiving health information visually. Our results did reveal that a match between format preference and experience was associated with greater health confidence, which may be an important factor in patient engagement and adherence.

The Health VIPS is brief and quick to complete, meaning it could easily be administered before a clinical consultation. The second study demonstrated that patients could complete the tool while waiting for an outpatient appointment. Healthcare providers could use the Health VIPS to screen patients and identify those who would benefit most from receiving supplemental visual aids during clinical consultations. Visual tools are easy to incorporate into the clinical setting due to their low cost and portability (Jones et al., 2016, 2017). Furthermore, diagnostic scans and images are often available in certain specialties (such as cardiology) but are underutilised as education materials for patients (Devchich et al., 2014). Visual materials may therefore already exist that could be easily incorporated into explanations for patients with a visual preference. The scale may also be useful to inform clinical staff what proportion of their patient group would prefer visual information and how their patient information aligns with this group.

The Health VIPS may be particularly useful in the healthcare setting for patients with low literacy levels. Patients are unlikely to disclose literacy problems for fear of embarrassment (Parikh, Parker, Nurss, Baker, & Williams, 1996). Importantly, patients with literacy problems are likely to be those most in need of health advice (Michielutte et al., 1992), but least likely to adequately comprehend traditional written material (Kessels, 2003). The Health VIPS could therefore be a way to sensitively measure preferences for visual health information, without relying upon patient disclosure of literacy problems or issues with understanding material. Furthermore, future research could also assess whether the Health VIPS is associated with the comprehension of health information, as this would highlight the importance of this tool for improving the utilisation of health information.

Notable, when looking at all three samples, is the positive skew of scale responses suggesting a general preference for visual health information. This is perhaps unsurprising, yet an important consideration seeing as the default format for health information has been written material (Ngoh &
Shepherd, 1997). Patient health information often neglects the inclusion of visual aids (Fagerlin et al., 2004) although patients appear to prefer this format. Clinicians should therefore consider the format of supplementary health materials, and more broadly how incorporating visual aids and tools into their practise may improve patient education and outcomes.

To conclude, the Health VIPS is a short, reliable scale which appears to validly measure patient preferences for visual information about health. Clinically, this tool could be especially useful for increasing understanding and promoting health behaviour. Understanding patient preferences is an important aspect of healthcare, as aligning patient preferences with information delivery may also increase satisfaction and promote autonomy within the medical consultation. Further research should aim to replicate these results to understand if this construct can be reliably measured in other health populations.
Chapter Four

Understanding the Effects of Different Visualisation Mediums on Perceptions of Illness and Treatment

Preface

As outlined in Chapter Two, although there are few studies that constitute visualisation interventions, a more substantial body of research exists which broadly investigates the use of visual health information in changing perceptions and motivations for health behaviours. Many different forms of visual health information (e.g. diagnostic feedback imaging, animations, physical demonstrations, models) have effectively improved understanding, motivation, and illness perceptions across different patient groups. A gap within the existing literature is an understanding of how different visualisations compare, and whether the same visual information presented using different mediums will result in differing effects on perceptions and treatment motivations. Deducing whether a particular visualisation format produces the best outcomes in changing perceptions and motivations would help to inform the development of more effective visualisation methodologies and interventions.

To date, prior literature has investigated the effects of delivering one form of visual health information, and comparing outcomes between those who receive this information and a control group. As discussed in Chapter Two, previous studies have demonstrated that various, purposefully-designed visualisation tools appear effective in changing perceptions and motivation. It follows that just as presenting health information using different formats (e.g. written versus visual) may affect understanding and perceptions differently, so too may presenting the same visual information using different mediums. Furthermore, different visual mediums may result in varying levels of information saliency and motivational influence to change health behaviours.

Visual health information can be presented in physical formats, such as tactile models (Stephens et al., 2016) or live demonstrations (Karamanidou et al., 2008). In contrast, visual health information can also be virtual in nature, comprising of 2-D and 3-D animations (Jones et al., 2016; Perera et al., 2014) or computer modelling (Jones et al., 2016). To date, no research has directly compared how the same visual information presented using different visual mediums may have differential impact on modifying perceptions of illness and treatment.

The aim of the following study was to test whether two distinct forms of visualisation mediums differ with regard to their effectiveness in changing perceptions of illness and treatment.
Specifically, this randomised controlled trial assessed whether physical visualisation or virtual visualisation would be most effective in changing perceptions of osteoporosis and treatment motivation for women at-risk of developing osteoporosis. The context of osteoporosis was selected as previous research provides evidence that physical visualisation (3-D printed bone models) is efficacious in changing perceptions of osteoporosis in newly diagnosed patients (Stephens et al., 2016). This study compared 3-D bone models with bone model animations presented on a computer tablet. This research paradigm aimed to replicate the delivery of information during initial diagnosis and consultation by using at-risk, treatment naive women. The following manuscript describes the results from this study.
Citation

Abstract

**Background:** Osteoporosis is a degenerative bone disorder that disproportionately affects older women worldwide. Raising awareness regarding osteoporosis within this demographic is significant for health promotion. Initial evidence suggests that visualisations of illness and treatment can improve illness perceptions, increase treatment motivations, and even promote health behaviours. We are yet to understand whether different visualisation mediums vary in their impact on perceptions and motivations. **Purpose:** We investigated whether physical models or virtual animations had a greater impact on changing perceptions of osteoporosis and treatment motivation in an at-risk population of older women. **Methods:** A total of 128 women aged 50 and over were randomly assigned to view a brief presentation about osteoporosis using either 3-D printed bone models or electronic tablet animations. Illness perceptions, medication beliefs, and motivations were measured at baseline and post-presentation. Mixed ANOVAs were used to identify significant changes over time between groups. **Results:** There were no significant interaction effects, revealing that neither medium had a greater impact on beliefs over time. Significant main effects of time revealed that from baseline to post-presentation, both mediums increased consequence beliefs, personal and treatment control, understanding of osteoporosis, motivations to take treatment if needed, and medication necessity beliefs. Timeline beliefs and medication concerns decreased over time for both groups. **Conclusions:** Both 3-D models and animations of osteoporosis are equally effective in changing beliefs and treatment motivation in an at-risk population. Visualisation devices are brief, cost-effective, have high acceptability, and have considerable clinical applicability to promote awareness and prevention.
Introduction

Despite decades of research, theories, and intervention strategies, non-adherence to health behaviours (such as screening, adherence, and lifestyle changes) remains a significant issue in modern healthcare (Barnett, 2014; White, 2013). Patients’ beliefs and understanding of their illness and treatment are consistently linked with their participation in resulting health behaviours (Leventhal et al., 1980; Sabaté, 2003). Having accurate perceptions of disease aetiology and treatment mode of action are key in ensuring that patients correctly adhere to treatment plans and avoid poor clinical decision-making. However, supporting patients in understanding the pathophysiological processes of a disease, and thus the need for behaviour change, can be difficult (Burke et al., 2011; Houts et al., 2006). Patients often have misunderstandings regarding their condition and treatment (Braddock III et al., 1999), even with regard to the anatomical location of their affected organs (Weinman et al., 2009). Additionally, there are numerous factors which can compromise the receipt of information during the patient-provider interaction, including patient symptom burden, information volume, the over-utilisation of medical terminology, and a reliance on traditional information formats (i.e. written and verbal) (Houts et al., 2006).

Visual information, or visualisations, present a promising communication strategy to deliver brief yet accurate health information. Visual representations overcome barriers of comprehension by communicating information in a format that is easier to recall, recognise, and remember (Gardner & Houston, 1986; Mintzer & Snodgrass, 1999; Paivio et al., 1994). Visual imagery also has the ability to evoke heightened emotional responses (Cameron & Chan, 2008), which may increase information saliency and motivational impact. Furthermore, patients acknowledge the value of being able to see processes occurring inside their body (Devchich et al., 2014) and have been found to develop mental images of these processes (Broadbent et al., 2004; Harrow et al., 2008; Mabeck & Olesen, 1997). Providing accurate imagery of what an illness ‘looks’ like, alongside information about how treatment helps to control this, may create more concrete and accurate representations of the condition that in turn motivate positive health behaviours.

Research investigating how visualisation might facilitate positive health behaviours is limited. This may be due to the recent nature of the technology that allows these types of interventions to be created (B. Williams et al., 2012). One form of visualisation consists of using personalised imaging data, traditionally used for diagnostic purposes, to help patients visualise their disease or risk. More recently, other forms of visualisation such as abstract, virtual animations, physical models or
demonstrations have been used to facilitate changes in perceptions and understandings of disease and treatment. In randomised studies, three-dimensional (3-D), anatomical, animated interventions have been found to improve knowledge recall in periodontitis patients compared to real-time drawings (Cleeren et al., 2014), to increase understandings of heart disease and health behaviour intentions in students more so than text alone (T. Lee et al., 2011), and to reduce anxiety and increase understanding regarding thyroid surgery in comparison to written information (Hermann, 2002). A physical demonstration of the mode of action of medication has also been found to improve understanding, treatment efficacy, and medication necessity beliefs as compared to a written leaflet in a pilot study with end-stage renal disease patients (Karamanidou et al., 2008).

More recently, visualisation interventions have demonstrated the ability to improve health behaviours. Viewing a smartphone application incorporating animations demonstrating how suboptimal adherence to antiretroviral therapy reduces the ability to fight the HIV virus was associated with greater improvements in adherence for intervention patients, compared to those randomised to receive medication reminders alone (Perera et al., 2014). Animations presented on a tablet to cardiac patients during hospitalisation, which depicted the cause and treatment of myocardial infarction, have been found to improve exercise levels and result in a shorter return time to normal activities following discharge, in comparison to receiving standard care alone (Jones et al., 2016). Tangible visualisations have also been found to improve perceptions in a pilot study with newly diagnosed patients with osteoporosis. Showing patients 3-D models of healthy and osteoporotic bone during an initial consultation resulted in an increased emotional reaction to osteoporosis and a greater understanding of the condition, compared to those receiving a standard consultation (Stephens et al., 2016). There was also a trend towards greater rates of treatment initiation to oral bisphosphonates in participants who saw the models. Together, these studies provide some initial evidence of the power of visualisation in changing not only perceptions of disease and treatment but also health behaviours.

Although previous research posits the utility of visualisation in promoting health behaviour, we are yet to understand the most efficient format for presenting visual health information. Previous work has demonstrated that numerous visualisation mediums can be effective, but to our knowledge, no work has attempted to establish whether a particular format of visualisation is more powerful in changing perceptions and motivations. Indeed, a recent review stated the need for studies comparing the efficacy of education tools with equivalent health messages (Wilson et al., 2012). Do tangible, physical visualisations or virtual visualisations shown through a screen have a more profound influence
on perceptions of illness and treatment motivations? It may be true that a specific visualisation method is then more likely to influence health-promoting behaviours than another.

The current study examined whether a physical or virtual visualisation medium is more powerful in improving illness perceptions and treatment motivations regarding osteoporosis. Osteoporosis is a degenerative bone disorder, whereby decreased bone density results in an increased risk of skeletal fracture (Cosman et al., 2014). Osteoporosis patients have demonstrated problematic adherence levels to bisphosphonate treatment and misconceptions about their illness, including a poor understanding of how treatment can help to reduce fracture risk (Besser, Anderson, & Weinman, 2012). Women 50 years and above have a disproportionately higher risk of developing osteoporosis (International Osteoporosis Foundation, 2015), making this group a significant target for health promotion efforts. An at-risk population of women was used to simulate the level of knowledge that a newly diagnosed patient would likely have about osteoporosis.

Prior work has demonstrated that physical visualisation mediums can be effective in improving perceptions in osteoporosis (Stephens et al., 2016). This research has already distinguished that visualisation is more effective in improving perceptions of osteoporosis compared to standard verbal information alone. We were interested in seeing which of two different visualisation formats, 3-D bone models or tablet animations, would have a greater impact on changing perceptions of osteoporosis and treatment motivation in an at-risk population of older women. There were no prior hypotheses in terms of which medium would be more effective than the other due to an absence of research in this area. Research into learning style preferences suggests that middle and older aged adults tend to vary in whether they prefer more hands-on or viewing-based learning models (Truluck & Courtenay, 1999). The primary outcome was change in illness perceptions. Secondary outcomes included change in medication beliefs and motivation to take medication.

Method

Participants
A community sample of older women was recruited from September to December 2015 using email advertisements and flyers placed around the University of Auckland Research Clinic and community locations (e.g. women’s gyms). A G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) calculation revealed that 128 participants would be necessary to detect a medium effect size using a two-tailed test with 80% power on participant’s understanding of their disease based on previous research (partial $\eta^2 = 0.08$) (Stephens et al., 2016). Participants were included if they were female, aged 50 and over,
had no prior diagnosis of osteoporosis and were treatment naïve (all of which were ascertained by confirmation from the participant prior to the study session). Exclusion criteria included being unable to understand English and an inability to complete the questionnaire. Initial study interest was expressed by 147 women. Figure 6 depicts the flow of participants through the study. The study session was completed by 128 women, with 64 randomised to the 3-D model group and 64 to the animation group. Two participants were excluded from analysis after completing the study, leaving a final sample of 126 participants (63 in each group). One participant was excluded from the 3-D model group for not being able to complete the post-session questionnaire, and an animation group participant was excluded due to admitting a possible osteoporosis diagnosis (suggesting they were not treatment naïve) during the study session.

Procedure

Ethical approval for the study was obtained from the University of Auckland Human Participants Ethics Committee. The study was a parallel design, randomised trial that took place at the University of Auckland Bone Clinic in Auckland, New Zealand. The study session took approximately 30 min in total. Upon arrival to the study session, participants provided written informed consent before completing a baseline questionnaire assessing existing perceptions of osteoporosis, treatment beliefs and motivations. Participants were randomly assigned to either the 3-D model group or the tablet animation group. Randomisation was created by a person independent of the study and sealed in consecutively numbered envelopes. Participants then received the brief presentation about osteoporosis accompanied by the medium that they were randomised to view. Following this, the participant completed the post-presentation questionnaire, which included the same measures as the baseline questionnaire and additional questions regarding the visualisation devices. Participants received a NZ$20 shopping voucher at the completion of the study session.
Presentation

The presentation provided information regarding the aetiology of osteoporosis and how treatment can help to reduce bone loss. The presentation was delivered by the same researcher (AJ) each time using a standardised script (see Appendix C). The same verbal information was given to participants in both conditions, with the only difference being whether this was accompanied by the 3-D models or tablet animations (see Figure 7). The two 3-D models were created using iliac crest biopsies from a healthy versus an osteoporotic individual. These models were printed using a Dimension Elite 3-D printer at the Auckland Bioengineering Institute. The models were created using the same biopsy data as the previous study (Stephens et al., 2016), however, the current models were doubled in size and included an additional piece that represented cortical bone. The 3-D model group were given the models to hold and were encouraged to notice the difference in the weight of the two models (this was the only variation in the script between the two conditions). The tablet group watched a series of animations alongside the verbal information. The animations portrayed the cycle of bone growth, the development of osteoporosis, treatment efficacy in reducing bone loss, and virtual models of osteoporotic and

Figure 6. CONSORT diagram depicting the flow of participants through the study.
healthy bone (created using the same data as the 3-D printed bones). Animations used to inform participants were derived from CT images and bone remodelling teaching tools used previously in a human anabolic bone study (Sreenivasan et al., 2013). The animations were created and edited using the visualisation software CMGUI (http://physiomeproject.org/software/opencmiss/cmgui) developed at the Auckland Bioengineering Institute as part of the Physiome Project (Hunter, Smith, Fernandez, & Tawhai, 2005). The animations were collated onto Microsoft PowerPoint and displayed on a tablet. Both presentations took 10 min to deliver.

Figure 7. Visualisation tools used within the presentation: (a) 3-D printed healthy (left) and osteoporotic (right) bone models, (b) animated versions of the same bone models when still (c) and rotating.
**Measures**

**Demographic information.** Age, ethnicity, and highest level of education were self-reported by participants in the baseline questionnaire.

**Illness perceptions.** Items from the Brief Illness Perception Questionnaire (Broadbent, Petrie, Main, & Weinman, 2006) were used to measure perceptions of osteoporosis at baseline and post-presentation. The questions were adapted to ask participants about their views towards osteoporosis and osteoporosis patients instead of asking about personal experience with osteoporosis (e.g. ‘How much does your osteoporosis affect your life?’ was changed to ‘How much do you think osteoporosis would affect a patient’s life?’). The item assessing identity perceptions was not included in the current study as it was not relevant to the non-clinical sample. Items were rated on an 11-point scale (from 0 to 10) with relevant anchors for each. The Brief Illness Perception Questionnaire has demonstrated good psychometric properties including sensitivity to change (Broadbent et al., 2015).

**Medication beliefs.** Two items based on the necessity-concerns framework assessed participants’ beliefs about osteoporosis medication at both baseline and post-presentation (Horne et al., 2013). One item measured how necessary participants believed medication was for osteoporosis (‘How much do you feel that patients need medication prescribed for their osteoporosis?’), the other measured their concern about taking osteoporosis medication if needed (‘If you were diagnosed with osteoporosis, how concerned would you be about taking medication prescribed for the illness?’). These items were rated on the same 11-point scale with relevant anchors.

**Motivation, risk, and other beliefs.** Additional beliefs, risk, and motivation were also measured at both time points. A single item assessed how motivated participants would be to take medication if they were diagnosed with osteoporosis. Risk perceptions were assessed by asking participants how at-risk they believed an osteoporosis patient was of breaking a bone in the next 10 years. Additional items assessed how serious participants believed a diagnosis of osteoporosis was, how likely they thought osteoporosis would be to become worse, and how likely they thought a patient’s bone health would be to become worse in the future. All items were measured on the same 11-point scale as the other measures.

**Evaluation of visualisation devices.** At post-presentation, all participants rated the visualisation mediums and presentation on a number of outcomes, including satisfaction, interestingness, believability, how well they understood the information, and how helpful the mediums were in improving their understanding of osteoporosis. Participants also reported the extent to which
they still had questions about osteoporosis, whether or not the medium made them anxious, and how much the visualisation would motivate them to take treatment if they had osteoporosis. Some of these items were developed specifically for this study and others were taken from previous visualisation intervention studies (Jones et al., 2016; Perera et al., 2014). Two separate versions of the questionnaire were created for each group, where questions matched the medium the participant saw (‘visual animations’ or ‘3-D bone models’). These items were measured on the same 11-point scale with relevant anchors for each item.

**Open-ended item.** A final, open-ended item assessed participants’ thoughts regarding the visualisation medium they saw (‘What did you think of the visual animations of bone/3-D bone models? What thoughts ran through your mind as you saw them?’). The researcher (AJ) read all of the responses for this item and characterised them into five main groups for analysis as reported below. Two independent raters categorised the responses (Kappa= 0.73, p < .001). A third independent rater made a final decision on the response category when there were discrepancies between the two initial ratings.

**Statistical Analyses**

Data were analysed using the Statistical Package for the Social Sciences version 22.0. Tests were considered significant when a significance level below .05 was achieved. Mixed between-within ANOVAs were used to assess differences between groups from baseline to post-presentation in illness perceptions, medication beliefs, motivation, risk, and other beliefs. Independent samples t-tests were used to assess differences between groups in the visualisation evaluation items. Independent samples t-tests and χ² tests were used to assess differences between groups in demographic characteristics and baseline variables. A χ² test was also used to examine the association between response category (minus the ‘other’ category) and group for the open-ended item.

**Results**

**Demographic Characteristics**

The majority of the sample identified as New Zealand European (83.3%). The sample was highly educated with half reporting having completed at least tertiary level education (50.8%). The mean age of the sample was 61 years (M= 60.88, SD= 8.44) and participant ages ranged from 50 to 85. There were no significant differences between groups in demographic characteristics (see Table 4) or baseline measures.
Table 4. Demographic characteristics of the sample.

<table>
<thead>
<tr>
<th></th>
<th>Animation M (SD) (n= 63)</th>
<th>3-D models M (SD) (n= 63)</th>
<th>Test statistic (t or χ², df, p)</th>
<th>Total sample M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>60.65 (8.80)</td>
<td>61.11 (8.11)</td>
<td>-0.31 (5.91, 124, .761)</td>
<td>60.88 (8.43)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Zealand European</td>
<td>48 (76.2%)</td>
<td>57 (90.5%)</td>
<td>105 (83.3%)</td>
<td></td>
</tr>
<tr>
<td>Maori</td>
<td>2 (3.2%)</td>
<td>1 (1.6%)</td>
<td>3 (2.4%)</td>
<td></td>
</tr>
<tr>
<td>Samoan</td>
<td>1 (1.6%)</td>
<td>0 (0%)</td>
<td>1 (0.8%)</td>
<td></td>
</tr>
<tr>
<td>Chinese</td>
<td>5 (7.9%)</td>
<td>1 (1.6%)</td>
<td>6 (4.8%)</td>
<td></td>
</tr>
<tr>
<td>Indian</td>
<td>3 (4.8%)</td>
<td>1 (1.6%)</td>
<td>4 (3.2%)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>4 (6.3%)</td>
<td>3 (4.8%)</td>
<td>7 (5.6%)</td>
<td></td>
</tr>
<tr>
<td>Education level</td>
<td></td>
<td></td>
<td>2.51 (3, .473)</td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>0 (0%)</td>
<td>1 (1.6%)</td>
<td>1 (0.8%)</td>
<td></td>
</tr>
<tr>
<td>Secondary</td>
<td>17 (27%)</td>
<td>23 (36.5%)</td>
<td>40 (31.7%)</td>
<td></td>
</tr>
<tr>
<td>Tertiary</td>
<td>35 (55.6%)</td>
<td>29 (45.3%)</td>
<td>64 (50.8%)</td>
<td></td>
</tr>
<tr>
<td>Post-graduate</td>
<td>11 (17.5%)</td>
<td>10 (15.9%)</td>
<td>21 (16.7%)</td>
<td></td>
</tr>
</tbody>
</table>

Illness Perceptions and Medication Beliefs

There were no significant interaction effects between groups over time for illness perceptions and medication beliefs. Table 5 demonstrates that the patterns of change in mean scores between the two groups over time were not significantly different from each other. When assessing the main effects for each variable, there was no significant main effect of group, but there were significant main effects of time for numerous outcome measures (see Table 6). There was a significant increase from baseline to post-intervention in consequence beliefs, personal control beliefs, treatment control beliefs, and illness understanding across all participants. Additionally, all participants had a significant increase in necessity medication beliefs from baseline to post-presentation. There were also significant decreases in timeline beliefs and medication concerns from baseline to post-presentation. There were no significant main effects of time for concern or emotion beliefs.

Motivation, Risk, and Other Beliefs

There were also no significant interaction effects for motivation, risk, and other belief measures, suggesting that the change over time between the two groups was not significantly different (as seen in Table 5). There was no significant main effect of group on these outcome measures, but there were significant main effects of time across all participants for motivation to take medication, whereby motivation increased from baseline to post-presentation. All participants also had a significant increase in seriousness perceptions from baseline to post-presentation. There were no significant main effects of time for beliefs regarding the risk of a patient breaking a bone in the next 10 years, how likely
osteoarthritis would be to become worse, and how likely a patient’s bone health would be to become worse (see Table 6).
Table 5. Interaction effect of time by group on illness perceptions, medication beliefs, and other perceptions.

<table>
<thead>
<tr>
<th></th>
<th>Animation group</th>
<th>3-D model group</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline M (SD)</td>
<td>Post-presentation M (SD)</td>
<td>Baseline M (SD)</td>
<td>Post-presentation M (SD)</td>
<td>F</td>
<td>df</td>
</tr>
<tr>
<td>Illness perceptions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consequences</td>
<td>7.79 (1.49)</td>
<td>8.21 (1.52)</td>
<td>7.63 (1.81)</td>
<td>7.89 (1.94)</td>
<td>0.25</td>
<td>1, 124</td>
</tr>
<tr>
<td>Timeline</td>
<td>9.11 (1.32)</td>
<td>8.60 (1.81)</td>
<td>9.19 (1.39)</td>
<td>9.01 (9.02)</td>
<td>1.16</td>
<td>1, 124</td>
</tr>
<tr>
<td>Personal control</td>
<td>5.33 (2.31)</td>
<td>7.08 (2.60)</td>
<td>5.94 (2.00)</td>
<td>7.49 (1.50)</td>
<td>0.18</td>
<td>1, 124</td>
</tr>
<tr>
<td>Treatment control</td>
<td>6.81 (2.13)</td>
<td>8.62 (1.56)</td>
<td>6.87 (1.70)</td>
<td>8.44 (1.33)</td>
<td>0.46</td>
<td>1, 124</td>
</tr>
<tr>
<td>Concern</td>
<td>8.05 (2.17)</td>
<td>7.84 (2.22)</td>
<td>7.95 (2.41)</td>
<td>8.10 (2.10)</td>
<td>1.10</td>
<td>1, 124</td>
</tr>
<tr>
<td>Understanding</td>
<td>5.25 (2.49)</td>
<td>8.86 (1.19)</td>
<td>5.65 (2.35)</td>
<td>8.46 (1.43)</td>
<td>3.56</td>
<td>1, 124</td>
</tr>
<tr>
<td>Emotions</td>
<td>6.06 (2.62)</td>
<td>6.19 (2.80)</td>
<td>6.38 (2.47)</td>
<td>6.37 (2.64)</td>
<td>0.24</td>
<td>1, 124</td>
</tr>
<tr>
<td>Medication beliefs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Necessity</td>
<td>7.57 (2.04)</td>
<td>9.19 (1.22)</td>
<td>7.54 (1.98)</td>
<td>9.02 (1.42)</td>
<td>0.20</td>
<td>1, 124</td>
</tr>
<tr>
<td>Concern</td>
<td>6.17 (3.19)</td>
<td>5.38 (3.36)</td>
<td>6.27 (2.94)</td>
<td>5.46 (3.51)</td>
<td>0.00</td>
<td>1, 124</td>
</tr>
<tr>
<td>Other perceptions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motivations to take medication</td>
<td>8.57 (1.67)</td>
<td>9.25 (1.23)</td>
<td>8.52 (2.08)</td>
<td>9.08 (1.70)</td>
<td>0.30</td>
<td>1, 124</td>
</tr>
<tr>
<td>Risk of break in next 10yrs</td>
<td>8.95 (1.29)</td>
<td>9.19 (1.09)</td>
<td>8.76 (1.56)</td>
<td>8.87 (1.54)</td>
<td>0.25</td>
<td>1, 124</td>
</tr>
<tr>
<td>Seriousness</td>
<td>8.19 (1.35)</td>
<td>8.71 (1.20)</td>
<td>7.79 (1.72)</td>
<td>8.14 (1.89)</td>
<td>0.66</td>
<td>1, 124</td>
</tr>
<tr>
<td>Osteoporosis worsening</td>
<td>8.40 (1.60)</td>
<td>8.56 (1.63)</td>
<td>7.88 (1.88)</td>
<td>8.27 (1.90)</td>
<td>0.56</td>
<td>1, 124</td>
</tr>
<tr>
<td>Bone health worsening</td>
<td>8.22 (1.54)</td>
<td>8.41 (1.90)</td>
<td>8.35 (1.71)</td>
<td>8.35 (1.74)</td>
<td>0.46</td>
<td>1, 124</td>
</tr>
</tbody>
</table>
Table 6. Main effects of time on illness perceptions, medication beliefs, and other perceptions.

<table>
<thead>
<tr>
<th>Illness Perceptions</th>
<th>Baseline $M$ (SD)</th>
<th>Post-presentation $M$ (SD)</th>
<th>$F$</th>
<th>df</th>
<th>$p$</th>
<th>Partial $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequences</td>
<td>7.71 (0.15)</td>
<td>8.05 (0.16)</td>
<td>4.48</td>
<td>1, 124</td>
<td>.036</td>
<td>.04</td>
</tr>
<tr>
<td>Timeline</td>
<td>9.15 (0.12)</td>
<td>8.81 (0.16)</td>
<td>4.88</td>
<td>1, 124</td>
<td>.029</td>
<td>.04</td>
</tr>
<tr>
<td>Personal control</td>
<td>5.64 (0.19)</td>
<td>7.29 (0.19)</td>
<td>52.12</td>
<td>1, 124</td>
<td>&lt;.001</td>
<td>.30</td>
</tr>
<tr>
<td>Treatment control</td>
<td>6.84 (0.18)</td>
<td>8.53 (0.14)</td>
<td>92.80</td>
<td>1, 124</td>
<td>&lt;.001</td>
<td>.43</td>
</tr>
<tr>
<td>Concern</td>
<td>8.00 (0.20)</td>
<td>7.97 (0.19)</td>
<td>0.04</td>
<td>1, 124</td>
<td>.849</td>
<td>.00</td>
</tr>
<tr>
<td>Understanding</td>
<td>5.45 (0.22)</td>
<td>8.66 (0.12)</td>
<td>232.53</td>
<td>1, 124</td>
<td>&lt;.001</td>
<td>.65</td>
</tr>
<tr>
<td>Emotions</td>
<td>6.22 (0.23)</td>
<td>6.28 (0.24)</td>
<td>0.15</td>
<td>1, 124</td>
<td>.703</td>
<td>.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Medication Beliefs</th>
<th>Baseline $M$ (SD)</th>
<th>Post-presentation $M$ (SD)</th>
<th>$F$</th>
<th>df</th>
<th>$p$</th>
<th>Partial $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Necessity</td>
<td>7.56 (0.18)</td>
<td>9.10 (0.12)</td>
<td>93.42</td>
<td>1, 124</td>
<td>&lt;.001</td>
<td>.43</td>
</tr>
<tr>
<td>Concern</td>
<td>6.63 (0.27)</td>
<td>5.39 (0.31)</td>
<td>8.14</td>
<td>1, 124</td>
<td>.005</td>
<td>.06</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Perceptions</th>
<th>Baseline $M$ (SD)</th>
<th>Post-presentation $M$ (SD)</th>
<th>$F$</th>
<th>df</th>
<th>$p$</th>
<th>Partial $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivations to take medication</td>
<td>8.55 (0.17)</td>
<td>9.17 (0.13)</td>
<td>28.08</td>
<td>1, 124</td>
<td>&lt;.001</td>
<td>.19</td>
</tr>
<tr>
<td>Risk of break in next 10yrs</td>
<td>8.85 (0.13)</td>
<td>9.04 (0.12)</td>
<td>1.89</td>
<td>1, 124</td>
<td>.171</td>
<td>.02</td>
</tr>
<tr>
<td>Seriousness</td>
<td>7.99 (0.14)</td>
<td>8.43 (0.14)</td>
<td>18.49</td>
<td>1, 124</td>
<td>&lt;.001</td>
<td>.13</td>
</tr>
<tr>
<td>Osteoporosis worsening</td>
<td>8.14 (0.16)</td>
<td>8.41 (0.16)</td>
<td>3.16</td>
<td>1, 124</td>
<td>.078</td>
<td>.03</td>
</tr>
<tr>
<td>Bone health worsening</td>
<td>8.29 (0.15)</td>
<td>8.39 (0.16)</td>
<td>0.46</td>
<td>1, 124</td>
<td>.501</td>
<td>.00</td>
</tr>
</tbody>
</table>

Note. Bolded $p$ value indicates a significant difference at $p<.05$, $p<.01$, or $p<.001$ level.
Evaluation of Visualisation Devices

There were no significant differences in levels of satisfaction, understanding, helpfulness, anxiety, interest, motivation, and believability of the devices between the two groups. There was a significant difference in the extent to which participants still had questions about osteoporosis after seeing the presentation \((t_{145} = -2.172, p = .032, d = 0.389)\), with the bone model group reporting significantly higher scores \((M = 5.59, SD = 3.05)\) compared to the animation group \((M = 4.41, SD = 3.02)\). Overall, there were high mean scores for satisfaction \((M = 9.10, SD = 1.33)\), understanding \((M = 9.48, SD = 0.75)\), helpfulness \((M = 9.58, SD = 0.87)\), interest \((M = 9.29, SD = 1.13)\), motivation \((M = 9.23, SD = 1.34)\) and believability of the devices \((M = 9.52, SD = 1.34)\), and a lower mean score for anxiety \((M = 4.25, SD = 3.20)\).

Open-ended answers were reviewed and categorised into five groups: clarity of information, sensory/visualisation focused responses, concern responses, positive response to the presentation, and other. Clarity of information answers included comments about the devices making the information easier to understand. Sensory/visualisation comments included descriptions of the sensory and visualisation aspects of the devices or the visualisation itself. General comments about being satisfied with the presentation were coded as positive responses to the presentation. Concern responses consisted of personal concern regarding osteoporosis or comments about finding the information frightening. ‘Other’ comments were miscellaneous ideas that did not fit into any categories and did not show a cohesive theme. There was no significant association between group and response category \((\chi^2 = 2.51, p = 0.473, \phi = 0.15)\). Table 4 depicts example responses from each category and the percentage of responses in that category for each group.
Table 7. Example responses and frequencies of each category within the two study groups.

<table>
<thead>
<tr>
<th>Category</th>
<th>Example responses</th>
<th>Frequency of category in animation group</th>
<th>Frequency of category in bone models group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarity of Information</td>
<td>It made me understand in a simple way what osteoporosis is all about</td>
<td>55.3% (21/38)</td>
<td>44.7% (17/38)</td>
</tr>
<tr>
<td></td>
<td>I thought they were a very clear graphic communication, simple and effective</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>It was clearly obvious the difference between healthy and non-healthy bone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory/visualisation</td>
<td>They made ‘real’ the concept of losing bone and strength</td>
<td>44.1% (15/34)</td>
<td>55.9% (19/34)</td>
</tr>
<tr>
<td></td>
<td>Visual image very powerful being able to touch and feel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I’m a visual person so actually seeing the good vs. bad (oste) structures was very helpful</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concerns</td>
<td>A bit frightening to see what happens to the bone &amp; osteoporosis!!</td>
<td>47.8% (11/23)</td>
<td>52.2% (12/23)</td>
</tr>
<tr>
<td></td>
<td>Wondered what scan of own bones would reveal</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I just hope I am not diagnosed with osteoporosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive response to</td>
<td>Interesting visual presentation</td>
<td>33.3% (6/18)</td>
<td>66.7% (12/18)</td>
</tr>
<tr>
<td>presentation</td>
<td>Extremely good</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wow!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>That it is also what I think my father-in-laws brain looks like with alzheimers</td>
<td>76.9% (10/13)</td>
<td>23.1% (3/13)</td>
</tr>
<tr>
<td></td>
<td>I felt neutral</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extremely frank</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion

This study examined whether 3-D printed bone models or animations were more effective in changing perceptions of osteoporosis and treatment motivation. The results revealed that neither format of visualisation resulted in a greater change in perceptions of osteoporosis and treatment motivation than the other. Instead, it was found that changes in perceptions from baseline to after the presentation occurred similarly in both groups. At post-presentation, all participants had an improved understanding of osteoporosis, greater beliefs regarding how osteoporosis could be controlled both personally and through treatment, believed that there were more consequences from having osteoporosis, had fewer concerns about treatment, and believed treatment was more necessary. This provides promising initial
evidence that both physical and virtual visualisation mediums can change perceptions of osteoporosis and treatment motivation in a similar way. Other visualisation interventions using patient samples have found similar changes in beliefs, both through the use of virtual (Jones et al., 2016; Perera et al., 2014) and physical visualisation (Stephens et al., 2016).

Both visualisation devices also produced similar increases regarding motivation to take medication for osteoporosis if needed. This aligns with previous work where visually depicting risk inside the body has been found to increase motivation to adhere to health behaviours in non-patient samples (Bovet et al., 2002; Stephens et al., 2016). It is important to acknowledge that these changes were found in a group of healthy, at-risk individuals. The ability of the devices to change perceptions and increase motivations in individuals who do not have the illness targeted suggests the effectiveness of using visualisation tools to communicate health information to non-patient populations. This finding also supports the idea that being able to see risk inside the body appears to have the ability to change perceptions and increase motivations for health behaviours (Mols et al., 2015).

The decrease in timeline perceptions after seeing either visualisation, demonstrating beliefs that osteoporosis would last a shorter amount of time, was an unexpected finding. It may be that participants perceived osteoporosis as less chronic after learning that an effective medication could reduce the rate of bone loss. This hypothesis is supported by the increase over time in personal and treatment control beliefs. Previous work has demonstrated a relationship between timeline perceptions and control, whereby patients with stronger control beliefs also perceive a shorter illness timeline (Petrie, Weinman, Sharpe, & Buckley, 1996). Alternatively, perhaps the timeline in this non-clinical sample was indexing ideas about how long the illness would affect a patient’s life, rather than the chronicity of the condition itself.

Importantly, participants evaluated both visualisation devices highly. Over a quarter of the sample noted the sensory and visualisation aspects of the devices, which suggests that these aspects were highly salient and interesting to participants. The only difference in ratings between the two groups was that the 3-D model group reported having more unanswered questions about osteoporosis compared to the animation group. The animation medium did allow more parts of the information to be visualised, particularly in terms of how treatment works, which may have resulted in fewer unanswered questions in this group. Regardless, both mediums resulted in a significant increase in understanding of osteoporosis, which suggests that the information received was well understood by participants.
It was also positive to see that low levels of anxiety were reported for both groups. As mentioned previously, visual information can create a heightened emotional response in comparison to traditional forms of information (Cameron & Chan, 2008). Being visually confronted with osteoporotic bone had the potential to be anxiety provoking for at-risk individuals. Eliciting fear alone is an ineffective method to change perceptions and behaviour. It is important to additionally provide information about how the threat can be reduced (i.e. treatment efficacy) (Leventhal et al., 1997). It may be that explaining how bisphosphonate medication works buffered potential anxiety by providing information about threat reduction.

This is the first study to examine whether different methods of visualising an illness can have differing impacts on illness perceptions and treatment motivation. Strengths of the study in comparison to previous visualisation research include the use of a randomised design, the baseline measurement of understanding, perceptions and motivations, and the standardisation of the information given to each group. The study also provides further support that visualisation devices can effectively communicate health information.

There are several limitations to the study. Firstly, using only female participants restricts the generalisability of the findings to all at-risk individuals. Second, the high level of education in the sample may have increased participants’ ability to comprehend the information. Thirdly, the observed changes in perceptions and motivation occurred within a short time period (the study session), meaning we are unable to comment on more long-term effects and patterns. Although participants reported high satisfaction with both visualisation mediums, it is important to acknowledge that this may have been influenced by socially desirable responding. It is also possible that the scales assessing satisfaction were restricted by a ceiling effect. It should also be noted that our study advertisement (which described providing information about osteoporosis) and where we posted the study information (e.g. women’s gyms) may have attracted more health-conscious women to participate. Finally, we did not measure how these changes in perception may affect health behaviour. Viewing the devices may have led to information seeking about osteoporosis from a medical professional or to requesting a bone density assessment, but these outcomes were not measured in the current study.

The implications for using these visualisation devices within a clinical setting are substantial. The devices could easily be incorporated into consultations with at-risk individuals, to help them understand the condition of osteoporosis and to encourage bone density screening and treatment initiation if appropriate. Although a cost analysis was not conducted for the current study, creating and
disseminating either of the visualisation devices would be very low cost in terms of an intervention. Using the animations requires the one-off purchase of a computer tablet and the bone models are 3-D printed in plastic. In terms of time costs, using the models would not necessarily increase consultation times as they could easily be incorporated into existing explanations of osteoporosis given by clinicians of other medical staff, such as nurse educators. Both devices are portable, meaning they could be used in clinics, at patients’ bedsides, or even in community settings. The fact that both visualisation devices changed perceptions similarly means that the decision of which to use can be based on personal preference and practicality for the healthcare provider. For example, a general practitioner may prefer to have physical models that sit in their office, whereas a physiotherapist or nursing staff working in a hospital may prefer to have tablet animations to show patients at their bedside.

Future research should replicate the study in a more representative sample in terms of gender and education level. Further investigations should also consider whether there are differences in the effectiveness of physical versus virtual visualisation in depicting other illnesses and treatments. There may be something inherent to the pathophysiological nature of osteoporosis that means it can be easily understood by any visualisation format. Most individuals will likely receive exposure to images and concepts of bone and the skeleton through the media, health communication, and education about human biology. Other illnesses or treatments may be less visible in the public domain and may require a specific visualisation format to accurately portray biological processes. The implications of using the devices to improve treatment initiation in newly diagnosed patients, preventative strategies to increase awareness, and bone density screening rates should also be investigated. Advances in technology such as 3-D printing, mobile technology, and anatomical modelling mean that creating and disseminating visualisation devices is becoming more achievable and cost-effective. Increasing support for the use of visualisation devices will hopefully encourage their incorporation into modern healthcare for both education and intervention.
Chapter Five

Active Visualisation: A New Intervention Approach

Preface

Chapter Four explored whether different mediums of visualisation have differing efficacy in changing perceptions of illness and treatment. This study concluded that both forms of visualisation were equally effective in this regard. When considering this finding in the context of designing visualisation tools, it may be more important to focus on the content of visualisation rather than the format used.

In the following manuscript, we define a new concept of health visualisation titled “active visualisation”. Active visualisation interventions could be either virtual or physical in nature. The distinction between standard visualisation and active visualisation is the content, rather than the medium of presentation. Active visualisation interventions deliver visual health information using dynamic representations of an illness or treatment process. While static images and models can be helpful, they often require additional contextual information. In isolation, these standard visualisations could cause confusion, particularly if a conceptual link between the image presented and treatment process cannot be made. In contrast, active visualisations provide more complete representations of a process occurring within a specific physiological context, using mediums such as animations or demonstrations. The comprehensive nature of active visualisations may therefore enable a more thorough understanding of the health condition or treatment being represented.

Active visualisation has been effectively utilised in previous intervention studies. The most common form of active visualisation has been virtual animations displayed on either a computer tablet (Jones et al., 2016) or smartphone application (Perera et al., 2014). Both of these studies found changes in illness perceptions and treatment beliefs, in addition to improved health outcomes for patients who saw the intervention compared to those in control conditions. These studies included patients recovering from an acute coronary event and patients living with HIV infection respectively.

An alternate and underutilised form of active visualisation is physical demonstrations. The only previous empirical study utilising a physical demonstration was conducted by Karamanidou and colleagues (2008), who created a device to demonstrate the mode-of-action of phosphate-binding medication to patients with end-stage renal disease. The intervention helped patients to develop a concrete representation of treatment efficacy, which endured through the follow-up period (four months). In addition to improving patients’ understanding of treatment efficacy, physical
demonstrations also have high transferability into specific clinical contexts. In contrast to virtual active visualisation, physical demonstrations have the advantage of being non-reliant upon technological infrastructure and therefore highly transportable. Furthermore, viewing a live demonstration may be a highly salient and powerful way to communicate information about illness and treatment efficacy to patients in low socioeconomic contexts, who have limited access to technology.

The following manuscript is an invited editorial piece, which provides a definition of active visualisation and describes the design and methodology of an example active visualisation device. The active visualisation tool described is a physical demonstration, designed to explain the efficacy of two treatments in the context of HIV infection - antiretroviral therapy for people living with HIV infection and pre-exposure prophylaxis (PrEP) for those at high risk of HIV infection.
Citation

Abstract
Non-adherence remains a perplexing issue in HIV treatment. After decades of research supporting the efficacy of antiretroviral therapy (ART), non-adherence to medication remains an important issue. For patients who are non-adherent to ART, there appears to be a mismatch between their model of illness and the necessity for ART treatment. We propose that ‘active visualisation’ is a technique that could be utilised to improve understanding of treatment, and subsequently adherence, for both individuals living with HIV and those at risk of infection. We discuss the theoretical background and highlight the initial evidence suggesting the utility of active visualisation. We then discuss how active visualisation could be utilised in a live demonstration to improve adherence to ART and pre-exposure prophylaxis medications (PrEP).
Introduction

Advances in HIV treatment have transformed the management of the illness but have increased the importance of improving adherence to treatment. Consistently high levels of adherence to antiretroviral therapy (ART) provide direct clinical benefits for the patient through preventing increases in viral load and disease progression, while also substantially reducing the risk of HIV transmission (Cohen et al., 2011). Despite the benefits of adherence to the individual and population, low adherence to ART is the most common reason for treatment failure (Conway, 2007).

While a small proportion of long term non-adherence and treatment failure is related to non-intentional factors, such as forgetting to take medicines, the most common reasons for why patients do not take their ART lie in how they make sense of their illness, the judgements they make about the usefulness or harmful effects of the treatment, and the lack of immediate visible consequences for non-adherence. Maintaining high levels of adherence requires a cognitive model of the illness and treatment that appreciates the necessity of taking ART consistently in order to control the virus.

For most patients, their previous experience with medication is that the treatment works when you take the medicine and fails to work when you stop. However, when you start the medication again it generally works just as well as before. Unlike hypertension medication, analgesics, or indeed most other types of medication, ART adds a new element to treatment that patients have likely not seen previously: if you do not take your medicine regularly the medicine may fail to work at all, and second or third line treatment options may be limited. Indeed, the scarcity of treatment options for ART is something that patients are largely unaware of (Ramadhani et al., 2016). Thus the challenge is to provide patients with a simple model for how ART is working on the inside of the body and a clear rationale for why consistent medication is critical for controlling the virus. We propose that 'active visualisation' could be used to improve adherence for individuals living with HIV or those at risk of infection.

Why Might Visualisation Work?

There is evidence to suggest that visual information may be an effective format to deliver information about illness and treatment processes. A certain level of abstract thinking is required in order for a patient to understand the cause of their illness and how treatment helps to control their condition. Visual information may therefore make these intangible processes easier to understand. Additionally, visual information is easier to attend to and remember compared to more traditional forms of information (Gardner & Houston, 1986). Visual information is more uniquely encoded into our memory,
which makes the information easier to remember, retrieve, and therefore utilise (Brotherstone et al., 2006). Research further suggests that visual information is highly accepted by patients as a form of conceptualising their illness. Patients are believed to develop their own mental images of what their illness ‘looks like’ inside themselves (Broadbent et al., 2004; Harrow et al., 2008; Mabeck & Olesen, 1997). These images provide vital insight into patients’ understandings of their condition. Patients also acknowledge the value in being able to ‘see’ what is going on inside (Devcich et al., 2014).

Visual information may also result in increased motivation for positive health behaviours in comparison to standard forms of information. Visualisation can transform previously intangible concepts into concrete representations of health threats. Emotions research suggests that the increased anxiety brought about by the presence of a concrete threat should provide strong motivation to take actions that alleviate this unpleasant feeling (Janis & Feshbach, 1953). Of course, extreme levels of anxiety may result in maladaptive coping strategies such as avoidance. Therefore, to motivate adherence while avoiding high levels of anxiety, it is crucial to visualise both the health threat itself as well as how treatment works to increase perceived personal control over the illness threat.

Finally, visualisations have high clinical applicability as they can be adapted to a wide range of different illnesses, treatments, and patient demographics. Visualisations can be tailored to a specific patient (which is likely to increase the power of that information) or be made so they are suitable for an entire patient group. Visualisation mediums can also be made to suit particular patient demographic profiles and the relevant clinical context. For example, physical demonstrations or models may be more suitable for use in under-resourced areas as they can be low-cost and easily transportable options. In contrast, animations presented on mobile devices will presumably be more appropriate in areas where that technology is available and familiar to patients. This suggests that visualisation interventions are highly transferrable into diverse contexts, illnesses, and conditions.

What We Know So Far

Although there is sufficient theoretical support for the use of visualisation in promoting adherence, there is limited empirical work investigating this concept. Early studies utilised existing images from diagnostic testing, which were shown to patients and at-risk individuals to try and increase motivation for health behaviours. Showing smokers ultrasound images of their own atherosclerotic plaques has been found to increase their motivation for smoking cessation and increase quit rates (Bovet et al., 2002; Rodondi et al., 2008). Similarly, arterial imaging has been used to improve adherence to statin medication and reduce risk behaviours in individuals with coronary calcification (Kalia et al., 2006;
Orakzai et al., 2008), and to increase exercise levels and reduce cholesterol in patients with cardiac disorders (Devcich et al., 2012; Mols et al., 2015). Showing personal retinal images has also been associated with greater blood glucose control in patients with diabetic retinopathy (Rees et al., 2013). The premise of these studies is that presenting patients with a visual image of their own personal risk influences their illness beliefs and motivation to adhere to treatment.

In contrast to showing patients existing images from diagnostic testing, visualisations can also be created using more abstract, non-personalised methods. Three-dimensional (3-D), anatomical animations have been utilised to improve colorectal cancer screening literacy (Hassinger et al., 2010), to improve recall in periodontitis patients (Cleeren et al., 2014), and to reduce anxiety and increase understanding regarding thyroid surgery (Hermann, 2002). 3-D printed, physical models have also been utilised to represent biopsies of osteoporotic versus healthy bone and encourage preventative treatment (Stephens et al., 2016). These more abstract forms of representation are underutilised and under-researched, particularly in regards to their ability to improve adherence.

Active Visualisation

Active visualisation interventions are created to specifically represent the internal processes of an illness or treatment in a more dynamic way. Active visualisation can be animations, computer modelling, or even live, physical demonstrations of an illness process or treatment mode-of-action. Advances in technology, particularly in regards to the availability of mobile devices, means that animated active visualisation can be easily incorporated into everyday life for patients in an on-demand, open format.

The earliest work investigating what we classify as active visualisation was a pilot study by Karamindou et al. (2008) which used a live, physical demonstration to improve end-stage renal disease patients’ understanding of phosphate-binding medication. The demonstration explained the mode-of-action of phosphate-binding medication by showing how the ‘medication’ (a phosphate-binding solution) worked inside the patient’s ‘body’ (a plastic container) after they had eaten their favourite high phosphate food (represented by a phosphate solution). The demonstration focused on simplifying what can often be perceived as a difficult concept for patients by showing them what is actually going on inside the body and why they need to take their medicine. Seeing this intervention resulted in improved renal knowledge and treatment coherence, and increased treatment efficacy beliefs at four months following the intervention compared to the control group.
A recent study with myocardial infarction patients utilised active visualisation to explain both the aetiology of a heart attack, as well as how statin medication works to reduce subsequent risk (Jones et al., 2016). Animations demonstrating these processes were shown on an iPad to patients hospitalised following an acute coronary event. At seven weeks following discharge, patients who saw the intervention, compared to those who received standard care alone, reported more accurate perceptions of their illness and treatment, reduced levels of cardiac anxiety, as well as improved exercise levels and shorter return times to normal activities. Although limited in number, the initial research suggests that active visualisation appears to be a powerful intervention for improving patient understanding.

Theory would suggest that active visualisation may be most useful for illnesses which are typically asymptomatic, for treatments that do not result in obvious symptom reduction for patients, or for medications that work differently from others the patient may have used previously. This is true for patients taking PrEP as a preventative treatment to reduce infection risk, as well as for many early-stage patients living with HIV who are often asymptomatic. Active visualisation could increase perceptions of treatment necessity for patients taking PrEP and ART by presenting illness and medication mode-of-action information which is otherwise difficult to conceptualise.

There is evidence to suggest that active visualisation may improve adherence to ART from an initial study using mobile technology (Perera et al., 2014). Participants (patients living with HIV) received two versions of a smartphone application: one with a standard 24 h medication clock, or an augmented version that included an animated representation of how their personal adherence levels affected their viral load activity and T cell protection within the body in real-time. Patients who saw the augmented version of the application (which included active visualisation) were found to have greater self-reported levels of adherence and decreased viral loads at three month follow-up when compared to participants who received the standard version. Furthermore, those participants who reported greater engagement with the augmented application had greater perceived understanding of their HIV infection and greater necessity beliefs regarding their ART. Although limited by a small sample size, this preliminary evidence suggests that being able to visualise the biological process of ART appears to be more effective in improving adherence when compared to interventions that address non-intentional aspects (e.g. forgetfulness) alone.
Using Active Visualisation for HIV and PrEP

We have recently developed an active visualisation device that can be used to demonstrate the necessity of consistent adherence to ART and PrEP therapy. This active visualisation device uses a clear Perspex outline of the body and dynamic changes in colour to illustrate the action of the medication (see Figure 8). The device uses the changing colour of a liquid to represent two states; one where the virus is able to replicate (pink colour) and one where the presence of medication controls this from happening (clear colour). The device uses a diluted solution of sodium hydroxide, water, and a pH indicator, so that the addition of more acidic or basic solutions can change the colour accordingly. A demonstration using the device can be seen in a video in the supplementary material of the online article.

In the demonstration, the acid is an effervescent tablet representing the patient’s ART (actually an aspirin tablet) that when added to the pink solution looks potent as it fizzes and changes the pH balance to result in a clear liquid. The second solution is a sodium hydroxide basic solution which represents the HIV virus. This solution is added to the body each ‘day’ during the demonstration. The demonstration takes the participant through a series of days to convey the message that their ART needs to be taken every day. This is achieved by showing patients that when they take their medication (and the solution becomes clear) on day one, on day two the virus is still in their body, meaning that they need to again take their medicine to control the risk of their viral load increasing (see Figure 8). This message and the demonstration are repeated several times to the patient.

The device also demonstrates to patients what happens if they repeatedly miss doses of their medication and how this affects the body’s ability to control viral load. In this part of the demonstration the participant sees that each day the ‘virus’ is inside of their body, but this time there is no medication being taken to control the virus from replicating. The solution becomes more pink as the level of virus within the body is increasing. When the participant eventually ‘remembers’ and medicine is added to the device, this time the solution does not change back to clear (see Figure 9). The message here is that if the patient does not consistently adhere to their medication, the viral level is not controlled within their body and so they will become resistant to their medication.

There is also an application for using the active visualisation device to explain how PrEP works preventatively to lower the risk of HIV infection. In this version of the demonstration, PrEP medication (aspirin tablet) is continuously added into a water solution, which actively dissolves and leaves a clear mixture. Following this, a vial with a purple coloured solution representing the HIV virus is poured into
the liquid but the mixture remains clear (see Figure 10). The message here is that consistent adherence to PrEP maintains the level of the medicine within the body, meaning that the risk of contracting an HIV infection is greatly reduced. This demonstration can be contrasted with a solution where no medication or irregular medicine is taken. In this version, when the purple liquid is added to the solution it does turn the whole body purple, representing the higher risk of contracting an HIV infection when PrEP is not taken consistently.
Figure 8. The active visualisation device demonstrating the need for adherence to ART. Photos 1 to 3 show the medicine controlling the virus inside the body, and photo 4 shows the virus still being present the next day (indicating that medication needs to be taken once again).

Figure 9. The active visualisation device demonstrating what happens when a patient is not adherent to their medication. Medicine is added but the solution does not change to clear.
Figure 10. The adapted active visualisation device demonstrating how adherence to PrEP lowers risk of HIV infection. When the virus is added into the device (photo 3) the solution remains clear.
Future Applications

Our device has the potential to increase understanding regarding the necessity of consistent adherence to both ART and PrEP, meaning that it could be a powerful intervention to improve adherence to both of these medications. The device has key features that make it a promising tool for use within this disease population. Firstly, the use of a simple, visual representation should make the concept of consistent adherence to PrEP and ART easier for patients to understand. The device could therefore be especially useful as an educational tool for specific populations, such as children and adolescents, or other individuals with low health literacy. Second, the device is a highly portable and low-cost resource. This makes it ideal for use within hard to reach, under-resourced areas where other formats of active visualisation (such as mobile technology) may not be as suitable. The next step forward in attempting to understand the utility of active visualisation in improving adherence to ART and PrEP is to therefore conduct more research using larger and more diverse samples.

There are also future applications for using active visualisation with other chronic illnesses. There are many conditions where adherence does not always directly relate to a change in symptom experience (e.g. hypertension, asthma). Relatedly, active visualisation may be particularly useful for patients to comprehend the need for a preventative medicine, such as statins prescribed to patients with angina or high cholesterol. In addition, active visualisation may be a useful tool for explaining the biological process of particularly complex treatments, where other methods of communication may be insufficient. The dynamic nature of active visualisation means that there are many contexts within which it could be applied to provide a clearer explanation and, more importantly, to fit the purpose of treatment to the patient’s model of illness.

Active visualisation presents a new frontier in patient education. Using visual information may seem like common sense, but active visualisation is about more than simply drawing a picture or creating a model. Visualisation interventions need to be carefully considered, and must be created based on the theoretical approaches that we have discussed above. They must be presented in the context of the clearly defined ‘problem’, and subsequently highlight how treatment can be used to try and control or cure the health threat. Active visualisation must create a fit in the patient’s mind between their illness model and the purpose of their treatment. The initial evidence and considerable background theory suggests that visualisation could be an immensely useful tool in helping patients to ‘see’ what is actually going on inside.
Chapter Six

Using Active Visualisation to Improve Medication Adherence in Chronic Illness

Preface

Chapter Five discussed active visualisation as a new method to consider when creating visualisation devices and tools. Active visualisation provides a more complete representation of the link between an illness threat and the purpose of treatment, meaning it may be more effective than other visual health information. However, empirical evidence is needed to establish whether an active visualisation intervention can improve health outcomes, and in particular, whether an active visualisation intervention can produce objective changes in health behaviours. Previous studies have found that both active visualisation (Perera et al., 2014) and visual health information (Rees et al., 2013) can produce changes in objectively measured health outcomes, but these studies were limited by small sample sizes. Understanding the effectiveness of active visualisation in increasing self-management behaviours is particularly pertinent to designing effective interventions for patients with chronic illness. Larger randomised controlled trials (RCTs) are therefore necessary to assess the efficacy of active visualisation in objectively improving health behaviours.

The manuscript in Chapter Five described a newly-developed active visualisation device for improving understanding and adherence to antiretroviral therapy (ART) for people living with HIV infection (Jones & Petrie, 2017). Designing effective adherence interventions to ART is a significant health concern that has garnered considerable research attention. The advent of ART transformed the timeline of HIV infection from a terminal illness, into a manageable, chronic condition requiring consistent, high levels of adherence to maintain virological suppression (Swendeman, Ingram, & Rotheram-Borus, 2009). Suboptimal adherence to treatment has therefore remained a substantial concern in the HIV context (Mills et al., 2006; Ortego et al., 2011), and the main reason for poor treatment outcomes and treatment failure (Conway, 2007).

The World Health Organisation recommends text messaging interventions as a strategy for improving adherence to ART (World Health Organization, 2013a), supported by findings from systematic reviews and meta-analyses (Kanters et al., 2017). Reminder-based Interventions, however, are only likely to improve unintentional non-adherence behaviours. Intentional non-adherence can be influenced by a range of variables, including attitudinal and cognitive factors. Concerns about
medication and health, and misinformation about treatment efficacy, are additional treatment barriers associated with greater non-adherence to ART (Genberg, Lee, Rogers, & Wilson, 2015). Reminder-based interventions typically fail to address negative perceptions of treatment and medication necessity beliefs. A meta-analysis of predictors and correlates of adherence identified greater treatment necessity beliefs and fewer concerns about ART as factors strongly associated with adherence (Langebeek et al., 2014). This review concluded that interventions designed to improve adherence to ART should target these psychological factors.

Other common intervention strategies for ART include cognitive-behavioural therapy (CBT) and directly-observed therapy (DOT) (Chaiyachati et al., 2014). CBT and DOT are labour intensive interventions which may require considerable resources to implement. Furthermore, studies that include ‘education’ as an intervention component do not clarify whether this includes explanations of disease aetiology and treatment efficacy (Chaiyachati et al., 2014). In comparison to other intervention methods, active visualisation can provide a representation of treatment efficacy that may improve intentions and subsequent adherence behaviour.

Another unclear area within HIV intervention research is the measurement of adherence as an outcome. While self-reported adherence can provide insight into behaviour, the most direct measure of viral suppression, and therefore adherence to ART, is HIV viral load (Holstad, Diiorio, & McCarty, 2011). Using plasma viral load as a marker of adherence allows a clearer indication of intervention efficacy in the form of objective change in clinical outcomes. However, not all studies assess biological markers of adherence, and studies using both self-reported and objective adherence measures report inconsistent findings (Chaiyachati et al., 2014).

The visualisation tool described in Chapter Five was developed specifically for use within the context of South Africa. It is important to consider the context of the target population when designing a visualisation intervention tool. Unlike biological interventions, behavioural interventions are influenced by the socio-cultural context, which needs to be accounted for when choosing appropriate intervention strategies (Chaiyachati et al., 2014). Utilising a previous visualisation method from prior research in the same patient population (e.g. Perera et al., 2014), would therefore be inappropriate when considering the differences in cultural environments. Instead, a physical demonstration (e.g. Karamanidou et al., 2008) that does not rely on access to technological infrastructure presents a more practical visualisation solution for patients within a treatment context like South Africa.
South Africa has the largest HIV pandemic, despite having the greatest numbers of patients receiving treatment (UNAIDS, 2016). At present, more than half of the HIV population (53%) resides in Sub-Saharan Africa (UNAIDS, 2018). Considering the prevalence of HIV within South Africa, there have been limited previous trials to improve adherence to ART. Interventions which have demonstrated improvement, such as didactic counselling (van Loggerenberg et al., 2015), require significant time and resources from staff involved. The level of resources required may make these interventions impractical to incorporate into this treatment context. Interventions are therefore needed that are brief, portable, and deliverable to remote communities without adequate healthcare access.

Another important consideration is the demographics of the HIV population within South Africa. There is consistent evidence of greater HIV morbidity, mortality risk, and prevalence within lower socioeconomic groups (Bunyasi & Coetzee, 2017; Probst, Parry, & Rehm, 2016; Wabiri & Taffa, 2013). Importantly, these groups are likely to have the poorest health literacy and access to healthcare, meaning they are most at risk of misunderstandings and most in need of effectively delivered health information. Previous work in a South African sample of HIV patients with limited education found that an information sheet incorporating simple illustrations significantly improved antiretroviral knowledge and self-efficacy for medication-taking six months after intervention, compared with standard care patients (Dowse, Barford, & Browne, 2014). Active visualisation in the form of a physical demonstration may therefore be a powerful, simple, and appropriate method for delivering treatment information to this population.

The following manuscript describes the results of an intervention study using an active visualisation device to improve adherence to ART in non-adherent patients living with HIV infection in South Africa. This RCT aimed to provide evidence for the utility of a new active visualisation device in improving an objectively measured health outcome. This study also aimed to determine the efficacy of active visualisation in improving adherence within a chronic illness population requiring consistent adherence to prevent disease progression. This intervention was conducted with samples from a community clinic and a peri-urban outpatient service, who were identified as non-adherent to ART.
Abstract

Non-adherence remains the largest cause of treatment failure to antiretroviral therapy (ART). Despite having the largest HIV pandemic, few successful adherence interventions have been conducted in South Africa. Active visualisation is a novel intervention approach that may help effectively communicate the need for consistent adherence to ART. The current study tested an active visualisation intervention in a sample of non-adherent patients. 111 patients failing on first- or second-line ART were recruited from two sites in the Western Cape, South Africa. Participants were randomly allocated to receive the intervention or standard care (including adherence counselling). The primary outcome was adherence as measured by plasma viral load (VL). There was a clinically significant difference ($p= .06$) in VL change scores between groups from baseline to follow-up, where the intervention had a greater decrease in log VL ($M_{adj}= −1.92$, CI $[-2.41, −1.43]$), as compared to the control group ($M_{adj}= −1.24$, CI $[-1.76, −0.73]$). Participants in the intervention group were also significantly more likely to have a 0.5 log improvement in VL at follow-up ($\chi^2(1)= 4.82, p=.028, \phi= 0.28$). This study provides initial evidence for the utility of this novel, brief intervention as an adjunct to standard adherence counselling for improving adherence to ART.
Introduction

The introduction of antiretroviral therapy (ART) has revolutionised HIV from a once fatal infection into a manageable chronic illness. Despite the ability of ART to maintain virological suppression and prevent clinical progression, non-adherence remains the prevalent reason for treatment failure (Conway, 2007), and therefore a critical area for intervention. South Africa has the largest global HIV pandemic. In 2017, the estimated countrywide prevalence rate was 12.6%, and the total number of South Africans living with HIV was 7.06 million. This estimated prevalence is even greater (18%) among those aged 15–49 years (Statistics South Africa, 2017). While disparity in treatment availability remains a substantial contextual issue for healthcare, it is also vital to prevent treatment failure within those patients who do have access to care.

Non-adherence, as opposed to resistance, is regarded as the most significant reason for treatment failure for patients living with HIV in South Africa (Murphy et al., 2012). Few successful adherence interventions for ART have been conducted within South Africa. Recent meta-analyses of interventions which included South African samples found that enhanced standard of care (adherence counselling) supplemented with text messaging or treatment supporters produced distinguishable improvements in adherence as compared to standard care (Kanters et al., 2017; Mills et al., 2014). However, the South African studies included here did not report consistent objective changes in adherence from the interventions delivered (Nachega et al., 2010; Peltzer et al., 2012). Overall, the interventions that do create change have small effects, which decrease when the intervention is withdrawn (Kanters et al., 2017).

A significant issue highlighted by these meta-analyses is the variation in the measurement of adherence as an outcome. Many studies rely on self-reported adherence, which may overestimate the positive effects found. While there is no “gold standard” adherence measure for HIV (Mugavero et al., 2012), viral load (VL) as measured through plasma provides an objective biological marker of treatment adherence. Using VL as a measure can therefore negate some of the uncertainty around actual medication-taking behaviour when using self-report, pill counts, prescription refills, or other proxy measures. Although collecting blood test data may be more laborious than other measures of adherence, VL provides an objective way to evaluate the effectiveness of adherence interventions on clinical progression.

Active visualisation is a method of delivering health information that could be particularly useful in educating patients about ART. Patients with HIV may discontinue treatment due to a lack of change
in symptoms experienced (Dahab et al., 2008), and additionally may not perceive immediate consequences of increased symptoms from non-adherence. Active visualisation can educate and motivate patients to adhere by helping them to understand the processes occurring inside their body and the purpose of their treatment. Active visualisation uses dynamic visual representations, such as animations, computer modelling, or physical demonstrations to present information about internal bodily processes of disease and treatment mode-of-action (Jones & Petrie, 2017).

A previous study found that incorporating active visualisation into a smartphone application improved adherence to ART as compared to medication reminders alone (Perera et al., 2014). Participants received either a standard application with reminders only or an augmented version including a simulation of VL and CD4 cell activity, based on self-reported adherence. The augmented application group self-reported greater adherence and had reduced VL at three month follow-up, as compared to the reminder only group. Although limited by a small sample size, this study demonstrates the additive effect that active visualisation may have on adherence to ART.

A physical demonstration of the physiological treatment process may be the most appropriate form of active visualisation to use within the South African context. This format does not rely on access to technology, yet is still portable and easy to disseminate. An example physical demonstration has been found to improve understanding and treatment efficacy beliefs of phosphate binding medication in end-stage renal disease patients (Karamanidou et al., 2008).

A similar physical demonstration has been created to visually demonstrate the effects of adherence or non-adherence to ART (Jones & Petrie, 2017). This device presents an innovative way to portray the importance of consistent adherence, a message relevant to patients failing first- and second-line treatment and a concept often misunderstood by patients (Kagee et al., 2011). A visual depiction of VL and treatment mode-of-action may provide a more salient representation of the effects of treatment failure, in contrast to standard verbal information the patient may have already received. The current study was a randomised controlled trial (RCT) assessing the efficacy of an active visualisation device in improving adherence to ART, within a sample of non-adherent patients in Western Cape, South Africa.
Method

Participants

Study participants were patients living with HIV attending two separate infectious diseases clinics in Western Cape, South Africa. Both clinics provide basic non-specialised hospital services and offer full ART services as part of their outpatient services. Patients are referred from general services to the clinics following an HIV positive test result. The ART programmes enrol new patients on a continuous basis and provide regular patient care, blood tests, and ART medication refills to patients. The areas served by the clinics have wide socio-economic disparities, and levels of poverty and unemployment are high.

Due to the large variability of effect sizes found in previous adherence intervention studies, we choose to detect a medium effect size only. A G*Power (Faul et al., 2007) calculation revealed that 128 participants would be necessary using a two-tailed test, with 80% power, and a significance level of 0.05. We were able to recruit a total of 111 patients, which included 78 participants from the Infectious Diseases Clinic at a major peri-urban hospital between May and November 2016, and a further 33 patients from a community clinic between August and October 2017.

Patients were included in the study if they were failing on first- or second-line treatment, over 15 years of age, and fluent in either English or Afrikaans. Treatment failure was classified as having been on ART for four months and having a baseline VL of more than 1000 copies/mL. Clinical staff referred patients to the research assistant for recruitment based on this eligibility criteria for treatment failure. Informed consent or assent was obtained from all participants included in the study. Figure 1 depicts the flow of participants through the study.

Procedure

Patients were recruited after their appointment with the treating clinician. All patients recruited into the study were receiving standard care. Standard care for patients with a raised VL within these treatment settings includes adherence counselling from the treating clinician and a discussion of potential causes of their sub-optimal adherence during their appointment. If patients continue to default, they receive monthly consultations with the doctor and counsellor.

During recruitment, the treating clinician at each clinic identified patients who fit study criteria. Following the consultation, the research assistant met interested patients in a separate counselling room. The research assistant discussed the participant information sheet with the patient and obtained
informed consent. After participants completed the baseline questionnaire, an opaque sealed envelope was opened containing their randomisation allocation into one of two study groups (control n= 55, intervention n= 56). These envelopes were created by one of the researchers (AJ) independent to the recruitment process, using a random number sequence generator. This concluded the study session for those assigned to the control group. Participants in the intervention group were shown the active visualisation demonstration (details below). Following the intervention, participants completed the post-intervention questionnaire before concluding the study session and their contact with the research assistant. The research assistant collected follow-up blood test data from patient medical files.

Figure 11. CONSORT diagram depicting the flow of participants through the study.
**Intervention**

The intervention was an active visualisation device developed by the study authors (AJ, KP, EC, & MT). The intervention was delivered by the research assistants who were trained by one of the researchers (AJ). The intervention took approximately 10 minutes with each participant (see Appendix D for intervention script).

The intervention demonstrates the importance of consistent adherence to ART by symbolising the treatment mode-of-action within a ‘body’. The body-shaped container was created using two pieces of laser cut Perspex (total height= 32.5 cm, total length= 40.5 cm, and width= 2.4 cm) and waterproof sealant. When the ART ‘medication’ (an aspirin tablet) is added to the body, the liquid inside changes colour from pink (indicating the presence of the virus) to clear (representing medication controlling viral replication). The change in colour occurs through manipulating the pH balance of the liquid inside using an acid (aspirin tablet) versus a basic solution (sodium hydroxide).

The intervention runs through scenarios to demonstrate that medication must be taken each day, as even when medication is added to the ‘body’, the following day the pink colour returns because the infection cannot be reversed. This process demonstrates why consistent adherence is needed to achieve virological suppression. The intervention also demonstrates the effects of missing one or two doses of ART, versus how long-term non-adherence can lead to treatment failure. Detailed methodology of the device, including pictures and a video of the device in use, can be found in the supplementary material of our previously published editorial (Jones & Petrie, 2017).

**Measures**

**Demographic and clinical information.** Demographic variables were self-reported in the baseline questionnaire, including age, gender, ethnicity, highest level of education, and approximate monthly family income. Clinical information was obtained from patient medical records regarding current medication regimen (first- or second-line treatment) and date of diagnosis.

**Viral load.** The primary outcome of the study was adherence as measured by plasma VL. The amount of virus within each participant’s plasma was measured using the COBAS AmpliPrep/Taqman HIV-1 test (Roche Laboratories, California), a reverse transcription polymerase chain reaction test with the capacity to quantitate HIV-1 RNA over the range of 20–10,000,000 copies per mL. Baseline VL data was the most recent, available VL from no earlier than five months prior to study session for each participant (M= 40.92 days, SD= 37.41 days). Follow-up VL data was included from at least two months post study session, with the latest data point being 16.2 months later (M= 266.43 days, SD=...
121.66 days). Data were excluded from the analysis if baseline VL was less than 1000 copies/mL (n=5). Figure 11 details the number of participants included in the final analysis.

**Illness Perceptions, Medication Beliefs, and Other Perceptions.** Illness perceptions, beliefs about medication, and other perceptions were measured at baseline and post-intervention. The Brief Illness Perception Questionnaire (Brief IPQ) (Broadbent et al., 2006) asks participants to rate cognitive and emotional representations of their illness (“HIV infection”), on an 11-point, Likert-type scale from 0 to 10 with relevant anchors. Beliefs about medication were assessed using two items based on the necessity-concerns framework (Horne et al., 2013). One item asks participants how much they feel they need their medication (necessity belief); the other asks how concerned they are about long-term effects of their medication (concern belief). Both items are answered on an 11-point Likert-type scale with relevant anchors.

Additional items asked participants how motivated they were to take their ART medication, how serious of an illness they think HIV is, how difficult they find taking their HIV treatment, and their perceived risk of HIV developing into a more serious illness. Each of these items were rated on an 11-point, Likert-type scale from 0 to 10, with relevant anchors for each (e.g. “Not at all serious” versus “Extremely serious”).

**Depressive symptoms.** Symptoms of depression were measured at baseline using the Patient Health Questionnaire 9 (Kroenke, Spitzer, & Williams, 2001), due to the known relationship between depression and adherence in HIV (Gonzalez, Batchelder, Psaros, & Safren, 2011). The PHQ9 is a 10-item measure assessing frequency (from “not at all” to “nearly every day”) of depressive symptomatology over the past two weeks. The total score of the first nine items was used in the current study.

**Evaluation of the visualisation device.** Participants also completed six items in the post-intervention questionnaire evaluating their thoughts about the visualisation device. Participants rated the device on how interesting it was, how motivated it made them to take their medication, how it helped their understanding of HIV and their medication, and how anxious it made them about HIV and their medication. These ratings were made on an 11-point Likert-type scale from 0 to 10 with relevant anchors for each item.

Finally, an open-ended item asked participants “What thoughts ran through your mind when you were shown the device?”. This question has been used previously in visualisation research (Jones et al., 2017). Four main response categories were determined. Adherence thoughts were any thoughts
relating to medication taking, concerns were anxieties about the device or personal health, and education thoughts were those stating an improved understanding after seeing the device. Irrelevant comments (e.g. "pay attention") were coded into a fourth "other" category. Two independent raters coded whether each response fit into one or more categories, with a third coder making the final decision regarding discrepancies.

Statistical Analysis
The data were analysed using SPSS version 25.0. Tests were considered significant if a significance value below .05 was achieved. Independent samples t-tests and Chi-square tests assessed differences at baseline in demographic, clinical, and outcome variables between groups. Paired-samples t-tests were used to assess differences within the intervention group from baseline to post-intervention in illness perceptions, medication beliefs, and other beliefs. One-way, between groups ANCOVAs were used to assess differences between groups in change scores in raw and log VL from baseline to follow-up, controlling for baseline VL. A Chi-square test examined the association between group and whether there was an improvement in log VL of 0.5 or more from baseline to follow-up (yes/no).

Results
Demographic and Clinical Variables
Participants ranged from 15 to 59 years of age ($M$= 36.48, $SD$= 9.66), were mainly female (75/11, 67.6%), and identified as African (75/111, 67.6%) or Coloured (34/11, 30.6%) (see Table 8 for sample characteristics). There were no baseline differences found in any demographic or outcome variables between groups ($p$> .05). Baseline levels of depressive symptoms were not correlated with change in VL ($r$= −0.03, $p$= .775) or change in log VL scores ($r$= 0.01, $p$= .929). There was no significant association between medication regimen and group (see Table 8), with most participants on first-line treatment (83/107, 77.6%). Length of diagnosis ranged from 7.24 months to 20.68 years prior to recruitment ($M$= 6.81 years, $SD$= 4.56 years).

Baseline differences in demographic and clinical variables between the two treatment sites were also assessed. There were no significant differences between participants from each treatment site in demographic variables ($p$>.05). All clinical variables between sites were also not significantly different ($p$>.05) except for the amount of days between study session and follow-up, where participants from the peri-urban hospital had a significantly greater number of days before follow-up ($M$= 281.46, $SD$= 114.28), than participants from the community clinic ($M$= 148.73, $SD$= 106.13; $t_{(67)}$= 4.04, $p$< .001).
<table>
<thead>
<tr>
<th>Demographic and clinical characteristics of the sample.</th>
<th>Control M (SD) [%] (n= 55)</th>
<th>Intervention M (SD) [%] (n= 56)</th>
<th>Test statistic (t or χ²)</th>
<th>df</th>
<th>p</th>
<th>Total sample M (SD) [%]</th>
</tr>
</thead>
<tbody>
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<td><strong>Total sample</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Age (years)</strong></td>
<td>36.96 (10.90)</td>
<td>36.00 (8.33)</td>
<td>0.52</td>
<td>109</td>
<td>.602</td>
<td>36.48 (9.66)</td>
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<td></td>
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<tr>
<td>Female</td>
<td>40 [72.7%]</td>
<td>35 [62.5%]</td>
<td></td>
<td>1.32</td>
<td>.250</td>
<td>75 [67.6%]</td>
</tr>
<tr>
<td>Male</td>
<td>15 [27.3%]</td>
<td>21 [37.5%]</td>
<td></td>
<td></td>
<td></td>
<td>36 [32.4%]</td>
</tr>
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<td></td>
<td></td>
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</tr>
<tr>
<td>African</td>
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<td></td>
<td>3.70</td>
<td>3</td>
<td>.295</td>
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<td>14 [25%]</td>
<td></td>
<td></td>
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<td>34 [30.6%]</td>
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<td>0 [0%]</td>
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<td></td>
<td></td>
<td></td>
<td>1 [0.9%]</td>
</tr>
<tr>
<td>Indian</td>
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<td>0 [0%]</td>
<td></td>
<td></td>
<td></td>
<td>1 [0.9%]</td>
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<tr>
<td><strong>Education level</strong></td>
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<td></td>
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<tr>
<td>No formal education</td>
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<td>0 [0%]</td>
<td></td>
<td>1.66</td>
<td>3</td>
<td>.646</td>
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<tr>
<td>Primary</td>
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<td>40 [71.4%]</td>
<td></td>
<td></td>
<td></td>
<td>80 [72.1%]</td>
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<tr>
<td>Secondary</td>
<td>12 [21.8%]</td>
<td>15 [26.8%]</td>
<td></td>
<td></td>
<td></td>
<td>27 [24.3%]</td>
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<tr>
<td>Tertiary</td>
<td>2 [3.6%]</td>
<td>1 [1.8%]</td>
<td></td>
<td></td>
<td></td>
<td>3 [2.7%]</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Less than r2500</td>
<td>29 [52.7%]</td>
<td>26 [46.4%]</td>
<td></td>
<td>2.96</td>
<td>3</td>
<td>.399</td>
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<tr>
<td>r2500 to r5000</td>
<td>8 [14.5%]</td>
<td>12 [21.4%]</td>
<td></td>
<td></td>
<td></td>
<td>20 [18.0%]</td>
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<td>8 [14.3%]</td>
<td></td>
<td></td>
<td></td>
<td>12 [10.8%]</td>
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<td>10 [17.9%]</td>
<td></td>
<td></td>
<td></td>
<td>24 [21.6%]</td>
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<tr>
<td><strong>PHQ 9 total (N= 108)</strong></td>
<td>11.11 (6.45)</td>
<td>10.58 (6.95)</td>
<td>0.41</td>
<td>106</td>
<td>.681</td>
<td>10.84 (6.68)</td>
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<tr>
<td><strong>Baseline VL (N= 69)</strong></td>
<td>45198.26 (53415.26)</td>
<td>104742.00 (197262.69)</td>
<td>-1.72</td>
<td>39.10</td>
<td>.093</td>
<td>75401.61 (147445.38)</td>
</tr>
<tr>
<td><strong>Baseline Log VL (N= 69)</strong></td>
<td>4.19 (0.82)</td>
<td>4.26 (0.89)</td>
<td>-0.36</td>
<td>67</td>
<td>.720</td>
<td>4.22 (0.85)</td>
</tr>
<tr>
<td><strong>Days from baseline VL to study (N= 69)</strong></td>
<td>46.65 (43.82)</td>
<td>36.97 (30.60)</td>
<td>1.07</td>
<td>67</td>
<td>.290</td>
<td>41.74 (37.73)</td>
</tr>
<tr>
<td><strong>Days from study to follow-up VL (N= 69)</strong></td>
<td>252.71 (131.63)</td>
<td>252.51 (119.42)</td>
<td>0.01</td>
<td>67</td>
<td>.995</td>
<td>252.61 (124.66)</td>
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<tr>
<td><strong>Medication regimen (N=107)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First-line treatment</td>
<td>40 [75.5%]</td>
<td>43 [79.6%]</td>
<td></td>
<td>0.27</td>
<td>1</td>
<td>.606</td>
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<td>Second-line treatment</td>
<td>13 [24.5%]</td>
<td>11 [20.4%]</td>
<td></td>
<td></td>
<td></td>
<td>24 [22.4%]</td>
</tr>
<tr>
<td><strong>Length of diagnosis (days) (N= 94)</strong></td>
<td>2304.87 (1578.90)</td>
<td>2673.38 (1746.30)</td>
<td>-1.07</td>
<td>92</td>
<td>.286</td>
<td>2489.13 (1666.06)</td>
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</tbody>
</table>
Illness Perceptions, Medication Beliefs, and Evaluation of Visualisation Device

There were no significant changes in illness perceptions, medication beliefs, motivations to take treatment, seriousness beliefs, perceived risk, or treatment difficulty in the intervention group from baseline to post-intervention (p > .05). Perceptions of treatment control (M= 8.91, SD= 2.14), illness understanding (M= 8.48, SD= 2.62), and medication necessity beliefs (M= 8.71, SD= 2.77) were high at baseline (maximum score for each item is 10).

Intervention participants rated the device highly, finding it helpful in explaining their HIV infection (M= 9.5, SD= 1.56) and medication (M= 9.32, SD= 1.87), interesting (M= 9.55, SD= 1.40), and motivating regarding taking their medication (M= 9.33, SD= 1.16). The device made participants moderately anxious about their HIV (M= 6.80, SD= 3.79) and medication (M= 6.23, SD= 4.20).

Participants’ open-ended thoughts about the device most commonly fit into the adherence category (44.6%, 31/56), followed by education (41.1%, 23/56), and concern thoughts (19.6%, 11/56). Other thoughts comprised 23.3% of responses (13/56).

Adherence

Of the 111 participants recruited at baseline, 103 (92.8%) had a baseline VL, and 86 had a follow-up VL (77.5%). Only 84 participants in the sample (75.7%) had both a baseline and follow-up VL.

Additional information regarding data excluded from analyses can be found in Figure 11. There were no demographic differences between participants who did, and did not have a follow-up VL (p > .05). There were no differences in baseline VL between participants with a baseline VL only, versus the rest of the sample (p > .05). There was also no difference in VL change scores between participants attending the community clinic versus the peri-urban hospital (p = .198).

An ANCOVA controlling for baseline VL assessed group differences in VL change scores from baseline to follow-up. There was a significant difference in change in raw VL between groups (F(1, 58) = 5.33, p = .025, partial ƞ² = 0.08), where the intervention group had a significantly greater decrease in VL at follow-up (Madj = −76,961.47, CI [−100,099.81, −53,823.13]), compared to the control group (Madj = −37,836.03, CI [−62,166.48, −13,505.59]) (see Figure 12). A second ANCOVA assessed group differences in log VL change scores between groups, controlling for baseline log VL. Although the intervention group had a greater decrease in log VL at follow-up (Madj = −1.92, CI [−2.41, −1.43]), compared to the control group (Madj = −1.24, CI [−1.76, −0.73]), this difference was not statistically significant (F(1, 58) = 3.67, p = .06, partial ƞ² = 0.06) (see Figure 13). This group difference, however, can
be regarded as clinically significant, as a change in log VL of 0.5 or greater has been identified as a reduction of clinical significance (Mellors et al., 1997; Parsons, Golub, Rosof, & Holder, 2007). Each decrease of 0.5 in log VL is associated with a 30% reduction in the risk of clinical progression.

Based on the analysis used in a previous intervention trial (Parsons et al., 2007), we created a dichotomous variable to assess the association between group and whether an improvement in log VL of 0.5 or greater had occurred between baseline and follow-up. There was a significant association between group and improvement in 0.5 log VL or greater ($\chi^2(1) = 4.82$, $p = .028$, $\phi = 0.28$), with more participants in the intervention group demonstrating this improvement (26/42, 61.9%), as compared to the control group (16/42, 38.1%). There were also more participants who did not demonstrate an improvement of 0.5 or more in log VL in the control group (13/19, 68.4%), as compared to the intervention group (6/19, 31.1%).

*Figure 12.* Difference in viral load change scores between groups controlling for baseline viral load, from baseline to discharge. Bars represent adjusted mean and error bars represent standard error. *$p < .05.$*
This is the first trial investigating the utility of an active visualisation intervention for improving adherence to ART. The results of the trial provide preliminary evidence for the efficacy of this brief intervention in improving adherence for patients failing first- or second-line ART, as demonstrated by a greater improvement in VL.

This brief intervention resulted in a clinically significant improvement in adherence, when compared to those receiving standard care only. Furthermore, participants in the intervention group were significantly more likely to have a 0.5 log improvement in VL at follow-up. It is important to note that standard care in this context includes adherence counselling. As described above, this includes the treating clinician consulting with patients regarding the cause of their non-adherence and the risk of clinical progression, which may continue monthly if issues persist. It is therefore unsurprising that we see improvements across time in both groups, but also significant that this brief visualisation intervention was able to produce a greater improvement in adherence over and above that achieved.
through standard adherence counselling. This suggests that the intervention could be a worthwhile adjunct to standard care within this context. Our results also support the findings of Perera and colleagues (2014) and the use of active visualisation as a method for educating and motivating patients to improve adherence to ART.

Previous intervention studies conducted with HIV patients have relied on the use of counselling and treatment supporters (Kanters et al., 2017; Mills et al., 2006) or directly observed therapy (Nachega et al., 2010). These forms of intervention require extensive time commitments, training, and readily available support throughout. Furthermore, the small effects found within these trials can dissipate after the withdrawal of the intervention. The current intervention therefore presents an innovative, brief approach that can easily be added to standard care or incorporated into other adherence interventions.

Interestingly, we found no changes in illness perceptions or medication beliefs in participants who saw the visualisation device. This finding was surprising as these changes are often found in visualisation studies, particularly in regard to perceptions such as treatment control and understanding (Jones et al., 2016, 2017; Stephens et al., 2016). In the current study, however, participants did report high perceptions of treatment control, understanding, and necessity medication beliefs at baseline, meaning a ceiling effect may have occurred.

Participants appeared to be accepting of the intervention, rating the device as easy to understand, interesting, and motivating in regards to taking their medication. There were moderate levels of anxiety reported upon seeing the intervention. This is understandable as visualisation exposes the participant to the real threat of possible treatment failure. Combining this message with the information regarding treatment efficacy may have motivated participants to adhere to treatment, rather than making them avoidant due to raised anxiety. The open-ended question data suggested that the majority of participants understood the key message of consistent adherence in preventing treatment failure.

Finally, the study findings also support the use of visualisation as an alternate format for delivering health information. Participants had likely been exposed to multiple explanations regarding ART. Perhaps the unique visual delivery of this information increased salience and therefore motivation for these participants. The results also suggest that visualisation can improve health outcomes. These results are promising and promote the use of visualisation as an education tool for other illnesses and treatments.
Our study is limited by the lack of available VL data in our recruited sample and the variability in time between recruitment and follow-up VL data. This was due to an absence of routine monitoring and clinical data available within the treatment context of an overburdened health care system. Alternatively, some patients had to be excluded from the analysis who were referred by clinical staff and recruited into the study, but were ineligible due to low baseline VL (< 1000) or having no available baseline VL data. Research assistants did not have access to patient data at the time of recruitment, meaning they relied upon referrals from clinical staff to ensure patients were non-adherent and could be included. This could have been avoided by requesting an independent blood test as part of the study, however, knowledge of this monitoring may also have impacted adherence. Second, we did not have clear information regarding other medical issues that may have affected VL (such as alcohol use or breastfeeding), and were therefore unable to control for the impact of these variables. Third, we did not have information regarding resistance from the blood tests within our sample, meaning we are unable to assume that differences in VL are exclusively the result of changes in treatment adherence.

Another limitation to consider is the significantly shorter follow-up VL data available from the community clinic sample as compared to the peri-urban hospital sample. This could suggest that patients recruited from the community clinic were more adherent in terms of attending their appointments and providing blood samples, or alternatively, that this clinic kept better records than the peri-urban hospital. There were, however, no differences found between sites in VL change scores, suggesting that differences in the data available may not necessarily reflect differences in patient adherence. Finally, the reduced sample size with available VL data at baseline and follow-up decreased the statistical power in our analysis. This reduces the generalisability of our study findings. However, as stated above, analyses established that there were no demographic differences between participants who did and did not have follow-up VL, suggesting that the sample analysed was comparable to those recruited.

This study does however have significant strengths, including the use of a randomised controlled design, an objective measure of an adherence marker, and good ecological validity in a high-need population. The intervention has high clinical applicability and could be easily integrated into standard clinical care, as an adjunct to adherence counselling. The portability and low-cost of the device mean it could be utilised in hard to reach populations with limited access to healthcare and technology. This could overcome the geographic limitations of previous interventions such as cognitive behavioural therapy and counselling, which rely on access to trained health professionals (Kanters et
The simple message of the intervention may also translate well to adolescents with HIV in South Africa, a sub-population with significant adherence issues (Nachega et al., 2009; Nglazi et al., 2012). The intervention could also promote adherence to newly diagnosed patients at treatment initiation and potentially negate the occurrence of non-adherence.

**Conclusion**

The current study provides initial evidence that active visualisation may be an effective intervention for improving adherence to ART. This novel intervention presents an exciting opportunity for an alternative intervention strategy that is brief and could easily be added to adherence counselling or other adherence interventions in clinical practice. Further research could investigate the utility of the device in additional HIV patient populations, including remote populations, newly diagnosed patients, and adolescents.
Chapter Seven

Using Active Visualisation to Improve Adherence to a Health Behaviour Following an Acute Medical Procedure

Preface

Chapter Six reported the results from a randomised controlled trial (RCT) using active visualisation to improve adherence to antiretroviral therapy in patients living with HIV infection who were non-adherent. This study provided initial evidence for the utility of active visualisation in improving an objective marker of adherence to treatment. When considering previous visualisation studies, there is a lack of evidence for improving adherence to behaviours other than medication taking. Lifestyle changes can be equally significant to medication adherence in terms of producing clinical benefit and reducing illness progression. It is therefore important to determine whether active visualisation is also efficacious in changing health behaviours.

Previous studies examining the impact of visual health information in changing lifestyle health behaviours have generally utilised diagnostic feedback imaging (Devcich et al., 2012; Mols et al., 2015). One example of an intervention that included active visualisation (in the form of animations presented on a computer tablet) was a randomised controlled intervention study, which aimed to improve recovery in patients following an acute coronary event (Jones et al., 2016). Patients exposed to the intervention reported greater exercise (minutes of moderate exercise during the past week) at seven week follow-up compared to standard care patients. This finding, however, was based on self-reported exercise only, which has the potential to be influenced by social desirability. Furthermore, the visual information used in this intervention explained the efficacy of cardiac medication, and did not demonstrate the physiological effects of exercise upon cardiac outcomes.

Post-operative mobilisation is a health behaviour which can be objectively measured. While graded exercise is a commonly prescribed treatment for patients living with many chronic conditions, it is also an essential behaviour in more acute medical settings such as surgical recovery. Views towards the importance of early mobilisation following surgery have shifted significantly over time. Prolonged bed rest, which was once considered a normal part of surgical recovery (Brieger, 1983), is no longer part of post-operative management. Post-operative mobilisation is a component of the Enhanced Recovery After Surgery (ERAS) pathway, a set of preoperative to postoperative guidelines consisting of multi-component interventions to ensure the best patient outcomes and recovery from surgical
procedures. Over the last decade, ERAS protocols have become used for the management of surgical patients across a range of services worldwide, including colorectal, gynaecological, pancreatic, thoracic, and urological surgeries. Adherence to these guidelines reduces the risk of post-operative complications such as pneumonia (Gustafsson et al., 2013; Smart et al., 2012), and reduces return to work times (L. Lee et al., 2015).

Post-operative mobilisation is an important outcome measure, as mobilisation indicates recovery both in-hospital and once discharged (Abeles, Kwasnicki, & Darzi, 2017). Suboptimal adherence to ERAS guidelines, including early mobilisation, is still common (Bergman et al., 2014; Fiore et al., 2017). Understandably, patients may be hesitant to follow recommendations for immediate mobilisation post-surgery, particularly those with traditional lay beliefs which value resting after illness or surgery. For these patients, advice to mobilise during recovery does not align with these beliefs, and may exacerbate anxiety about exercising.

Interventions to improve adherence to patient mobilisation after surgery generally include one-on-one support from a nurse or physiotherapist (Fiore et al., 2017). This approach can be resource-intensive and burdensome for staff. Helping patients to understand how the physiological mechanisms of early mobilisation promote faster recovery after surgery may be effective in increasing motivation and exercise behaviour. Visualisation depicting the biological changes occurring inside the body during resting and mobilising states could help correct unhelpful beliefs about early mobilisation. Visualisation could therefore be used as a simple way to educate patients about the link between early mobilisation and enhanced recovery from surgery. This may encourage patients to achieve self-led mobilisation, without waiting for guidance or prompting by a staff member. A visualisation intervention could also help reduce burden upon staff resources and time.

To date, no intervention has provided visual imagery of the physiological processes involved in post-operative mobilisation. We are therefore yet to understand whether visualisation can improve adherence to post-operative mobilisation, in the same way that it can improve adherence to medication. Furthermore, no visualisation studies have focused upon changing health behaviour in the acute, clinical setting in contrast to chronic illness or at-risk populations.

The following manuscript describes the development and implementation of an active visualisation intervention in improving post-operative mobilisation in patients recovering from colorectal and gynaecological surgery. These two conditions were selected as they both involve operative procedures in the lower abdomen and therefore have similar recommendations with regard to ERAS.
protocols (Abeles et al., 2017). This study aimed to provide evidence of the efficacy of active
visualisation in improving adherence to the health behaviour of post-operative mobilisation, as
assessed through objective measurement (step count measured by a fitness tracker watch). This study
also aimed to determine the applicability of an active visualisation intervention in an acute surgical
patient population, as opposed to an at-risk or chronic illness population.
Citation

Abstract

Objective. Enhanced Recovery After Surgery (ERAS) programmes fast-track recovery for surgical procedures, including colorectal and gynaecological oncology surgery. Early mobilisation is a postoperative ERAS module that can be self-managed by patients, but poor adherence is common. Visualisation is increasingly being used to improve patient understanding of pathological and treatment processes, and adherence to health behaviours. This study tested whether an animated visualisation intervention could improve adherence to postoperative mobilisation. 

Methods. 100 colorectal and gynaecological surgery patients were randomised to an intervention, active control, or standard care control group. Intervention participants saw an animated intervention on a computer tablet at day one post-surgery. All patients wore fitness trackers from day one to seven days post-discharge, and completed psychological measures at baseline, day one and seven days post-discharge. 

Results. Step count data was available for 50 participants. Intervention participants had a higher average daily step count ($M= 2118.50, SD= 1994.40$), compared to control participants ($M= 991.75, SD= 194.77; p= .046$). There was also a between groups main effect in maximum daily step count ($p= .048$). At post-surgery, intervention participants reported significantly greater perceived quality of recovery, less difficulty in being mobile, and decreased traditional surgery recovery beliefs compared to control participants. Intervention participants also significantly increased their understanding of the value of early mobilisation from baseline to follow-up, compared to the control group. 

Conclusion. This brief intervention appears effective in improving perceptions of early mobilisation, and initial evidence suggests improvements in adherence to post-operative mobilisation. This intervention has high clinical applicability and could be incorporated into post-operative standard care.
Introduction

The surgical post-operative recovery period is vital in determining return to good health and functioning for patients. Delayed or problematic post-operative recovery not only increases medical care and burden, but can also indirectly negatively impact the patient and their wider support network emotionally and financially (Lee et al., 2014). Over the last decade, Enhanced Recovery After Surgery (ERAS) programmes have been introduced into hospitals worldwide for a number of surgical services, including colorectal and gynaecological surgery (Gustafsson et al., 2013). ERAS programmes encompass a multi-disciplinary care pathway preoperatively to postoperatively, to reduce surgical trauma and metabolic stress on the body, and to optimise patient outcomes and a faster recovery (L. Lee et al., 2014; Varadhan, Lobo, & Ljungqvist, 2010). The ERAS items cover biological and medical recommendations (e.g. pre-operative fasting, anaesthesia, intraoperative technique, post-operative analgesia) to instructing pre-admission information, education and counselling, and post-operative nutrition and mobilisation (Gustafsson et al., 2013). ERAS programmes have been adopted as standard practise in hospitals worldwide and within New Zealand.

In comparison to standard care, ERAS patients are typically discharged faster with fewer illness-related complications, while experiencing no increased rates of hospital re-admission or mortality (Varadhan et al., 2010). However, optimal recovery is reliant upon adherence to the components of the ERAS pathway. Despite the widespread introduction of ERAS recommendations and guidelines worldwide, non-adherence to ERAS that cannot be explained by major surgical and medical complications is common (Smart et al., 2012).

One key postoperative ERAS module is early mobilisation. Combining early mobilisation with early oral nutrition can help prevent post-operative loss of muscle strength (Henriksen, Jensen, Hansen, Jespersen, & Hessov, 2002). Despite this, adherence to early mobilisation remains poor (Bergman et al., 2014; Fiore et al., 2017). Failure to complete early mobilisation is a common reason for ERAS deviation and is associated with poorer recovery (Vlug et al., 2012) and increased hospital stay (Smart et al., 2012). Efforts directed at getting patients to mobilise early can conflict with lay beliefs about bed rest and limited activity being necessary for the body to recover following a major operation (Brieger, 1983). Indeed, the difficulties of attempting to change these perceptions have been highlighted by staff (Pearsall et al., 2015).

There is limited evidence regarding the optimal methods for enhancing post-operative mobilisation. Previous research with colorectal patients has found that staff-facilitated mobilisation
(dedicated walking assistance) can improve step count during in-hospital recovery but this is not maintained once the patient leaves hospital (Fiore et al., 2017). A recent systematic review of studies examining the impact of early mobilisation on post-operative recovery all used similar one-on-one style training with patients (Castelino et al., 2016). These staff-facilitated interventions require considerable resources and the efficacy of these interventions in improving mobilisation is inconsistent (Castelino et al., 2016). Staff-directed interventions may force patients to mobilise in hospital, but may not promote self-directed behaviour from the patient once discharged. Finding ways to increase patient self-adherence to postoperative mobilisation could therefore improve patient outcomes, without increasing staff burden.

Enhancing patient understanding of the biological mechanisms and purpose of early mobilisation in improving recovery time could help reduce anxiety and increase adherence to this behaviour. Visual health information or active visualisation is increasingly being used as an intervention technique to improve understanding, motivation, and adherence to health behaviours (Jones et al., 2016, 2017; Jones & Petrie, 2017; Perera et al., 2014; Stephens et al., 2016). A recent active visualisation intervention for HIV patients failing on treatment in a resource poor area improved adherence as demonstrated by a reduction in the clinical outcome of viral load (Jones et al., 2018a). Visualisation can help patients to understand abstract and conceptual information about how treatments relate to illness by providing a concrete demonstration of processes occurring inside the body. Visualisation interventions are brief and portable, and have successfully been delivered to patients in hospital using technology (Jones et al., 2016). Staff encourage ERAS patients to be mobile postoperatively, however, adherence to that recommendation is largely determined by the patient. A visualisation intervention may therefore help patients to establish a concrete link between the purpose of early mobilisation and their recovery. This understanding may further drive maintenance outside the hospital environment and improve both patient adherence and recovery.

The current study aimed to assess whether a visualisation intervention explaining the purpose of early mobilisation could increase adherence to this behaviour postoperatively. Therefore, the primary outcome of this study was adherence to post-operative mobilisation, operationalised as step count from day one post-surgery to seven days post-discharge. Secondary outcome measures included changes in perceived quality of recovery from surgery and beliefs about ERAS recovery behaviours. This study also aimed to assess whether this visualisation intervention would be more effective than receiving the same information verbally. To assess this idea, an animated visualisation...
intervention was developed to deliver to ERAS patients following colorectal and gynaecological oncology surgeries.

**Method**

**Trial Design and Participants**

This study was a parallel, 3-arm, randomised controlled intervention trial with blinded assessors (Australia New Zealand Clinical Trials Registry ID # ACTRN12617000288325). A sample of 100 ERAS patients undergoing colorectal (n=74) or gynaecological oncology surgery (n=26) were recruited. A recent trial protocol to increase postoperative mobilisation in ERAS patients following visceral surgery, aimed to detect a large effect size (Wolk et al., 2017). A G*Power (Faul et al., 2007) calculation revealed that 84 participants would be necessary to detect a more conservative medium to large effect size of 0.35, at α= 0.05, with 80% power and three groups. A sample of at least 96 participants was needed to account for an estimated 15% attrition rate.

Colorectal and gynaecological oncology pre-admission patients at Greenlane Clinical Centre, Auckland District Health Board, were recruited from July 2017 to July 2018. These surgeries have similar operative procedures (within the lower abdominal/pelvic cavity) and ERAS elements (Abeles et al., 2017). Included participants were having elective gynaecological oncology or colorectal surgery at Auckland City Hospital, Auckland District Health Board, could read and understand English, and were over 18. Exclusion criteria included known mobility issues pre-surgery, feeling too unwell during hospitalisation, and having surgery while admitted for other reasons as an inpatient. Figure 14 depicts the flow of participants through the study. This study was approved by the Health and Disability Ethics Committee (17/CEN/47/AM02) and Auckland District Health Board Research Review Committee (A+7552).

**Procedure**

At pre-admission clinic, specialist nurses from each service referred patients to the researcher (AJ). Study information was provided and written informed consent was received before participants completed the baseline questionnaire. Randomisation occurred once each participant had a scheduled surgery date. Study participants were randomised into a standard care control group, visualisation, or active control group. Randomisation was created by someone independent of the study, using a random number generator and contained in opaque, sealed envelopes.
At day one post-surgery, participants were seen by one of two study researchers who delivered the active control and intervention presentations to the patient at their bedside (AJ & MK). A script was used to ensure consistency (see Appendix E). Both the intervention and active control presentations took up to ten minutes to deliver. Following this, an independent research assistant (blinded to study group) provided participants with the post-surgery questionnaire, fitted the fitness tracker, and provided a pre-paid courier bag for returning the tracker. Control participants completed the post-surgery questionnaire and were fitted with the fitness tracker.

At approximately seven days post-discharge ($M=8.61$, $SD=3.67$), the blinded research assistant completed a five minute follow-up telephone questionnaire with all participants, and reminded them to return the fitness tracker. Participants were sent a $20$ shopping voucher to thank them for their participation after the return of the tracker.
Figure 14. CONSORT Diagram depicting flow of participants through study.
**Intervention**

The intervention materials were created by the study authors (AJ, KP & JF) with guidance from clinical collaborators (AM & AM). The intervention described the purpose of early mobilisation, the importance of early oral nutrition, and the link between these two behaviours. The presentation included animations contrasting the internal bodily processes when resting versus when mobile, animations demonstrating digestive processes, as well as real life footage of patient actors (examples in Figure 15). Two versions were created using either a male or female patient actor, and participants saw their gender-match. The intervention was delivered to patients on a computer tablet at their bedside.

The intervention began by addressing common lay surgery beliefs about the need for extended bed rest following surgery, and challenged this by providing information about improved patient outcomes under ERAS. Next, a clip showed the patient actor lying in a hospital bed. The camera zooms in and transitions to an animation showing the resulting effects upon heart rate, blood circulation, and the lungs. These clips were contrasted with the patient sitting upright and walking, and animations showing increases in heart rate, improved blood circulation, and lung function. Following this, participants were given specific instructions about their exercise plan during recovery (from day one to discharge) taken from the ERAS booklet provided as part of standard care.

The intervention also explained the importance of early oral nutrition post-surgery. An animation showed the digestive process from ingestion to the extraction and absorption of nutrients into the bloodstream. This was then linked to early mobilisation and improved blood circulation to establish the importance of both behaviours in promoting recovery. Again, participants received specific instructions about their in-hospital nutrition plan. The final film clip showed the patient actors walking outside once home, and the researcher explained the importance of gentle exercise once discharged.

The intervention ended with an elaborative reasoning task to help participants contextualise how they could incorporate mobilisation into their recovery. Participants were asked to discuss specific examples of ways they could include exercise into their time in-hospital and their daily life once discharged. The active control group received the exact same verbal script as the visualisation group but saw no animations. The control group received standard post-operative ERAS care.
Figure 15. Screenshots from intervention. Top right and left show the patient actor. Bottom left shows image from blood circulation animation and bottom right shows image from heart rate animation

Measures

Demographic and clinical information. At baseline, participants self-reported gender, age, ethnicity, and highest level of education. Clinical information recorded from patient notes included date of surgery, primary surgical procedure, length of hospital stay (days), 30 day hospital re-admission for complications, and cancer diagnosis.

Step count. Post-operative mobility was assessed by step count using Jawbone Up Move fitness trackers. Jawbone trackers have been found to have high measurement precision due to the use of triaxial accelerometers (Balto, Kinnett-Hopkins, & Motl, 2016). Up Move trackers were chosen specifically to try and minimise effects upon activity, as these trackers do not display numerical step count. Each participant was instructed to wear the tracker at all times (except showering) until they were contacted seven days post-discharge. The tracker was placed on the participant’s non-dominant wrist, except when not possible due to intravenous lines. Participants with larger wrists were given a clip attachment to wear the tracker on their belt or shirt.
Step count data was included from the day after the patient received the tracker to the day before the follow-up phone call was completed, to prevent any inconsistencies in the time that the tracker was fitted and taken off. Average daily step count was calculated for each participant by dividing the total number of steps across the data collection period by the number of days. Maximum daily step count for each participant across the data collection period was also measured. Participants were excluded from the analysis if they had extreme missing data (more than 75% missing), were re-hospitalised during the first seven days following discharge, or if they reported not wearing the fitness tracker across the data collection period (see Figure 14).

Self-reported exercise. At baseline and follow-up, participants self-reported how many minutes they had spent completing moderate exercise (e.g. going for a walk) during the past seven days.

Quality of recovery. The Quality of Recovery short form (QoR-15) was used to assess perceptions of surgical recovery both post-surgery and at follow-up (Stark, Myles, & Burke, 2013). The QoR-15 measures five dimensions of recovery including physical (pain, physical comfort, and physical independence) and mental well-being (psychological support and emotional state). Responses are given on an 11-point scale from 0 (none of the time) to 10 (all of the time). Items 11 to 15 assess physical and psychological symptoms and are reverse-coded. Items are summed to create total scores. The post-surgery questionnaire excluded item 8 (“Able to return to work or usual home activities”) and the follow-up questionnaire excluded item 7 (“Getting support from hospital doctors and nurses”). For this reason, total scores at each time point were analysed separately. This QoR-15 demonstrated good internal reliability at both post-surgery ($\alpha = .84$) and follow-up ($\alpha = .89$).

Perceptions of surgery and recovery. Items from the Brief Illness Perception Questionnaire (Broadbent et al., 2006) were adapted to assess perceptions of surgery and recovery at baseline and postoperatively. Words “illness” and “treatment” were replaced with “surgery” and “recovery”. Items assessed beliefs of treatment control (of surgery), identity (post-surgery symptoms), concerns (for both surgery and recovery), emotional response (to surgery), consequences (of surgery), timeline (of recovery), and personal control (of recovery). The post-surgery questionnaire excluded the concern about surgery item. Items are scored on an 11-point scale from 0 to 10, where higher scores indicate higher perceived levels of the construct (e.g. more control or more distress).

Perceptions of ERAS recovery behaviours. Six items were created to assess perceptions of early mobilisation and early oral nutrition. Participants reported how much they understood each behaviour, how motivated, and how anxious they were about completing each behaviour at all three
assessments. At post-presentation and follow-up only, participants also answered how difficult they felt it was to be active and to eat healthily during their recovery. Questions were answered on an 11-point scale from 0 to 10, with relevant anchors for each item in order to ensure response familiarisation.

**Traditional surgery recovery beliefs.** Three items at baseline and post-surgery assessed traditional surgery beliefs. These items asked participants how important they felt complete bed rest, extended hospital stay, and intravenous fluids were after surgery. These questions were answered on the same 11-point scale as previous items, with relevant anchors for each item. Items were summed to create a composite total score, which demonstrated good internal reliability (baseline α= .82, post-surgery α= .83). Higher scores indicated stronger traditional beliefs.

**Health Visual Information Preference Scale.** The Health Visual Information Preference Scale (Health VIPS) (Jones, Kleinstäuber, Martin, Fernandez, & Petrie, 2018c) was included in the baseline questionnaire to assess moderating effects between this scale and changes in primary outcome for the active treatment groups. The Health VIPS assesses preferences for receiving supplementary visual health information. The 9-item Health VIPS is measured on a 5-point Likert-type scale (from 1 to 5), with anchors from strongly disagree to strongly agree. Total Health VIPS score is calculated by averaging the items (items 4, 7, and 9 are reverse-coded), and internal consistency was good in the current sample (α= .79).

**Evaluation of intervention and active control materials.** At post-surgery, the intervention and active control group answered seven items evaluating the material they received in-hospital. Items asked how material improved understanding, and whether it increased motivation or anxiety about being active and re-introducing food and drink. One item also asked how interesting participants found the material. Items related to either the “animations” (intervention) or “information” (active control) received. Items were answered on an 11-point scale from 0 to 10 with relevant anchors for each.

**Statistical Analysis**

Data were analysed using SPSS version 25.0. Tests were considered significant at p< .05. Independent samples t-tests and Chi-Square tests for independence assessed associations or differences between groups in demographic, clinical, and baseline variables.

The Jawbone “UP” mobile application was used to retrieve data through Bluetooth connection. Unfortunately, Jawbone underwent liquidation and removed their application and online servers in May 2018, meaning fitness tracker data was only available if collected before this date (n= 50). One-way ANOVAs assessed differences in step count (both average and maximum). ANOVAs are robust to
violations of normality, which is significant as step count data can have large variation. Bonferroni corrections were used in post-hoc tests. One-way ANOVAs also assessed between group differences in QOR-15 scores at both post-surgery and follow-up, and difficulty regarding ERAS behaviours at post-surgery.

ANCOVAs, controlling for baseline levels, assessed between group differences in change scores from baseline to post-surgery in perceptions of surgery and recovery, and traditional surgery beliefs. ANCOVAs controlling for baseline levels also assessed between group differences in change scores of perceptions of ERAS behaviours and self-reported exercise from baseline to follow-up. Independent samples t-tests assessed differences in intervention ratings between the intervention and active control conditions.

Two mediation analyses examined if the change in understanding the value of being active between baseline and follow-up mediated the effect of group (1=intervention, 2=active control) on both average and maximum daily step count. 95% confidence intervals (CI) of the indirect effect of the mediator variable were calculated with a bootstrapping method (N bootstrap samples=10000) and heteroscedasticity-consistent standard errors (Hayes, 2013). The H0 hypothesis which assumes the indirect effect to be zero has to be declined if the CI does not include zero. Mediation analyses were performed with the PROCESS v3.1® macro (Hayes, 2013) for SPSS Statistics. Linear regression analyses were applied in order to examine if the effect of group (1=intervention, 2=active control) on the primary outcomes was moderated by visual health information preference at baseline. Besides the moderator variable (Health VIPS scale total score) and predictor (group: 1=intervention, 2=active control) the regression model also included a moderator*group interaction term.

Results

Demographic and Clinical Characteristics of the Sample

Figure 2 shows the study CONSORT scheme. Of the 97 participants randomised to the three study groups, 89 completed the post-surgery assessment, and 87 completed the seven day follow-up. Participants ranged from 18 to 91 years of age (M= 58.71, SD= 16.48). Most participants identified as NZ European or European (69/97, 71.1%), were female (61/97, 62.9%), and had completed at least secondary level education (45/96, 46.9%). Participants reported an average of 182 minutes of moderate exercise in the last seven days at baseline (SD= 186.10). There were no baseline differences in demographic, clinical, or baseline variables between groups except for length of hospital
stay, where the control group had a significantly longer hospital stay than the active control group ($p = .031$) (see Table 9).

As reported above, usable step count data was available for 50 out of 87 participants who completed all study assessments. Clinical and demographic variables that did differ between those with and without step count data were a reflection of differences between the colorectal and gynaecological oncology patient samples (as available data was exclusively from colorectal patients). These differences included a significant association between those who did and did not have data and both ethnicity ($\chi^2(1) = 6.91, p = .009, \phi = -.27$), and gender ($\chi^2(1) = 16.89, p < .001, \phi = .45$). There were more male participants with available step count data (26/30, 86.7%) than without, and more NZ European participants with available step count data (42/67, 62.7%) than without. There was also a significant difference between the groups in length of hospital stay (with step count data $M = 6.76, SD = 4.11$; without step count data $M = 3.83, SD = 2.94$; $t_{(83)} = -3.62, p = .001$), which again was a reflection of this difference between the gynaecological oncology and colorectal samples.
### Table 9. Demographic and clinical characteristics of the sample.

<table>
<thead>
<tr>
<th></th>
<th>Intervention</th>
<th>Active Control</th>
<th>Control</th>
<th>Test statistic</th>
<th>df</th>
<th>p</th>
<th>Total sample</th>
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<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>(t, F or χ²)</td>
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<tr>
<td></td>
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<td>[%] (n= 32)</td>
<td>[%] (n= 32)</td>
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<td>Age (years)</td>
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<td>.716</td>
<td>58.71 (16.48)</td>
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<tr>
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<tr>
<td>Female</td>
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<td>20 [62.5%]</td>
<td>19 [59.4%]</td>
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<td>NZ European/European</td>
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<td>24 [75.0%]</td>
<td>23 [71.9%]</td>
<td>5.18</td>
<td>8</td>
<td>.738</td>
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<td></td>
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<td>Exercise per week (mins)</td>
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<td>168.23 (163.11)</td>
<td>133.17 (133.17)</td>
<td>1.02</td>
<td>2, 88</td>
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<td>9.32 (1.30)</td>
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<td>6.25 (2.27)</td>
<td>6.77 (1.96)</td>
<td>0.63</td>
<td>2, 94</td>
<td>.537</td>
<td>6.42 (2.04)</td>
</tr>
<tr>
<td>Concerns</td>
<td>5.70 (3.18)</td>
<td>6.09 (2.60)</td>
<td>6.25 (3.06)</td>
<td>0.30</td>
<td>2, 94</td>
<td>.739</td>
<td>6.01 (2.94)</td>
</tr>
<tr>
<td>Emotional response</td>
<td>4.72 (3.09)</td>
<td>5.66 (2.46)</td>
<td>5.03 (2.74)</td>
<td>0.95</td>
<td>2, 94</td>
<td>.392</td>
<td>5.14 (2.77)</td>
</tr>
<tr>
<td>Recovery Perceptions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consequences</td>
<td>6.06 (2.26)</td>
<td>6.65 (2.19)</td>
<td>6.50 (2.38)</td>
<td>0.60</td>
<td>2, 94</td>
<td>.552</td>
<td>6.40 (2.27)</td>
</tr>
<tr>
<td>Timeline</td>
<td>4.20 (1.63)</td>
<td>4.13 (1.64)</td>
<td>4.95 (2.54)</td>
<td>1.69</td>
<td>2, 93</td>
<td>.190</td>
<td>4.42 (1.99)</td>
</tr>
<tr>
<td>Personal control</td>
<td>7.45 (2.00)</td>
<td>6.72 (1.76)</td>
<td>6.88 (1.93)</td>
<td>1.36</td>
<td>2, 94</td>
<td>.263</td>
<td>7.02 (1.90)</td>
</tr>
<tr>
<td>Concerns</td>
<td>4.33 (2.35)</td>
<td>4.81 (2.40)</td>
<td>5.82 (3.09)</td>
<td>2.72</td>
<td>2, 94</td>
<td>.071</td>
<td>4.98 (2.68)</td>
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<tr>
<td>Early Mobilisation Perceptions</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Understanding</td>
<td>Motivation</td>
<td>Anxiousness</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>--------------------------</td>
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</tr>
<tr>
<td></td>
<td>8.67 (1.98)</td>
<td>8.48 (2.50)</td>
<td>3.88 (3.24)</td>
<td></td>
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<tr>
<td></td>
<td>8.70 (1.56)</td>
<td>8.56 (1.87)</td>
<td>4.47 (2.82)</td>
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<tr>
<td></td>
<td>9.06 (1.11)</td>
<td>8.41 (1.80)</td>
<td>5.42 (3.11)</td>
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<tr>
<td></td>
<td>0.59</td>
<td>0.04</td>
<td>2.01</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>2, 92</td>
<td>2, 92</td>
<td>2, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.558</td>
<td>.963</td>
<td>.140</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.81 (1.60)</td>
<td>8.49 (2.07)</td>
<td>4.56 (3.09)</td>
<td></td>
<td></td>
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</tbody>
</table>

**Early Oral Nutrition Perceptions**

<table>
<thead>
<tr>
<th></th>
<th>Understanding</th>
<th>Motivation</th>
<th>Anxiousness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8.03 (2.58)</td>
<td>8.21 (2.07)</td>
<td>3.33 (2.99)</td>
</tr>
<tr>
<td></td>
<td>8.03 (2.01)</td>
<td>7.97 (1.96)</td>
<td>3.97 (2.97)</td>
</tr>
<tr>
<td></td>
<td>8.70 (1.60)</td>
<td>4.98 (3.05)</td>
<td>4.02 (2.09)</td>
</tr>
<tr>
<td></td>
<td>1.03</td>
<td>2.41</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>2, 92</td>
<td>2, 92</td>
<td>2, 92</td>
</tr>
<tr>
<td></td>
<td>.363</td>
<td>.796</td>
<td>.845</td>
</tr>
<tr>
<td></td>
<td>8.24 (2.12)</td>
<td>8.16 (2.00)</td>
<td>3.92 (2.43)</td>
</tr>
</tbody>
</table>

**Traditional surgery beliefs**

|                          | 8.48 (2.50)   | 8.56 (1.87)| 3.72 (2.47) |
|                          | 8.30 (2.00)   | 4.98 (3.05)| 4.02 (2.09) |
|                          | 0.23          | 2.41       | 0.17        |
|                          | 2, 92         | 2, 92      | 2, 92       |
|                          | .04           | .096       | .814        |
|                          | 2, 92         | 2, 92      | 2, 92       |
|                          | .140          | .096       | .814        |

**Confirmed cancer (Y)**

|                          | 25 [34.7%]    | 24 [33.3%] | 13 [24.5%]  |
|                          | 4.74 (3.05)   | 3.72 (4.88)| 4.04 (2.78) |
|                          | 13 [24.5%]    | 18 [34.0%]| 22 [41.5%]  |
|                          | 25 [34.7%]    | 23 [31.9%]| 24 [33.3%]  |
|                          | 0.77          | 0.77       | 1.03        |
|                          | 2, 92         | 2, 92      | 2, 92       |
|                          | .681          | .681       | .814        |
|                          | 72 [78.3%]    | 72 [78.3%]| 72 [78.3%]  |

**Length of hospital stay (days)**

|                          | 5.13 (3.08)   | 7.25 (4.88)| 8.74 (1.60) |
|                          | 4.74 (3.05)   | 7.25 (4.88)| 4.04 (2.78) |
|                          | 23 [31.9%]    | 0.17       | 0.17        |
|                          | 2, 92         | 2, 92      | 2, 92       |
|                          | 7.07 (2.70)   | 4.04 (2.78)| 7.65 (2.35) |
|                          | .022          | .140       | .140        |
|                          | 5.71 (3.90)   | 7.07 (2.70)| 7.65 (2.35) |

**30 day re-admission (Y)**

|                          | 5 [33.3%]     | 4 [26.4%]  | 2 [10.0%]   |
|                          | 6 [40.0%]     | 2 [8.7%]   | 4 [44.4%]   |
|                          | 4 [26.4%]     | 4 [26.4%]  | 4 [44.4%]   |
|                          | 0.48          | 0.48       | 0.67        |
|                          | 2             | 2          | 2           |
|                          | .787          | .787       | .787        |
|                          | 15 [16.7%]    | 15 [16.7%]| 15 [16.7%]  |

**Laparoscopic surgery (Y)**

|                          | 13 [24.5%]    | 18 [34.0%]| 22 [41.5%]  |
|                          | 4.77          | 4.77       | 4.77        |
|                          | 2             | 2          | 2           |
|                          | .097          | .097       | .097        |
|                          | 15 [16.7%]    | 15 [16.7%]| 15 [16.7%]  |

**Stoma (Y)**

|                          | 13 [24.5%]    | 18 [34.0%]| 22 [41.5%]  |
|                          | 3 [9.7%]      | 3 [9.7%]  | 3 [9.7%]    |
|                          | 0.67          | 0.67       | 0.67        |
|                          | 2             | 2          | 2           |
|                          | .714          | .714       | .714        |
|                          | 9 [9.8%]      | 9 [9.8%]  | 9 [9.8%]    |

**Primary procedure CR (n=66)**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segmental colectomy</td>
<td>3</td>
<td>15.0%</td>
</tr>
<tr>
<td>Anterior resection</td>
<td>7</td>
<td>35.0%</td>
</tr>
<tr>
<td>Ileostomy reversal</td>
<td>8</td>
<td>40.0%</td>
</tr>
<tr>
<td>Proctectomy</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>10.0%</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>23.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Primary procedure gynae (n= 26)**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAHBSO + PLND</td>
<td>5</td>
<td>50.0%</td>
</tr>
<tr>
<td>RH + PLND</td>
<td>1</td>
<td>10.0%</td>
</tr>
<tr>
<td>Ovarian debulking +/- BR</td>
<td>4</td>
<td>15.4%</td>
</tr>
<tr>
<td>Staging laparoscopy</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>11</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Note.** Bold indicates significance at $p < .05$. TAHBSO= Total abdominal hysterectomy with bilateral salpingo-oophorectomy, PLND= Pelvic lymph node dissection, RH= Radical hysterectomy, BR= Bowel resection
Post-Operative Mobility

**Fitness tracker data.** There were no significant group differences in demographic or clinical variables between groups within participants who had usable step count data (p > .05). A one-way ANOVA revealed a significant between groups effect in total average step count ($F(2, 47) = 3.35, p = .044$, partial $\eta^2 = 0.12$). Post-hoc comparisons revealed that the intervention group had a significantly greater step count ($M= 2118.50, SD= 1994.40$) than the control group ($M= 991.75, SD= 194.77; p = .046$). There were no significant differences in step count between the active control and control ($M= 1230.43, SD= 977.92; p = .999$), or intervention group ($p = .202$) (see Figure 16).

There was also a significant difference between groups effect in maximum daily step count ($F(2, 47) = 3.23, p = .048$, partial $\eta^2 = 0.12$). Post-hoc comparisons revealed a trend towards significance between the intervention ($M= 4652.47, SD= 3313.67$) and active control group ($M= 2677.40, SD= 2006.44; p = .091$), and between the intervention and control group ($M= 2789.75, SD= 1914.40; p = .094$). There were no significant differences between the active control and control group ($p = .999$).

*Figure 16.* Mean difference in average step count per day between groups across data collection period. Error bars depict standard error. *indicates significant post-hoc comparison at $p < .05$. 

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Moderator analysis. Linear regression analyses showed that neither average nor maximum daily step count regressed significantly on the moderator (Health VIPS total score)*predictor (group) interaction term (p>.05). This result demonstrates that intervention effects on primary outcomes were not moderated by visual health information preference.

Mediation analysis. The mediation analyses showed that change in understanding of the value of being active between baseline and follow-up did not mediate the effect of group on average daily step count (indirect effect= 99.92, CI [-154.97, 556.66]) or on maximum daily step count (indirect effect= 239.15, CI [-445.02, 1142.65]).

Self-reported exercise. An ANCOVA (controlling for baseline self-reported exercise) revealed no group differences in change scores in self-reported exercise from baseline to follow-up (p>.05).

Psychological Outcomes

Perceptions of surgery and recovery. ANCOVAs (controlling for baseline) revealed no significant group differences in change scores in surgical and recovery beliefs (p>.05). There was a trend towards significance in timeline of recovery change scores from baseline to post-surgery (F(2, 84)= 2.77, p=.068, partial η²=.06), with the intervention group having a greater decrease in timeline perceptions (M_adj= -0.62, CI [-1.37, 0.13]) as compared to the control (M_adj= 0.42, CI [-0.36, 1.20]), and active control group (M_adj= 0.52, CI [-0.25, 1.28]).

Quality of recovery. A one-way ANOVA revealed a significant group difference in QOR-15 scores at post-surgery (F(2, 78)= 3.45, p= .037, partial η²=.08) (see Figure 17). Post-hoc comparisons revealed significantly higher scores for the intervention (M= 104.92, SD= 20.45) compared to the control group (M= 90.37, SD= 20.86; p= .032). There were no differences between the active control and intervention (M= 98.27, SD= 19.32, p>.05), or control group (p>.05). Differences between groups in QOR-15 scores were not maintained at follow-up (p>.05).
Figure 17. Mean difference in Quality of Recovery score between groups at post-surgery. Error bars indicate standard error. *indicates significance at $p > .05$.

**Perceptions of early mobilisation and early oral nutrition.** ANCOVAs (controlling for baseline) found no group differences in change scores from baseline to post-surgery in perceptions of early mobilisation and oral nutrition ($p > .05$).

There were significant group differences in baseline to follow-up change scores in understanding the value of being active during recovery, and anxiety about eating and drinking (see Table 2). Post-hoc tests revealed that the intervention group had a significantly greater increase in understanding compared to the active control group ($p = .006$). There were no significant differences between the control and the intervention ($p > .05$) or active control group ($p > .05$). There was also a significant difference in anxiety about eating and drinking following surgery. Post-hoc analyses revealed a significantly greater increase in anxiety about re-introducing food and drink in the control group, compared to both the intervention ($p < .001$) and active control group ($p = .045$). There were no significant differences between the intervention and active control group ($p > .05$). There was a trend towards a significant group effect in anxiety regarding early mobilisation. The control group had a
greater increase in anxiety from baseline to follow-up compared to the intervention group, but this did not reach significance ($p = .081$). There were no significant differences between groups in understanding the value of eating and drinking, or motivations to be active or eat and drink ($p > .05$).

At post-surgery, an ANOVA revealed a significant difference between groups in anticipated difficulty of being active while in-hospital ($F_{(2, 86)} = 4.46, \ p = .014$, partial $\eta^2 = .09$). Post hoc comparisons revealed significantly higher perceived difficulty in the control group ($M = 5.70, SD = 2.37$) compared to the intervention group ($M = 3.57, SD = 3.13; \ p = .011$). There were no significant difference between the active control and intervention ($M = 4.72, SD = 2.76$), or control group ($p > .05$). Significance was not maintained at follow-up ($p > .05$).

**Traditional surgery recovery beliefs.** An ANCOVA (controlling for scores at baseline) revealed a significant group difference in change scores of traditional surgery recovery beliefs from baseline to post-surgery (see Table 10). Post-hoc analyses showed a significantly greater decrease in traditional surgery recovery beliefs in the intervention compared to the control group ($p = .025$). There was also a trend towards significance with the active control group having a greater decrease in traditional surgery recovery beliefs compared to the control group ($p = .062$), but no differences between the intervention and active control group ($p > .05$).
Table 10. Differences in change scores in perceptions of ERAS behaviours from baseline to follow-up, and in traditional surgery beliefs from baseline to post-surgery.

Note. Bold indicates significance at $p< .05$.

<table>
<thead>
<tr>
<th></th>
<th>$\Delta M_{adj}$ [95% CI] or $M$(SD)</th>
<th>$F$</th>
<th>$df$</th>
<th>$p$</th>
<th>Partial $\eta^2$</th>
<th>Post-hoc comparisons $p$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intervention (1)</td>
<td>Active Control (2)</td>
<td>Control (3)</td>
<td></td>
<td></td>
<td>(1-2)</td>
</tr>
<tr>
<td>Early mobilisation</td>
<td>Understanding</td>
<td>1.12 [0.73, 1.51]</td>
<td>0.26 [-0.11, 0.63]</td>
<td>0.60 [0.21, 0.99]</td>
<td>5.18</td>
<td>2, 81</td>
</tr>
<tr>
<td></td>
<td>Motivation</td>
<td>-0.15 [-0.96, 0.67]</td>
<td>-0.68 [-1.47, 0.11]</td>
<td>-1.00 [-1.83, -0.17]</td>
<td>1.09</td>
<td>2, 81</td>
</tr>
<tr>
<td></td>
<td>Anxiousness</td>
<td>-2.11 [-3.31, -0.91]</td>
<td>-0.51 [-1.65, 0.63]</td>
<td>-0.15 [-1.37, 1.07]</td>
<td>2.93</td>
<td>2, 81</td>
</tr>
<tr>
<td>Early oral nutrition</td>
<td>Understanding</td>
<td>1.45 [1.04, 1.86]</td>
<td>1.07 [0.67, 1.46]</td>
<td>0.98 [0.56, 1.40]</td>
<td>1.50</td>
<td>2, 81</td>
</tr>
<tr>
<td></td>
<td>Motivation</td>
<td>-0.05 [-0.84, 0.74]</td>
<td>0.33 [-0.43, 1.09]</td>
<td>-0.23 [-1.03, 0.58]</td>
<td>0.52</td>
<td>2, 81</td>
</tr>
<tr>
<td></td>
<td>Anxiousness</td>
<td>-2.37 [-3.39, -1.34]</td>
<td>-0.87 [-1.84, 0.11]</td>
<td>0.92 [-0.13, 1.97]</td>
<td>9.70</td>
<td>2, 81</td>
</tr>
<tr>
<td>Traditional beliefs</td>
<td>Understanding</td>
<td>-1.54 [-2.29, -0.80]</td>
<td>-1.37 [-2.12, -0.61]</td>
<td>-0.09 [-0.86, 0.68]</td>
<td>4.31</td>
<td>2, 83</td>
</tr>
</tbody>
</table>
Evaluation of Intervention and Active Control Materials

Intervention participants rated the presentation high in helping to improve their understanding of early mobilisation ($M = 9.17, SD = 1.28$) and eating and drinking following surgery ($M = 9.17, SD = 1.23$). They also rated the presentation as interesting ($M = 7.64, SD = 2.16$), and motivating in terms of being active ($M = 8.32, SD = 1.83$) and consuming a healthy diet during recovery ($M = 8.43, SD = 1.89$). The animations did not make intervention participants highly anxious about being active ($M = 1.75, SD = 2.76$) or eating and drinking ($M = 1.48, SD = 2.25$).

The active control information was also rated highly in terms of improving understanding of early mobilisation ($M = 8.59, SD = 2.04$) and eating and drinking after surgery ($M = 8.66, SD = 1.61$), being interesting ($M = 8.07, SD = 1.89$), motivating mobility ($M = 8.14, SD = 1.77$) and consuming a healthy diet ($M = 8.03, SD = 1.82$). This information also caused little anxiety about early mobilisation ($M = 2.66, SD = 3.09$) and eating and drinking ($M = 2.24, SD = 2.79$). There were no significant differences between the intervention and active control group in their ratings of the information received ($p > .05$).

Discussion

This study is the first to examine how an active visualisation intervention could improve adherence to early mobilisation following surgery. Intervention participants, consisting of colorectal surgery patients, showed greater step count following surgery compared to those who received standard care only. The intervention group also demonstrated greater step count than the active control condition, although this effect did not reach significance.

Our intervention also produced changes in psychological outcomes consistent with a shift in beliefs and perceptions of post-operative ERAS behaviours. Intervention participants had more positive perceptions of recovery at post-surgery and found mobilisation less difficult than control participants. Intervention participants also had decreased traditional surgery recovery beliefs compared to control participants, and a greater understanding of the value of being active at follow-up in comparison to the active control condition. Finally, the intervention made participants less anxious at follow-up about eating and drinking a healthy diet, as compared to both the active control and control conditions.

Overall, these findings provide initial evidence for the intervention to improve adherence to early mobilisation. It may be that seeing the physiological processes of early mobilisation provides a link between the information and behaviour, as compared to standard care or only receiving this information verbally. These results align with visualisation theory which suggests that visual information
has increased salience, is easier to understand (Brotherstone et al., 2006), and therefore can increase intentions to change behaviour (B. Williams et al., 2012).

As highlighted above, previous studies with ERAS patients have relied upon one-on-one staff-directed methods to increase adherence to mobilisation (Castelino et al., 2016). To the authors’ knowledge, this is the first intervention with ERAS surgery patients that has not used staff-direction and monitoring to increase adherence to early mobilisation. These findings suggest that this brief intervention may be useful in encouraging patients to self-manage their mobilisation effectively.

The changes in psychological outcomes also demonstrate a shift in mindset that would promote adherence and support the objective data. It has been suggested that changing traditional recovery beliefs can be challenging (Pearsall et al., 2015). If traditional recovery beliefs are associated with hesitations to mobilise, simply instructing a patient to be active will likely be ineffective. This intervention provides an example of how visualisation can modify these beliefs.

No previous visualisation studies have reported objective improvements in a health behaviour other than adherence to medicine. A similar animated intervention successfully improved seven week self-reported exercise in patients recovering from acute coronary syndrome (Jones et al., 2016). Our findings provide initial objective evidence that visualisation can improve post-operative mobilisation, a behaviour important to recovery from any surgery.

Furthermore, the intervention group did demonstrate a nearly two-fold greater average daily step count than active control participants. This is an important finding, as previous visualisation interventions have only compared receiving visualisation with standard care. The differences between the intervention and active control group in step count and understanding of mobilisation suggest that visual information appears to provide an important, additive effect upon outcomes. This is the first study to demonstrate the utility of visual imagery compared to providing verbal information only.

There are strengths of the current study and findings presented. First, the study used a randomised controlled design. The primary outcome was assessed using an objective, continuous, non-invasive measure of physical activity, which has been a limitation of previous ERAS research (Abeles et al., 2017). Nearly all studies included in a recent review of post-operative mobilisation (Castelino et al., 2016) assessed outcomes such as complications and length of stay, which are not direct measures of adherence to mobilisation. Furthermore, mobilisation was assessed not only in-hospital, but also once discharged. This provides an indication of how participants’ self-managed their
recovery behaviour in the home environment. Finally, another strength of the study is the use of a three-arm trial and an active control group, to ascertain the additive effects of visual information in comparison to receiving the same information verbally.

This intervention has high clinical applicability to be incorporated into post-surgical care. The intervention is not resource-intensive, and is brief and portable. Any staff member could deliver the presentation on a computer tablet at the patients’ bedside. This could be useful before initial mobilisation. The intervention seems particularly worthwhile if it can increase patient self-management of their mobility without additional staff input. The intervention could also be utilised by ERAS nurse specialists as part of the preoperative education materials provided during surgical pre-admission.

Limitations of the study findings should also be taken into consideration. First, although all participants wore our trackers, data was not retrievable for over 40% of our sample. This issue was uncontrollable as the company suddenly removed their online servers and application preventing access to data received later in the recruitment period. This had clear implications for statistical power and ability to detect significant results. Regardless, the significance found provides initial evidence with a reduced sample size that the intervention appears efficacious in objectively increasing adherence to early mobilisation.

A related limitation is that step count data was only available from colorectal surgery patients. As discussed above, there are clinical and demographic differences between the two samples, meaning that results cannot be generalised to gynaecological oncology patients. It is uncertain whether the intervention would also have been effective in this group. The psychological outcomes, however, do suggest that the intervention is effective in improving perceptions of ERAS behaviours and traditional surgery beliefs for both patient groups.

Another important consideration is that simply wearing a fitness tracker can influence patient behaviour (Low et al., 2018). Attempts to limit this influence included selecting a fitness tracker without numerical display of step count. Step count average was only visible around the perimeter of the tracker face by pushing a button. Participants were not informed about this function and were instructed not to push any buttons on the tracker. Furthermore, study participants in all groups wore trackers to account for any influence upon mobilisation.

Finally, there was a significant difference between groups in length of hospital stay, where the control group had a significantly longer stay than the active control group. This could be due to
differences in surgical procedures, although there were no significant differences between groups. However, it is important to consider that longer admission time may have affected ability to mobilise following surgery in the control group. Regardless, there were no differences in length of hospital stay between the intervention and active control group, but there was still a near two-fold increase in step count between the two conditions.

Future research should include replication of our findings within a larger trial. The same presentation could be used with other ERAS patients or any surgery patients who would benefit from increasing early mobilisation. Future research should also attempt to understand the underlying mechanisms of visualisation. Although the intervention increased understanding of early mobilisation, these changes did not mediate the effects of the intervention upon step count. Therefore, a clear area for future research is to examine the mediators and moderators of these effects, as this may inform intervention design to increase effects even further. This brief intervention, however, provides initial promise of a new strategy for promoting patient self-management to post-surgery mobilisation.
Chapter Eight

Discussion

Overview
The thesis presents empirical work investigating the efficacy of visualisation as an intervention to improve perceptions of illness and treatment, and promote adherence to health behaviours. Accurately understanding medical advice is essential for ensuring adaptive health behaviours, such as adherence to treatment and patient self-management. Patients, however, can fail to gain an adequate understanding of medical information due to a number of factors that are inherent to the clinical context and the nature of seeking medical help. Finding methods to communicate information that provide a fit between the illness ‘problem’ and treatment could promote understanding and additionally improve health behaviours.

Theoretical work suggests that visual health information can increase patient understanding and memory for health advice, while also enhancing motivation to adhere by providing an insight into otherwise intangible and invisible biological processes. Visualisation interventions, which use visual health information to portray internal bodily processes of disease and treatment, may be a novel approach for improving patient behaviours such as adherence. The few existing visualisation interventions suggest efficacy in improving perceptions of treatment and illness, and preliminary evidence of increased adherence to health-promoting behaviours.

The limited evidence demonstrating the use of visual health information in healthcare means there are significant gaps in the current understanding of visualisation as an intervention technique. First, no study has investigated whether there are distinctions in how different visual formats can change perceptions of illness and treatment. Second, more substantial evidence is needed regarding the ability of visualisation to change health behaviours. Finally, we are yet to understand how visualisation interventions can be effectively applied to patients across different healthcare trajectories (i.e. acute versus chronic conditions) to influence behaviour change.

The thesis had several aims to address these limitations within the current literature. A more general aim of this thesis was to broaden understanding of visualisation as an intervention technique, by examining the use of different visualisation tools across different patient populations. This included investigating whether types of visualisation formats differ in their effects upon perceptions of illness and
treatment. This thesis also aimed to provide insight into whether visualisation could be an effective intervention technique to improve objective health behaviours and clinical outcomes.

This final chapter consolidates the conclusions drawn from the work presented within this thesis. First, key findings of the four empirical studies are summarised. The contributions of findings are then integrated into the existing visualisation literature. Study limitations are then considered, followed by strengths and clinical implications of the current research. Finally, some directions for future research are suggested.

**Summary of Study findings**

Four studies were conducted in order to investigate the aims of this thesis. The first two studies investigated methodological and assessment strategies for delivering visual health information. Chapter Three reports the development of a new questionnaire, the Health Visual Information Preference Scale (Health VIPS) (Jones et al., 2018c). This manuscript details the development and use of this brief 9-item scale for assessing preferences for visual health information within three distinct samples: a sample of undergraduate university students, a sample of acute surgical inpatients, and a sample of patients from an outpatient service. This scale demonstrated good psychometric properties and was associated with health information preferences. Overall, scores on this scale suggested a general community preference for visual health information.

The study in Chapter Four investigated how differences in visualisation format may effect changes in perceptions and understanding. Specifically, this randomised controlled trial (RCT) investigated whether physical (3-D printed bone models) or virtual (animations) visualisation was most effective in improving perceptions of osteoporosis and treatment beliefs in an at-risk population of older women (Jones et al., 2017). This study found that both formats were equally effective in improving illness perceptions and treatment beliefs. Both visualisation formats improved consequence beliefs about osteoporosis, personal and treatment control beliefs, and improved understanding of osteoporosis. Both visualisation tools also increased treatment necessity beliefs and motivation to take treatment (if needed), while decreasing timeline and concern beliefs. These results suggested that visualisation can be presented in different formats and be equally effective in modifying illness beliefs and treatment motivation.

The second part of the thesis presented three manuscripts, including two randomised controlled intervention studies. Chapter Five includes an editorial manuscript that defines a new concept of active visualisation (Jones & Petrie, 2017). This manuscript also describes the methodology
of a new active visualisation device for improving adherence to antiretroviral therapy (ART) in patients living with HIV infection. This tool is a physical demonstration that represents the effects of adherence and non-adherence on the replication of HIV (i.e. HIV viral load). Chapter Six reports the findings from a RCT using this active visualisation device to improve adherence to ART in non-adherent patients living with HIV in South Africa (Jones et al., 2018a). Participants who saw this brief intervention had a clinically significant reduction in HIV viral load at eight month follow-up, compared to standard care control participants. These results suggest that this brief, active visualisation tool could be used to improve adherence to ART in a targeted group of non-adherent patients. These findings also provide evidence for the utility of visualisation in improving an objective clinical marker of adherence.

Chapter Seven reports the findings from another RCT investigating whether animated visualisation could improve adherence to early mobilisation in patients undergoing colorectal and gynaecological oncology surgeries (Jones et al., 2018b). This intervention aimed to increase patient understanding regarding the purpose of post-operative mobilisation following surgery. Animations displayed on a computer tablet depicted how internal bodily processes occurring during post-operative mobilisation can accelerate recovery and reduce complications. Participants in the intervention group were compared with a standard care group and an active control group (who received verbal information only). Available data from colorectal patients revealed a significantly higher average step count in the intervention group compared to the standard care control group, from day 1 post-surgery to seven days following discharge. Intervention participants also had nearly twice as many average steps per day as active control participants, however, this difference was not statistically significant. Across the entire sample, intervention patients reported decreased traditional surgery beliefs (i.e. decreased beliefs favouring bed rest, increased hospital stay, and continuation of IV fluids) from baseline to follow-up, improvements in perceptions of recovery behaviours, and less difficulty when mobilising. These results indicate that the intervention could promote post-surgery mobilisation and change maladaptive beliefs about post-operative recovery behaviours. The intervention also demonstrated that visual information appears to have an additive effect in changing beliefs about behaviour, compared to receiving verbal information only.

Integration into Broader Literature

This thesis provides two main contributions to the existing literature. First, this thesis provides further evidence for the effectiveness of visualisation as a means for delivering health information. This includes some important considerations to inform the design of future visualisation tools. Second, the
randomised controlled intervention trials presented in this thesis demonstrate how visualisation can be applied in healthcare to improve objective health outcomes for patients. In the following section, these contributions are considered and integrated into the existing literature.

The first major contribution of this work is increased evidence for the effectiveness of visualisation in delivering health information. Across studies, visualisation tools improved understanding and perceptions of the demonstrated treatments (Jones et al., 2017; Jones et al., 2018b), and increased motivations to adhere to treatment (Jones et al., 2017). These findings are concordant with previous visualisation research which has also established the capacity of visualisation to modify and improve illness perceptions and treatment beliefs (Jones et al., 2016; Karamanidou et al., 2008; Perera et al., 2014; Stephens et al., 2016). These findings also support visual health theory which suggests that visual information can transform abstract concepts of illness into concrete representations of disease or dysfunctional physiological processes (B. Williams et al., 2012). These visual models of illness will then influence a patient’s perceptions and motivations. Taken together, these findings provide efficacy for the use of visualisation models to demonstrate information about disease and treatment across different chronic illnesses (Jones et al., 2018b), but also with populations at risk of developing disease (Jones et al., 2017).

Another contribution to the literature is the development of a scale to identify individuals with greater preferences for receiving visual health information (Jones et al., 2018c). No scale existed to assess differences in preferences for health information among patients, and to identify individuals who may prefer supplementary visual information. The Health Visual Information Preference Scale (Health VIPS) developed in this research has considerable clinical utility. This scale could be utilised in healthcare consultations to screen patients for health information preferences, but could also be used to target visualisation interventions to those with greater preferences for information presented in this format.

Importantly, the empirical work presented here can inform the design of future visualisation tools. Chapter Four includes the first study to compare the effectiveness of different formats of visualisation. This study found that both physical and virtual formats of visualisation appear equally effective in changing perceptions of illness and treatment (Jones et al., 2017). Previous work has only tested a single visualisation tool against a standard care control group. This finding suggests that visualisation can be effective, regardless of format. Furthermore, this study also reveals that
visualisation is effective in changing perceptions of illness and treatment, even within an at-risk, treatment naive group.

The findings presented in this thesis also suggest that content, as opposed to format, is the most imperative consideration when designing visualisation tools. Chapter Two highlighted that static, 2-dimensional, personalised feedback imaging is limited by being unable to provide a comprehensive representation of both illness and treatment. Presenting a health threat without providing information on how to reduce that threat is unlikely to successfully change behaviour (Leventhal et al., 2003). Visualisation instead focuses on providing a link between a treatment and how this helps to minimise or manage a health problem. The studies presented in this thesis demonstrate the importance of providing a framework around visual imagery, and considering how best to increase patient understanding of the context of treatment.

In Chapter Five, the concept of ‘Active Visualisation’ was presented as a sub-category of visualisation. Active visualisation tools use dynamic representations of illness and treatment processes to provide a more comprehensive message regarding implications for health. This new theoretical concept can inform future visualisation design. Past examples have demonstrated that visualisation is most effective in changing behaviour when patients can see a connection between a behaviour and the resulting physiological implications (Jones et al., 2016; Perera et al., 2014). The studies presented in Chapters Six and Seven both utilised active visualisation and demonstrated how effective this form of visualisation can be in improving patient outcomes.

This thesis also provides evidence for the added benefits of visualisation compared to traditional forms of health communication. Chapter Seven described the first study to include a third comparative group to the intervention versus control design used in previous visualisation research. An additional active control group received the same verbal information as the intervention group, but with no animations. Therefore, the only difference between groups was the supplementary active visualisation material. The intervention group demonstrated improved understanding of the purpose of early mobilisation compared to the active control group. Intervention participants also displayed a nearly two-fold greater average step count following surgery in comparison to the active control group, although this finding did not reach significance. Furthermore, the study discussed in Chapter Six also demonstrated that the visualisation intervention was more effective in improving adherence to ART than receiving standard adherence counselling. Adherence counselling includes similar information about treatment efficacy and the importance of consistent adherence, however, it appears that
visualisation provided an additive effect in improving adherence above receiving this standard adherence information. These findings suggest that dynamic visual imagery is more effective than receiving verbal information only and has an additive effect in improving health outcomes.

The second main contribution of the work presented is support for visualisation as an intervention technique to improve clinical and health outcomes. Chapters Six and Seven report two intervention studies of RCTs demonstrating improvements in the visualisation intervention groups in objective markers of health (Jones et al., 2018a) and health behaviours (Jones et al., 2018b). These studies align with previous preliminary evidence that visualisation tools can improve adherence to health behaviours (Jones et al., 2016; Perera et al., 2014; Stephens et al., 2016). However, the two trials presented in Chapters Six and Seven of this thesis are the largest trials to demonstrate objective improvements from visualisation interventions.

Processing theories provide insight into how visual health information could result in behaviour change. This theoretical work would suggest that the increased saliency, motivational impact, and enhanced encoding of visual information into memory (Brotherstone et al., 2006; Mintzer & Snodgrass, 1999) may persist and influence changes in patient behaviour. The Elaborative Likelihood Model (Petty et al., 2009) might suggest that visual information is elaborated at a higher level, which maintains changes in attitudes that are sustained in memory, and are more likely to affect behaviour change long term. The saliency of the visualisation tools used within these studies appears to have not only modified attitudes towards illness and treatment, but to have also increased health-promoting behaviours.

Importantly, these results suggest the efficacy of visualisation as more than merely an educational strategy for improving the delivery of health information. Instead, visualisation can be considered an effective intervention that can produce valuable improvements in patient adherence. Non-adherence to treatment and health behaviours remains an enduring issue for modern healthcare (Clyne et al., 2016; Kvarnstrom, Airaksinen, & Liira, 2018). Establishing interventions that can effectively improve adherence remains a prevailing goal for health psychology research. While theory has suggested the superiority of visual health information in enhancing patient understanding, these findings provide a novel contribution to the literature by demonstrating how visualisation interventions can improve adherence and objective health behaviours. Furthermore, this thesis also provides evidence that visualisation can be applied to health behaviours across the healthcare spectrum,
including adherence to a chronic medication or adherence to a more acute behaviour of post-operative mobilisation.

**Limitations of Study Findings**

There are important limitations which should be acknowledged when interpreting these results. This section considers general limitations that apply across the studies reported. First, change in perceptions, understanding, and motivation are outcomes measured within visualisation studies. The measurement of these concepts relies upon self-report, which can be susceptible to sources of bias. Most relevant to the current research would be social desirability or socially-favourable responding. In intervention studies, patients can be motivated to appease those delivering the information rather than providing their true evaluations (Nolte, Elsworth, & Osborne, 2013). This may be especially relevant when participants receive psychoeducation and are asked to report on changes in their understanding of that information, where the socially desirable response would be to state an improvement. Regardless, there are limited alternative methods to measure psychological constructs such as perceptions within the clinical setting, and self-report allows simple measurement of changes in these outcomes. Furthermore, there is evidence that social desirability does not mediate evaluations in other chronic disease management programmes (Nolte et al., 2013).

Second, both intervention trials had limited primary outcome data available which diminished power to detect significant differences. In Chapter Six, this was reduced blood test data to assess change in HIV viral load (Jones et al., 2018a). Distinct factors of the clinical context may have affected the availability of data, such as poor clinical administration or patients failing to attend routine clinical appointments to provide blood samples. How the intervention might have affected participants without data available is therefore unknown. This limitation could be avoided by requesting independent blood tests as part of study participation instead of relying upon data collected from routine care. This would, however, introduce a potential confounding factor as requesting a blood test would heighten awareness of monitoring and could result in behaviour changes conflated with intervention effects.

The study in Chapter Seven also had limited step count data available from the fitness trackers. In this case, the absence of data was unavoidable due to the company removing access to data and online servers as a result of undergoing liquidation. Data was available for colorectal surgery patients only which limited the generalisability of study findings to both patient groups. Despite these limitations, however, the clinical and statistical significance of these results still provided initial evidence that these interventions appear effective in improving patient outcomes.
Another limitation is that the research presented here does not provide insight into lasting, long-term effects of visualisation interventions. The intervention in Chapter Six improved adherence to ART as measured through plasma viral load. Blood test data was used to measure viral load at approximately eight months following the intervention, although there was considerable variability in the time of this assessment point. HIV is a chronic illness, meaning interventions to improve adherence need to demonstrate long-term effectiveness. Indeed previous HIV research has highlighted that shorter follow-ups prevent an understanding of lasting intervention efficacy (Chaiyachati et al., 2014). The results of this intervention therefore provide only moderate insight into how the self-management of ART can be improved.

Finally, although the RCTs presented provide evidence of changes in objective health outcomes, we are yet to understand the mechanisms driving these improvements. Most visualisation tools resulted in changes in understanding and motivation after seeing the devices (Jones et al., 2017; Jones et al., 2018b). However, the mediation analysis in Chapter Seven found that change in understanding did not mediate improved step count in the intervention group. Furthermore, although the intervention group in Chapter Six had improved viral load and demonstrated an understanding of the device in qualitative feedback, there were no changes in illness perceptions or motivation from before to after seeing the intervention. Perhaps using a single item to measure understanding is not sensitive enough to accurately detect change in all contexts. Alternatively, other constructs may need to be considered as potential mediators of effects, such as memory or risk perceptions. Addressing this limitation in future work could inform intervention design and improve the effectiveness of future visualisation tools.

**Strengths and Clinical Implications**

Despite the limitations highlighted above, there are considerable strengths of the research included within this thesis. First, the intervention studies utilised randomised controlled designs to assess the efficacy of visualisation tools. Randomised controlled designs are the most rigorous to allow inferences to be drawn between the intervention and outcomes (Kendall, 2003). Second, the two intervention studies used objective primary outcome measures. This removes bias inherent to self-reported data, and allows greater understanding of effects upon health behaviours and subsequent clinical outcomes.

This thesis also includes the first three-arm visualisation trial, comparing the intervention and standard care groups with an active control group (Jones et al., 2018b). Although previous visualisation work has used an active control group (e.g. Perera et al., 2014), this study compared the visual
information to an alternative form of intervention (medication reminders). The active control group in the study described in Chapter Seven matched the intervention in amount of contact, length of session, and verbal information provided (the only difference being the animations used in the intervention group). The inclusion of an active control group allowed the non-specific effects of receiving the intervention to be controlled for, including time, attention, and therapeutic alliance. Non-specific effects can contaminate changes resulting from intervention contents and may account for most of the effects in psychological research (Baskin, Tierney, Minami, & Wampold, 2003), including psychoeducational interventions (Donovan, Kwekkeboom, Rosenzweig, & Ward, 2009). Incorporating an active control group in this study design therefore allowed greater understanding of the active, additive components of visualisation.

Lastly, another strength of the research presented in this thesis is the use of distinct visualisation designs across diverse illness populations. The interventions developed in this thesis used a ‘bottom-up’ design approach, where the target population and context for delivery was considered. This is evident when examining the differences between the tools used in Chapters Six and Seven. Using a computer tablet to display animations may not be a highly-feasible delivery method for an intervention in low-resource communities in South Africa. Instead, a physical demonstration that did not rely on technological accessibility was more practical in this context. In contrast, animations were more suited to the setting of the study in Chapter Seven, where a physical demonstration would not be viable to deliver at a patients’ bedside in hospital. These examples demonstrate the importance of developing tools specific to the health context where they will be delivered. These tools therefore have high ecological validity to be incorporated into standard care within these contexts.

There are clear clinical implications of the research studies described within this thesis, as visualisation interventions are highly applicable to the clinical setting. The interventions used within this research were brief, one-off sessions, successfully delivered by a research assistant or PhD student. This suggests that these devices could be delivered to patients by healthcare professionals from any clinical background, and not only health psychologists. These interventions would not be intensive in regards to resources or time if incorporated into standard care. In addition to using visualisation tools for interventions, clinicians could also utilise these tools as supplementary material to accompany the verbal delivery of health information during consultations. Visualisation tools could also be used more informally as education materials in clinics or on hospital wards by medical staff, instead of outdated
videos or pamphlets. Interacting with these innovative materials may also improve patient engagement and learning compared to other health materials.

Visualisation tools that utilise technology such as computer tablets are also portable and could be easily disseminated to patients. Mobile technology is becoming increasingly incorporated into medical care (Ventola, 2014). Many clinical settings may therefore already have mobile devices that could be used to deliver visualisation interventions. Alternatively, the physical visualisation models used in the studies of Chapters Four and Six do not rely upon technology for delivery, and are suitable for low-resource settings without technological infrastructure. These physical visualisation tools may be especially useful for delivering information to patients in rural or remote communities. Visualisation interventions can therefore be delivered effectively irrespective of the clinical limitations of healthcare settings.

**Future Directions**

The research presented within this thesis adds to a growing body of literature assessing the utility of visualisation interventions. The results provide support for continued investigation into other applications of visualisation, as there are remaining limitations yet to be understood. Future work should investigate the potential mechanisms of visualisation upon health behaviours. As highlighted above, this would build upon the research presented in this thesis by ascertaining whether visualisation effects upon behaviour are mediated by concepts theorised within the visual health literature, such as changes in understanding, memory, risk perception, and motivation. Understanding the mechanisms of these effects could inform intervention design to maximise the effectiveness of visualisation tools and devices.

Another consideration for future work would be to investigate whether different visualisation mediums are equally effective in different illness groups. The study described in Chapter Four demonstrated that physical and virtual visualisation mediums were equally effective in improving illness perceptions and treatment motivation in individuals at risk of developing a health condition. However, we are yet to understand whether different visualisation mediums are equally effective in changing behaviour of patients with a diagnosis, and particularly those with chronic long-term illness. Compared to newly-diagnosed or at-risk individuals, patients with a long-term chronic illness are likely to be more familiar with health information, which may affect the saliency of different formats of visualisation. Future work could therefore attempt to understand whether there are any distinct differences in visualisation format effectiveness across different illness populations and trajectories.
Future work should also consider using increased follow-up assessment periods to establish the maintenance of visualisation effects following intervention. This is particularly pertinent to understanding adherence to treatment in chronic illnesses. Medication which requires long term, daily management such as ART requires interventions that will maintain behaviour change and prevent disease progression.

A related consideration for future work is to investigate dose-response effects of visualisation tools. A strength of visualisation interventions is their delivery in a brief, one-off session. Providing a follow-up ‘dose’ of the intervention, however, could boost effects or maintain behaviour change for a longer period. Intervention effects could also be enhanced by integrating visualisation into mobile technology and smartphone applications. Software applications provide on-demand access and could include real-time feedback of how behaviour is affecting bodily processes (e.g. Perera et al., 2014). Future research should investigate the feasibility and effects of utilising these formats.

Visualisation tools could be developed for different patient groups, particularly for chronic illnesses that require long term self-management. As the growing prevalence of chronic disease continues to increase burden upon healthcare, there will be substantial need for low-resource strategies which can improve patient self-care. Visualisation may be particularly effective for improving adherence in other asymptomatic conditions, such as bisphosphonate treatment for osteoporosis, or anti-hypertensives and statin medication for cardiovascular disease. Future research might also explore whether visualisation could integrate both representations of medication efficacy and representations of the physiological effects of other health behaviours (e.g. diet and exercise). Demonstrating how both pharmacological treatment and lifestyle behaviours influence health outcomes could be particularly useful for illnesses such as Type 2 diabetes or cardiovascular diseases. Research could also examine if visualisation tools are useful for targeted populations with reduced health literacy, such as children and adolescents with chronic illnesses.

Future research should consider designing visualisation for newly-diagnosed or at-risk populations, to deduce if visualisation can have preventative effects. In this sense, visualisation could help patients to understand the link between behaviours and the risk of illness, to prevent illness progression. For example, the active visualisation device used in Chapter Six could be used with patients initiating ART to convey the importance of consistent adherence from the outset of treatment. Targeting prevention, however, would be the most efficient intervention method for healthcare. Chapter Seven demonstrated that visualisation can improve adherence to a lifestyle behaviour, in the form of
early mobilisation following surgery. Future work could investigate whether visualisation can be used to prevent lifestyle diseases in at-risk individuals. For example, visualisation demonstrating the physiological link between exercise, serum lipid levels, and cardiovascular health, could explain the development of conditions such as atherosclerosis, hypertension, stroke, and cardiac disease. Research could also examine the efficacy of visualisation for describing the purpose and mode-of-action of preventative medications to patients. The manuscript in Chapter Five described how the active visualisation device could be used to demonstrate adherence to pre-exposure prophylaxis to prevent HIV infection. These are just some examples of how future work could investigate the utility of visualisation preventatively to reduce the incidence of chronic disease. It is clear that providing a visual link between pathology and health behaviours could have many applications across the spectrum of healthcare and health promotion, including significant implications for the individual and for public health more widely. Visualisation represents an innovative health tool which could include both social and economic benefits for healthcare.

Conclusion
The transaction of health information between clinicians and patients can be affected by many aspects of the clinical environment and individual patient factors. Poor communication results in dysfunctional health behaviours and problematic health outcomes. Methods which increase the effectiveness of delivering health information and produce changes in clinical outcomes deserve investigation through research. Although substantial theoretical support suggested the superiority of visual representations of health information, minimal empirical studies of visualisation had been conducted within the field of health psychology. In particular, there was a lack of understanding in the literature regarding how these visual interventions may change behaviour and improve clinical outcomes.

The work presented within this thesis aimed to extend previous work and provide greater evidence for the utility of visualisation in improving patient health outcomes. The two intervention studies presented here demonstrate that visualisation can improve understanding and perceptions of illness, but also adherence to treatment across different illness populations and contexts. The empirical work also provided insights regarding how we might assess preferences for visual information and methodological considerations for the design of visualisation intervention tools. The conclusions drawn from these studies provide significant contributions to the current literature and demonstrate a novel intervention strategy with high clinical applicability. While undoubtedly, further work is needed to understand the full scope of applications for visualisation, evidence suggests that incorporating
visualisation into modern healthcare can enhance the effectiveness and delivery of health information, and produce significant benefit in patient outcomes.
References


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Cambridge, B. (2007). The role of adherence to a


Appendices

Appendix A: The Health Visual Information Preference Scale (Health VIPS)

This scale is designed to assess how to best provide health information to you. People differ in the way they prefer to have health information presented, and this scale is designed to help us match information to your preferred format.

Please circle the number for each item that best reflects your view:

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Being shown a scan or an image of the inside of my body would help my understanding of a medical condition.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>I often find that medical information that uses words, but no pictures, is harder to follow.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>When it comes to understanding health information, I find an image is worth a thousand words.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>I am the sort of person who doesn’t need visual aids (e.g. pictures, diagrams) to understand medical information.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>If I were newly diagnosed with an illness, seeing animations or images would help me to create a picture of what the illness “looks like”.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>If I needed to have surgery, a visual illustration of the operation would help me to better understand the procedure.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>I prefer a straightforward verbal or written explanation of an illness to one that includes illustrations.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>If I was prescribed a new medicine, being shown a visual demonstration of how the medicine worked inside the body would be helpful for my understanding.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>When my doctor gives me health information, I prefer a simply-written document rather than one with added pictures or diagrams.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
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</tbody>
</table>
Appendix B: Preference test used in Jones et al. (2018c)

Q6. Below are two formats of the same information, using an example of insulin injections.

By having a brief look and without reading the text, please tick which form would most suit your preferences for receiving health information:

**OPTION A**
Please tick this box if prefer below

**OPTION B**
Please tick this box if prefer below

How to inject your insulin dose

1. Keeping the pen straight, insert the needle into your skin

2. Using your thumb, press the injection button all the way down

3. Then slowly count to 10. Counting to 10 will make sure that you get your full insulin dose

4. After counting a full 10 seconds, release the button and remove the needle from your skin

How to inject your insulin dose

1. [Diagram]

2. [Diagram]

3. [Diagram]
**Intervention Script PART A: Illness**

- I am going to discuss with you some information about osteoporosis or thin bones.

- Osteoporosis is a common problem for individuals of your age group.
  - It is a skeletal disorder where the amount and strength of bone is reduced.
  - It results in thin and brittle bones that can break or fracture more easily.

- Our bones are made up of living cells and tissues.
  - These cells are in a constant cycle of bone death and bone growth, also known as bone resorption and bone formation.

- During the initial process of bone loss, cells called osteoclasts clean up and remove old bone tissue.
  - Cells called osteoblasts then follow up and replace the old bone with new bone tissue.
  - This process of bone loss and growth is happening continuously within our bodies.
  - The remodelling of our bone is what helps to maintain the integrity of our skeleton.

- As our body ages, the cycle of bone growth becomes imbalanced.
  - The osteoclast cells which eat up the old bone begin to work more effectively than the osteoblast cells which create new bone.

- The body therefore begins to lose more bone than it can replace.
  - This decreases our bone density and strength, and increases our risk of fracture.

- Fractures caused by osteoporosis become increasingly common with age.
  - Approximately one in two women over the age of 50, and one in five men over the age of 50 will experience a fracture caused by osteoporosis during their lifetime.
  - The occurrence of an osteoporotic fracture can appear rather sudden because the process of increased bone loss and osteoporosis tends to occur ‘silently’ for the majority of sufferers – this means that their bones may begin to become weak and thin without any obvious symptoms or warning signs.

- There are several risk factors for developing osteoporosis.
  - Firstly, as we age, our bones naturally become weaker over time.
  - Individuals with a family history of fracture are also at a higher risk.
  - In NZ, there is a higher prevalence of hip fracture in individuals from European backgrounds in comparison to other ethnic groups.
    - However, this could be due to differences in lifestyle which contribute to health (e.g. diet, body mass).
  - Changes in hormone levels caused by thyroid conditions or menopause can also affect bone growth.
    - Oestrogen helps to control the cycle of bone growth within our bodies.
    - However, during menopause, the body produces less oestrogen.
    - The decreased oestrogen allows the cells that eat up old bone to work more effectively, which causes increased bone loss.
Here are two models of healthy versus osteoporotic bone.
These models were made using CT scans of bone samples from the hips of a healthy and an osteoporotic patient.

[If viewing physical demonstration: These models are made out of plastic and were created using a 3-dimensional printer]

You can see that there are two different layers which make up the bone.
The outer ‘shell’ layer which surrounds the bone is called cortical bone. Our leg and arm bones are made up almost entirely of cortical bone.
The inner part which looks like honeycomb is called trabecular bone. We have a lot of trabecular bone in our spine and hips.

Let’s take a closer look at the healthy bone of a patient who does not have osteoporosis.
You can see that this bone has no large gaps or holes and it appears rather solid.
The inner ‘honeycomb’ trabecular bone has lots of connections and the outer, cortical shell is quite thick.

Comparing the healthy bone we just looked at to the osteoporotic bone, you can see that the osteoporotic bone has a lot more holes and gaps within its structure.

Taking a closer look at the osteoporotic bone, you can see that the ‘honeycomb’, inner bone has a lot more holes and gaps than the healthy bone.
The surrounding layer of cortical bone is also thinner.
Overall, this bone looks a lot more brittle and fragile in comparison.
So why do osteoporotic bones break more easily?

If the same amount of force is applied to healthy versus osteoporotic bones, the osteoporotic bone experiences a lot more stress.
There is more pressure applied to the areas of large gaps and holes because the osteoporotic bone is weaker.
This increased pressure indicates that the osteoporotic bone would be a lot more susceptible to a fracture compared to the stronger, healthy bone.

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Intervention Script PART B: Treatment

There is an effective form of treatment available for individuals diagnosed with osteoporosis.
This treatment can help to alleviate symptoms, reduce fracture risk, and help to maintain patients’ physical functioning and abilities.

The most effective treatment is a medication called bisphosphonate.
Bisphosphonate medication can be administered using two different methods – either a drip infusion or a pill.
The drip infusion occurs once a year and the tablet is taken weekly.

Bisphosphonates help to manage osteoporosis by rebalancing the altered cycle of bone growth.
As I mentioned previously, the cells which eat up old bone work more efficiently than the cells which create new bone in patients with osteoporosis.

Bisphosphonates reduce this loss of bone by decreasing the activity of the (red) osteoclast cells, which slows bone loss.
By slowing the cells responsible for bone loss, the cells which build bone are able to work more effectively.
Bisphosphonates therefore rebalance the cycle of bone growth and help to maintain better bone health.

Bisphosphonate treatment can therefore help bones to become more solid and strong, which may reduce fracture risk and improve patient’s functioning and lifestyle.
### DAY 1
- As you know, the virus is always trying to grow inside of your body.
- This pink colour represents the virus.
- Watch what happens when you take your HIV medicine.
- As you can see, when the medicine is inside of the body, the water slowly starts to become less pink, and eventually it turns to clear.
- This clear colour shows that by taking your medication, your HIV is under control.

### DAY 2
- Now let’s see what happens the next day.
- On day 2, although you took your medicine yesterday on day 1, the virus is still in your body and trying to grow.
- Remember that your virus is always there because the infection cannot be reversed.
- So again, on day 2 you take your medicine.
- You can see that the same thing happens - when the medicine enters the body the liquid starts to change from pink to clear, meaning the virus is controlled and cannot grow.
- From this demonstration, you can see that you need to take your HIV medicine every single day.
- The virus is inside of your body all of the time.
- So by taking your medicine each day, you control the virus and this helps you stay healthy.
- What happens if you do forget to take your medicine for a day or two?

### DAY 3
- Here is the body on day 3, after taking medicine for the last two days.
- You can see again that the virus is still in your body, because it is always there.
- Perhaps today you forget to take your medicine.
- So on this particular day, no medicine is going into your body.
- Remember- this means that the virus will not be not controlled.

### DAY 4
- The next day, day 4, again you can see that the HIV virus is in your body.
- And again on day 4, you forget to take your medicine.
| Day 5 | Now it's day 5, and again the virus is still in your body.  
You can see that the body has become more pink which shows that your virus has been slowly growing without any medicine to control it.  
Perhaps on this day, you DO remember about your medicine and realise that you missed taking it for the past two days.  
Some people do miss a dose of their HIV medicine from time to time.  
Your body can recover from this, as long as you remember to take your next dose of medicine and then continue taking it each day again without forgetting.  
If this does happen to you, it is important to remember NOT to take all of the doses you missed.  
You should only ever take 1 pill per day.  
Your body can only handle a certain amount of the medicine, so taking more than 1 pill per day will not help, even if you missed more than one dose.  
So let's see how your body recovers from a couple of missed doses.  
So remember it's day 5, and today you remember that you need to take your HIV medicine after forgetting to for the past couple of days.  
You can see that today when we add the medicine, it makes the water become a bit lighter but it does not change back to clear.  
Because you forgot to take your medicine for two days, the amount of virus in your body was able to grow a small amount.  
Day 6, the virus is still in your body.  
Today, again you remember about your HIV medicine and you take a dose.  
You can see that the same as yesterday, the medicine makes the liquid become lighter but still not completely clear.  
The next day is day 7, and again the virus is there in your body as always.  
And again, today you remember to take your daily dose of HIV medication.  
You can see that eventually, after remembering to take your medicine each day, the body does change back to clear.  
This shows that your body can get your HIV back under control, if you remember to keep taking your medicine after missing only one or two doses.  
So if you do miss a dose, it is important to remember to keep taking your pills every day after, to keep your virus controlled and stop you from becoming sick.  
What will make you sick, is if you forget to take your HIV medicine all of the time.  
Now let's see what happens inside your body if you always forget to take your medicine.  
So, day 8 - the virus is there.  
And no medicine is taken.  
Day 9 - the virus again is inside your body.  
And again, you forget to take your medicine.  
The same thing happens again and again and you forget to take your medicines for all of these days.  
You can see that after no medication has been taken for so long, the water has become very pink.  
This is because the virus has been able to grow inside of your body.  
Perhaps you eventually remember to take your medicine after missing doses for all of this time.  
See what happens now. |
• This time, even though you remember to take your medicine, the liquid does not change at all and it stays a deep pink colour.
• So this time the medicine was not able to control the virus.
• When medication is not taken each day the virus grows inside your body.
• If this happens, the medicine cannot reverse this.
• Your medicine will stop working and won’t be able to keep you healthy.
• This isn’t good because there are not many different medicines that can treat HIV.

• So you can see how important it is that you take your HIV medicine every single day, all of the time.
• If you do miss one dose, remember to continue taking your medicine again each day so that your body can recover and you don’t become sicker.
• But if you forget to take your HIV medicine all of the time, the virus can grow inside your body.
• This means that the medicine will stop working and you will become sick.
• Remember that you are still able to lead a healthy, normal life with an HIV infection.
• Just remember to take one dose of your medicine each day, to stop the virus from growing and keep yourself healthy.
### Script for Intervention and Active Control Groups

I’m going to show you a short presentation which provides information about some activities that you can do while you are in hospital to help your body recover faster from your surgery.

After having a procedure such as [COLORECTAL OR GYNAECOLOGICAL] surgery, there are common myths that some patients believe about what is best for their recovery:

1. That it is best to completely rest your body afterwards.
2. That being active might aggravate the body and slow down your recovery.
3. It is best to stay in hospital care for as long as possible.

However, research over the last 10 years has actually proven that following recommended guidelines to get our bodies back up and working again immediately after surgery helps to speed up recovery and reduce complications.

This includes patients like you who have had [COLORECTAL OR GYNAECOLOGICAL] surgery.

Research studies have shown that surgery patients who go through an ERAS or ‘Enhanced Recovery After Surgery’ programme, such as yourself, are discharged from hospital in half the time of a normal patient, have fewer illness-related complications, with no increased rates of being readmitted to hospital or mortality. This is why these programmes are now used worldwide to give patients the best outcomes following their surgery.

Your nurse specialist would have spoken to you at Greenlane before your procedure about certain behaviours that you need to do in the days following your surgery.

I’m going to explain why these behaviours are important by showing you how they work inside your body to help speed up your recovery.

One important behaviour that your nurse specialist would have told you about is to get your body moving again after surgery.

Movement and mobility following surgery is important because we need to stimulate our system again to get our blood flow, circulation, and breathing occurring at a healthy rate.

People often believe that the best thing to do after having surgery is to lie down and rest for as long as possible. Although it is natural to think that this might be best, research actually shows that this is false.

If you spend too much time lying down in bed, your heart does not have to work as hard, meaning your heart rate is slower than normal.

This also means that blood is moving around your body at a much slower rate.

When you lie down in bed for a long time, your blood cells begin to stick together and this can cause blood clots to form.

Too much resting can also affect our lung function. When you are lying down, your lungs do not need to work as hard, so the rate at which they expand and contract becomes much slower. If we have long periods of bed rest following surgery, this increases the risk of complications such as chest infections.

Research now shows us that getting up and moving earlier is actually best for our recovery. If we move from a lying down to a seated position, and especially when we get up and walk, our heart rate increases.

When our heart rate is higher, this increases blood flow and circulates more blood to our muscles. Better blood circulation means that vital nutrients that are essential for recovery can be easily transported to the tissues in your body.
Being active also helps our lung function to get back to normal. When we move, our body requires more oxygen. Your lungs therefore expand to allow for larger intakes of oxygen which also increases the rate of your blood circulation.

Steady exercise is therefore a crucial recovery behaviour. It allows our body to get back to working normally again, which speeds up the recovery process and reduces complications. Being mobile during recovery also helps to keep our body strong by preventing the loss of muscle and strength.

To help improve your recovery during hospital you have a plan to follow to keep your body active:

On day 1 and day 2 following surgery, you will be out of bed for 8 hours, taking regular walks around the ward and sitting up in a chair with assistance from the nursing team. Aim to take 4x 10 minute walks throughout the day.
By day 3, you may be slightly slower than normal, but you should feel you’re able to move around rather well.
Once home, it’s important to keep up this movement and gradually increase each day to improve your strength and fitness. Aim for 3 or 4 short walks a day.

Another important recovery behaviour is re-introducing food and drink.

After your surgery, eating and drinking normally again is important.

Eating and drinking allows your body to get essential nutrients that it needs to re-build its strength and help with your recovery.

When we ingest food it travels from our stomach into the small intestine. In your gut tissue, the villi absorb vital nutrients from that food and transport them into the bloodstream.

Exercise assists in this process because it increases our blood flow which helps to transport these nutrients around our body. Combining these two behaviours therefore speeds up our recovery process.

Again, you have a plan to try and reintroduce food and drink slowly as you recover from your surgery:

On days 1 and 2 following surgery, you will aim to eat some food and drink 3-4 glasses of water or a preferred drink, plus 3 high protein drinks.
By day 3, you should be eating and drinking a normal diet. You will be encouraged to drink a lot of fluid including 3 high protein drinks.
Once home, it’s important to keep up eating and drinking a healthy diet. This will continue to help the recovery process.

The key points to remember are that both getting your body up and moving again, and eating and drinking early are important behaviours to help speed up your recovery from surgery.

Both behaviours also reduce the chance of complications occurring after surgery.

Remember the staff are here to safely assist you in this journey by helping you to perform these behaviours. You may be surprised at how quickly you are eating and drinking and getting up out of bed.

Once you have been discharged, it is important to keep up these behaviours. You should continue to maintain a healthy diet, and slowly build up into regular exercise. These behaviours are important for your long-term recovery and wellbeing.

So remember, getting up and moving, and eating and drinking, are going to help you have the best recovery possible following your surgery and get you back into enjoying everyday life.
| Researcher to ask participant: | 1. When you are on the ward (in-hospital), what are some specific ways you could incorporate exercise into your activities?  
2. When you are discharged and back home, what are some specific ways can you try and incorporate daily exercise into your routine? |
Appendix F: Revised and published manuscript of Study 1

Citation
Abstract

Objective. Patients are likely to have individual preferences for learning about health, which may influence their comprehension and utilization of health information. Some patients may prefer visual health information, which can make complex health information easier to understand. Aligning health information presentation with preferences may increase understanding and improve health outcomes, yet no scale measures preferences for visual health information. Design. Two studies examined the psychometric properties of the Health Visual Information Preference Scale (Health VIPS), a new measure designed to assess preferences for visual health information. Methods. In Study 1, 103 undergraduate students and 97 patients undergoing colorectal and gynaecological oncology surgery completed the Health VIPS. Exploratory factor analyses (EFA) were conducted for both samples. Internal consistency, test–retest reliability, and validity were assessed in the student sample. In Study 2, 196 outpatients completed the Health VIPS. Confirmatory factor analysis (CFA) was performed on this sample, in addition to measures of reliability and validity. Results. In Study 1, EFA analysis suggested a two-factor structure. The Health VIPS demonstrated good internal consistency in both the student sample (α= .70 – .80) and patient sample (α= .80), and good test–retest reliability in the student sample (r= .63, p< .001). Convergent validity and discriminant validity were also established. In Study 2, the CFA confirmed a two-factor structure is the best model fit for the Health VIPS. The Health VIPS also demonstrated discriminant and convergent validity. Scale item means in all samples were positively skewed, suggesting a general preference for visual health information. Conclusions. Initial evidence suggests the Health VIPS has good psychometric properties. This scale could identify patients who would benefit from additional visual aids when receiving health information.
Introduction

Delivering health information effectively to patients is an integral component of health care utilization. The effective translation of health information from provider to patient should improve the likelihood that treatment recommendations evolve into adherence. Effective comprehension, however, can be difficult to achieve for many reasons, including factors of the clinical environment such as short consultation times and the intrusion of psychological and physical symptoms (Houts, Doak, Doak, & Loscalzo, 2006). Furthermore, physicians often overestimate patients’ abilities to comprehend the information they conveyed during a consultation (Kelly & Haidet, 2007). This becomes problematic as misunderstandings of health information impair the ability of the patient to apply recommended treatment and lifestyle changes to promote health.

One approach that may increase the comprehension and utility of health information could be matching information delivery with the patient’s preferred information format. It is likely that idiosyncrasies exist regarding how patients would prefer health information to be delivered, which could influence their health behaviours. Evidence from health risk evaluation and decision-making research indicates that different methods of presenting risk result in differing evaluations and use of that information (Peters, Dieckmann, Dixon, Hibbard, & Mertz, 2007; Schapira, Nattinger, & McAuliffe, 2006). Indeed, the framing and packaging of information, particularly when unfamiliar and complex, can influence how that information informs choice (Peters et al., 2007). The medical encounter constitutes an unfamiliar and often complex scenario for most patients, meaning the ‘packaging’ and format of health information may influence understanding and subsequent behaviour.

In the health care setting, standard verbal explanations are generally supplemented with written materials such as pamphlets, medication inserts, and other printed instructions (Ngoh & Shepherd, 1997). Written health information may be helpful for patients with the capacity to read, understand, and remember that information (Hoffmann & Worrall, 2004). However, not all patients attend well to written health materials (Webster, Weinman, & Rubin, 2017; Williams, Baker, Parker, & Nurss, 1998), especially those with lower comprehension and literacy skills (Brotherstone, Miles, Robb, Atkin, & Wardle, 2006; Kessels, 2003). Poor health literacy is common. The lay public also demonstrates difficulties in understanding medical terminology, even with terms that are commonly used within the health care context (Smith, Trevena, Nutbeam, Barratt, & McCaffery, 2008). Furthermore, research shows that patients often have only rudimentary knowledge of their anatomy and bodily processes (Weinman, Yusuf, Berks, Rayner, & Petrie, 2009). Considering these widespread
issues with health literacy, it is likely that for some patients written health information is a barrier to understanding and utilizing health information and advice.

Patients may prefer to receive visual information about illnesses and treatments, particularly those who struggle with health literacy or who are cognitively aligned to best understand visual representations of information (Houts et al., 2006; Peregrin, 2010). Visual depictions of health risk material are often preferred by patients (Edwards, 2002; Goodyear-Smith et al., 2008) and can increase both understanding and health risk perceptions (Galesic, Garcia-Retamero, & Gigerenzer, 2009; Lipkus & Hollands, 1999). Patients with both high and low literacy value the inclusion of anatomical images in health materials (Smith et al., 2008), and the ability of visual images to explain ‘invisible’ anatomical processes (Carlin, Smith, & Henwood, 2014; Devcich, Ellis, Waltham, Broadbent, & Petrie, 2014; Vilallonga et al., 2012). Visual tools and interventions have become increasingly popular methods for communicating health information to patients (Jones, Ellis, Nash, Stanfield, & Broadbent, 2016; Jones, Fernandez, Grey, & Petrie, 2017; Jones et al., 2018; Perera, Thomas, Moore, Faasse, & Petrie, 2014; Phelps, Wellings, Griffiths, Hutchinson, & Kunar, 2017; Rees et al., 2013; Stephens et al., 2016). However, it is yet unclear how many patients prefer this style of information, and whether all, or only certain, individuals respond better to information delivered this way.

Despite the likely existence of distinct preferences for health communication, to our knowledge, no measure exists to assess preference for supplementary visual health information. There is considerable research on learning styles and identifying ‘visual learners’ (Childers, Houston, & Heckler, 1985; Fleming & Mills, 1992; Kirby, Moore, & Schofield, 1988; Richardson, 1977); however, there is an important distinction to be made. Measures of learning style abilities do not assess information preferences. These measures are concerned with identifying where the responder sits in regard to different cognitive styles (e.g., visual vs. verbal learner). There is no scale to identify patients with heightened preferences for receiving health information visually. Being able to identify patients with a visual health preference could ensure that additional information is provided in this format, which may increase comprehension and adherence to recommendations.

In this paper, we report on the development of a measure identifying preferences for receiving visual health information. This measure may help to identify patients who prefer and additionally respond better to visual explanations of health material in clinical settings. We report on the psychometric properties of the Health Visual Information Preference Scale (Health VIPS). Study 1 reports the results of exploratory factor analyses (EFA) conducted with both healthy and clinical
samples, and Study 2 reports the results of a confirmatory factor analysis (CFA) completed with a sample of outpatients attending hospital medical clinics.

**Study 1 Method**

**Participants**

Two independent samples completed the Health VIPS. The healthy sample comprised 103 undergraduate students from the Faculty of Medical and Health Sciences at the University of Auckland, studying between October and December 2017. The clinical sample consisted of 97 patients undergoing elective colorectal and gynaecological oncology surgery at Auckland City Hospital between July 2017 and July 2018, who completed the Health VIPS in a questionnaire battery as part of another clinical trial. Included participants spoke English, were over 18 years of age, and had no known mobility issues (as relevant to the clinical trial).

**Procedure**

The student sample was recruited by either a cohort email sent to a stage one health psychology course, or by Facebook invite in a medical student group. Participants received no compensation for taking part in the research. Respondents completed the questionnaire electronically by following a link to the website SurveyMonkey Inc. (2017) and provided informed consent before beginning the questionnaire. Participants answered demographic questions (age, gender, highest level of education), followed by the Health VIPS and other validation measures (reported below). Participants were emailed 2 weeks later and asked to re-complete the questionnaire for test–retest reliability assessment. Test–retest reliability was conducted in the student sample only, as the clinical sample was undergoing surgery and this intervention could have influenced test–retest reliability in this sample. The study was approved by the University of Auckland Human Participants Ethics Committee.

The clinical sample completed the Health VIPS as part of a baseline battery of measures collected at their surgical pre-admission appointment. Ethics approval was gained for this study from the Health and Disability Ethics Committee and the Auckland District Health Board.

**Health Visual Information Preference Scale Items**

To create the initial Health VIPS item pool, the authors AJ, MK, LM, KP reviewed the literature for existing scales attempting to assess visual learning preferences. Items were developed using a mixture of methods, including expert consultation from study authors to generate items, and reviewing two learning preference scales (Fleming & Mills, 1992; Kirby et al., 1988) for examples that could be used as a style guide for item wording. Each author was instructed to develop 5–6 items that considered the
use of different types of visual health information (e.g., diagrams, illustrations, scans) in different medical settings where information is commonly provided (e.g., surgical preparation, treatment initiation, consultations). These items comprised a raw pool of 22 items. The authors consulted and removed items from this list that had obvious overlap and addressed similar content from a face validity perspective, which resulted in an initial 12-item scale used for pilot testing.

This 12-item initial version was piloted with 45 postgraduate health psychology students at the University of Auckland, and undergraduate psychology students from La Sierra University, California and Philipps-University of Marburg, Germany. Reliability analysis of this data revealed that removing three items would not decrease Cronbach’s alpha for the scale, while removing any of the other items would reduce this (e.g. from $\alpha = .84$ to .81). These three items were removed from the scale, which resulted in the final nine-item measure.

The Health VIPS asks respondents to rate the degree to which they agree or disagree with each item (full item list can be found in Table 1) on a Likert scale ranging from 1 (‘strongly disagree’) to 5 (‘strongly agree’), with three reverse-coded items (items 4, 7, and 9). Total scores are calculated by averaging the items. The tool was designed to measure a single dimension where lower scores indicate less preference and higher scores indicate stronger preference for visually presented health information. Items compare receiving visual information with written information, as this is the standard form of supplementary material used in health care.
### Table 1. Mean and standard deviations of each Health VIPS item across the study samples.

<table>
<thead>
<tr>
<th>Study 1 (EFA samples)</th>
<th>Study 2 (CFA sample)</th>
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<tbody>
<tr>
<td>Student sample (N= 103)</td>
<td>Patient sample (N= 94)</td>
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<tr>
<td>Outpatient sample (N=196)</td>
<td></td>
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<tr>
<td>M (SD)</td>
<td>M (SD)</td>
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<tr>
<td>1. Being shown a scan or an image of the inside of my body would help my understanding of a medical condition.</td>
<td>4.30 (0.79)</td>
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<td>2. I often find that medical information that uses words, but no pictures, is harder to follow.</td>
<td>3.78 (0.91)</td>
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<tr>
<td>3. When it comes to understanding health information, I find an image is worth a thousand words.</td>
<td>3.79 (0.88)</td>
</tr>
<tr>
<td>4. I am the sort of person who doesn’t need visual aids (e.g. pictures, diagrams) to understand medical information.*</td>
<td>3.37 (1.03)</td>
</tr>
<tr>
<td>5. If I were newly diagnosed with an illness, seeing animations or images would help me to create a picture of what the illness “looks like”.</td>
<td>4.27 (0.78)</td>
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<tr>
<td>6. If I needed to have surgery, a visual illustration of the operation would help me to better understand the procedure.</td>
<td>4.35 (0.87)</td>
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<tr>
<td>7. I prefer a straightforward verbal or written explanation of an illness to one that includes illustrations.*</td>
<td>3.38 (1.13)</td>
</tr>
<tr>
<td>8. If I was prescribed a new medicine, being shown a visual demonstration of how the medicine worked inside the body would be helpful for my understanding.</td>
<td>3.54 (1.22)</td>
</tr>
<tr>
<td>9. When my doctor gives me health information, I prefer a simply-written document rather than one with added pictures or diagrams.*</td>
<td>3.64 (0.96)</td>
</tr>
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</table>

*Reverse-coded items
Validation Measures

**Style of Processing – Picture subscale.** The Style of Processing picture subscale (SOP-P) (Childers et al., 1985) was used to assess convergent validity of the Health VIPS. The SOP scale aims to assess preference for imaginal processing. We used the 11-item picture subscale only, as the verbal subscale items were irrelevant. The response scale for the SOP-P consists of four anchored response points ranging from 1 (‘always true’) to 4 (‘always false’), with one reverse-coded item. Example items include ‘When I’m trying to learn something new, I’d rather watch a demonstration than read how to do it’ and ‘My thinking often consists of mental “pictures” or “images”’. Higher scores reflect less preference for visual processing; therefore, we would expect a negative correlation with the Health VIPS.

**BRIEF health literacy screening tool.** The BRIEF health literacy screening tool (BRIEF) (Haun, Luther, Dodd, & Donaldson, 2012) was used to assess discriminant validity. The BRIEF health literacy screening tool is a four-item measure of health literacy which asks respondents four questions about health comprehension, and their confidence in understanding health information and completing tasks. Items 1–3 are answered using anchored responses from ‘always’ to ‘never’, and anchors ‘not at all’ to ‘extremely’ are used for item 4. Higher scores represent greater health literacy. We expected no correlation between the BRIEF and Health VIPS, indicating two distinct measurement constructs.

**Statistical Analyses**

Descriptive statistics and reliability and validity analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY, USA). The strength of correlations was used to assess test–retest reliability, and convergent and discriminant validity.

The EFA used maximum-likelihood estimation applied to the polychoric correlation matrix, which was conducted using Stata 15.1 (StataCorp LLC, College Station, TX, USA). To verify the appropriateness of the sample for performing a factor analysis, we examined the item and overall measures of sampling adequacy. According to Kaiser and Rice (1974), items with a measure of sampling adequacy below .50 should be excluded from the questionnaire and further analyses; none of the items were eliminated based on this criterion. In addition, we calculated the overall Kaiser–Meyer–Olkin sampling adequacy coefficient and performed a Bartlett test of sphericity to assure that the data set was suitable for factor analysis. Due to the fact that principal components analysis with Kaiser criterion is an error-prone extraction method, where the number of extracted factors may be overestimated (Costello & Osborne, 2005), Horn’s parallel analysis (1965) was used to determine the number of factors to extract. Parallel analysis is based on the assumption that significant factors or
components from observed study data have larger eigenvalues than those obtained from a random data set with the same sample size and number of variables (Crawford et al., 2010). Direct oblimin rotation was applied to the loadings on the extracted factors. Reliability analysis was used to test internal consistency of the scale, with satisfactory target values set at .70 (Bland & Altman, 1997; Nunnally, 1978), although scales with fewer items tend to have smaller values (Tavakol & Dennick, 2011).

**Study 1 Results**

**Undergraduate Student Sample**

**Sample characteristics.** 106 students opened the questionnaire link and began responding. Of those, 103 fully completed the Health VIPS and were retained in the sample (97.2% completion rate). Participants ranged from 18 to 50 years of age (M= 20.99, SD= 5.09), were mostly female (78.6%, 81/103), and reported having completed at least secondary level education (59.2%, 61/103), with some also having completed tertiary (35%, 36/103) or postgraduate study (5.8%, 6/103).

**Exploratory factor analyses.** No item had a measure of sampling adequacy coefficient below .50. A Kaiser–Meyer–Olkin coefficient of .67 indicated that the items were amenable to factor analysis. The Bartlett test of sphericity also affirmed that this data set was suitable for structure detection ($\chi^2_{36, N=103}= 167.60, p< .001$). Parallel analysis indicated a three-factor solution. The three-factor solution explained 64% of the total variance. The rotated pattern of factor loadings (Table 2) indicated items 1, 2, 3, and 8 formed a factor, items 5 and 6 formed a factor, and the negatively phrased items 4, 7, and 9 formed a factor. Factors 1 and 2 had a strong positive correlation ($r = .44$) and factor 3 had weak negative correlations with Factors 1 and 2 ($r = .34$ and .08, respectively).

We repeated the EFA with data collected at follow-up. No items had a sampling adequacy coefficient below .50. A Kaiser–Meyer–Olkin coefficient of .81 indicated very good applicability of the residual sample of items for factor analysis, and again the Bartlett test of sphericity affirmed this data set was suitable for applying EFA ($\chi^2_{36, N=83}= 191.26, p< .001$). Parallel analysis this time indicated a two-factor solution that explained 57% of the total variance. The pattern of item loadings was similar to that in the baseline data but combined items 1, 2, 3, 5, 6, 8 into a single factor (Factor 1), that correlated negatively with a second factor consisting of items 4, 7, and 9 (Factor 2; $r = .65$).

**Reliability and validity.** Descriptive statistics revealed a positive skew in scale item responses (see Table 1). The average mean total score of scale items was 3.82 (SD= 0.52). The
Health VIPS total score demonstrated good internal consistency at both baseline ($\alpha = .70$) and follow-up ($\alpha = .80$). At follow-up, 83 of the 103 students completed the Health VIPS (80.6% retention rate), between 14 and 34 days after the initial assessment ($M = 17.84$, $SD = 5.44$). The Health VIPS score demonstrated moderate test–retest reliability, reflected by a significant, positive correlation between baseline and follow-up data for the total scale ($r = .63$, $p < .001$). As predicted, the total Health VIPS correlated negatively with the SOP-P both at baseline ($r = .32$, $p = .001$) and follow-up ($r = .41$, $p < .001$), demonstrating convergent validity. No significant correlation was found between the BRIEF health literacy scale and Health VIPS total score at either baseline ($r = .06$, $p = .541$) or follow-up (total score $r = .18$, $p = .121$) demonstrating good discriminant validity.
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<th>Student sample (n=103)</th>
<th>Patient sample (n=97)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Factor 1</td>
<td>Factor 2</td>
</tr>
<tr>
<td>1. Being shown a scan or an image of the inside of my body would help my understanding of a medical condition.</td>
<td>0.61</td>
<td>0.13</td>
</tr>
<tr>
<td>2. I often find that medical information that uses words, but no pictures, is harder to follow.</td>
<td>0.56</td>
<td>-0.09</td>
</tr>
<tr>
<td>3. When it comes to understanding health information, I find an image is worth a thousand words.</td>
<td>0.75</td>
<td>-0.07</td>
</tr>
<tr>
<td>4. I am the sort of person who doesn’t need visual aids (e.g. pictures, diagrams) to understand medical information.</td>
<td>-0.15</td>
<td>0.59</td>
</tr>
<tr>
<td>5. If I were newly diagnosed with an illness, seeing animations or images would help me to create a picture of what the illness “looks like”.</td>
<td>0.10</td>
<td>0.12</td>
</tr>
<tr>
<td>6. If I needed to have surgery, a visual illustration of the operation would help me to better understand the procedure.</td>
<td>0.00</td>
<td>-0.15</td>
</tr>
<tr>
<td>7. I prefer a straightforward verbal or written explanation of an illness to one that includes illustrations.</td>
<td>-0.02</td>
<td>0.65</td>
</tr>
<tr>
<td>8. If I was prescribed a new medicine, being shown a visual demonstration of how the medicine worked inside the body would be helpful for my understanding.</td>
<td>0.35</td>
<td>0.02</td>
</tr>
<tr>
<td>9. When my doctor gives me health information, I prefer a simply-written document rather than one with added pictures or diagrams.</td>
<td>-0.01</td>
<td>0.55</td>
</tr>
</tbody>
</table>
Clinical Sample

Sample characteristics. Of 123 patients approached, 97 completed the baseline questionnaire for the trial. Patients were excluded for not meeting the larger trial inclusion criteria (n= 4) or for declining participation (n= 22). Of those 97 participants, 94 completed the Health VIPS as part of the baseline questionnaire. The majority of the clinical sample was female (62.9%, 61/97) and New Zealand European or European (71.1%, 69/97), ranging in age from 18 to 91 years old (M= 58.60, SD= 16.39).

Exploratory factor analyses. No item had a measure of sampling adequacy coefficient below .50. A Kaiser–Meyer–Olkin coefficient of .78 indicated very good applicability of the residual sample of items for factor analysis. Bartlett’s test of sphericity was again highly significant and confirmed that the data set is suitable for being analysed with a factor analysis ($\chi^2$ (36, N= 94) = 274.61, $p< .001$). Parallel analysis confirmed a two-factor structure within the patient sample. As with the student sample, items 1, 2, 3, 5, 6, 8 formed one factor (Table 2) that correlated negatively with a second factor consisting of item 4, 7, and 9 ($r = .39$). The descriptives for this sample revealed a positive skew in responses to each item (see Table 1), and the average mean scale score was 3.66 (SD= 0.69). The patient sample demonstrated good internal consistency in the total scale ($\alpha = .80$).

Study 2 Method

Participants and Procedure
The questionnaire was completed by 204 outpatients who were attending specialist services at Greenlane Clinical Centre, the main outpatient centre for Auckland City Hospital, New Zealand. Patients in the waiting room were consecutively approached by the research assistant who invited them to complete an anonymous questionnaire assessing preferences for health information. Patients were excluded if they did not speak English or were not interested in participating. Patients completed the questionnaire in the waiting room and returned the completed questionnaire to the research assistant before leaving. Ethical approval for the study was received from the Auckland Health Research Ethics Committee and the Auckland District Health Board Research Office.

Measures
In addition to the Health VIPS and demographic items (age, gender, ethnicity, level of education, and outpatient service), participants also answered additional measures to assess validity. Following the results from Study 1, the authors chose to include different validity measures to further assess relationships between the Health VIPS and other constructs, which are outlined below.
**Preference test.** To test preferences for health information using an example, participants saw a single page divided into two depictions of the same information in both picture and text format. This information was adapted from an instruction leaflet for self-injecting insulin. Patients ticked a box indicating their preference for either the written or pictorial information option. This item assessed convergent validity of the Health VIPS for establishing health information preference.

**Self-rated health.** A one item self-rated health question assessed discriminant validity of the Health VIPS. This item asks participants to rate their health compared to other people their age on a 10-point scale ranging from poor to excellent.

**Health confidence.** A two-item health confidence tool (Wasson & Coleman, 2014), measuring patients’ confidence with managing their health and with health information, was used to assess convergent validity. Each item asks patients to rate their response from 0 to 10, with higher scores reflecting more confidence.

**Satisfaction with health care.** One item from the General Satisfaction subscale of the Patient Satisfaction Questionnaire (PSQ-18) (Marshall & Hays, 1994) was used to assess convergent validity. Responses to the statement 'The medical care I have been receiving is just about perfect' are rated on a 5-point scale (strongly agree to strongly disagree).

**Experience with health information.** One item asked patients to select whether the majority of supplementary health information they have received in the past has been given in either a written or visual format. This item was used to assess convergent validity, by creating a variable reflecting match between preference and experience, and assessing the relationship between this and health confidence and satisfaction with health care.

**Statistical Analyses**

In accordance with recommendations for scale development (Byrne, 2016), a CFA within the structural equation framework was also applied to test the underlying factor structure of the Health VIPS in the outpatient sample. All tests were conducted using Stata 15.1 using maximum-likelihood estimation with a logit link function to account for the ordinal nature of the response scale. CFA models with one and two factors were considered since a unidimensional solution was initially hypothesized but a two-factor solution was shown to provide a more parsimonious empirical explanation of the interitem correlations. In addition, to these models a bifactor model was assessed since this approach allows for the consideration of a general factor, which might explain a two-factor solution where one is expected (Reise, Moore, & Haviland, 2010). To indicate goodness of fit for the model, we used the BIC, RMSEA,
CFI, TLI, and chi-square to degrees of freedom ratio indices. Good fit is indicated by values under .06 for RMSEA, values above .90 for CFI, and values close to .95 for TLI (Hu & Bentler, 1999). The standardized regression coefficient is reported for each item. Reliability analysis assessed internal consistency of the scale, in addition to reporting McDonald’s omega reliability estimate. Omega hierarchical was also reported for the bifactor solution as an indicator of the saturation of the scale by a general factor. Assumptions of convergent and discriminant validity were made by assessing the strength of correlations, or significance of independent samples t-tests.

Study 2 Results

Sample Characteristics

Of those participants who specified the service they were attending, most patients were attending surgical pre-admission (20.3%, 40/197), urology (19.8%, 39/197), orthopaedics (18.8%, 37/197), general surgery (11.7%, 23/197), or renal services (9.6%, 19/197). Other services included rheumatology (6.1%, 12/197), colorectal (3.6%, 7/197), gastroenterology, oncology and pain (all 2.0%, 4/197), neurology (1.5% 3/197), liver (1.0%, 2/197), and genetics, haematology, or nutrition (all 0.5%, 1/197). The majority of respondents were male (122/201, 60.7%). Most participants identified as NZ European or European (61.6%, 125/203), and most had completed at least secondary (82/201, 40.8%) or tertiary (74/201, 36.8%) education.

Confirmatory Factor Analysis

The authors compared the fit of one-factor, two-factor, and bifactor models. The BIC for the two-factor model was lowest indicating that this model provided the most parsimonious fit to the data: 4626.3 compared to 4712.8 for the one factor and 4628.7 for the bifactor. While the fit for the bifactor model was only marginally worse than for the two-factor model, omega hierarchical ($\omega_h = .50$) indicated the level of saturation of the total score by a general factor was low indicating that treating the scale as sufficiently unidimensional was inappropriate. Together this provides support for the two-correlated factor model observed in the samples in study 1. Factor loadings are presented in Figure 1. The fit of the two-factor model was acceptable (RMSEA = .08; CFI = .91; TLI = .87). Factor 1 (items 1, 2, 3, 5, 6, 8) was labelled as preference for additional visual information. Factor 2 (Items 4, 7, 9) was labelled satisfaction with standard health information.

Reliability and Validity

Mean scores of the Health VIPS items again suggested an overall positive skew (see Table 1), and the average of items was 3.63 ($SD= 0.57$). The Health VIPS scale demonstrated good internal consistency
Coefficients suggested Factor 1 had good reliability ($\alpha = .83$, omega= .88) and Factor 2 had moderate reliability ($\alpha = .60$, omega= .71). The preference test demonstrated good convergent validity, whereby those who selected the pictorial information had significantly higher total scores on the Health VIPS ($M= 34.07$, $SD= 4.83$) compared to those who selected the text option ($M= 31.43$, $SD= 5.20$; $t(160)= -3.33$, $p= .001$). To assess convergent validity, we calculated, for participants in the upper and lower quartiles of the Health VIPS total score, a binary variable indicating (mis)match of experience with health information and preference for modality of health information. Differences between these groups in scores on the health confidence and health satisfaction measures were then assessed. Individuals with a mismatch had significantly lower health confidence ($M= 6.18$, $SD= 2.02$), compared to those without no mismatch ($M= 7.14$, $SD= 2.04$; $t(99)= 2.33$, $p= .022$). Those with a mismatch also trended towards being more dissatisfied with their medical care ($M= 2.21$, $SD= 0.99$), than those with a match ($M= 1.90$, $SD= 1.07$), although this did not reach significance ($t(99)= -1.50$, $p= .137$). A weak, negative relationship was found between the Health VIPS and self-rated health ($r= -.14$, $p= .043$), thus demonstrating discriminant validity.

![Diagram](image)

*Figure 1.* Confirmatory factor analysis of a correlated two-factor model of the Health Visual Information Preference Scale (values in square brackets indicate lower and upper limit of the 95% confidence interval; N=204).
General Discussion

These studies assessed a new measure of patients’ preferences for receiving supplementary visual health information. Overall, the results suggest that the Health VIPS is a brief, reliable, and informative instrument for assessing visual health information preferences. The tool demonstrated good psychometric properties, including internal consistency across samples. The Health VIPS also demonstrated good test–retest reliability, discriminant validity to measures of health literacy and self-rated health, and convergent validity with a non-health-related measure of visual processing style and a measure of health information preference. These results suggest that the Health VIPS is assessing distinct constructs, specific to the health context.

The EFA suggested that the Health VIPS has a two-factor structure, which was confirmed by the CFA analysis. These two separate factors have been defined as a preference for additional visual information and a satisfaction with standard health information. The second factor consists of the reverse-coded items. These reverse-coded items did appear to load problematically in some samples included in the EFA analysis of Study 1. However, removing these items from the scale resulted in further reduced model fit, suggesting that these items are important to retain. These reverse-coded items additionally serve an important purpose in preventing acquiescent responding and allowing the potential for different levels of preferences to be identified by the Health VIPS. This is important considering that most people would like the addition of visual information, which would likely diminish variance in this construct. Therefore, while the factor structure of the measure suggests two subscales, the authors still suggest utilizing the total score for clinical application of the scale. In this case, the total score can be considered to be the amount that the individual prefers added visual information compared to standard information alone.

It is reasonable that the Health VIPS performed differently in the three independent samples across the two studies. Participants in each sample had different experiences and histories with health information. The student sample likely had limited experiences with health information as patients. The two patient samples were also distinct. The patient sample in Study 1 was currently undergoing a medical procedure (surgery), whereas the Study 2 outpatient sample was undergoing diagnostic investigations or regular check-ups. Preferences and scores on the Health VIPS are likely to be distinct between those with differing levels of exposure to health information.

This study is limited by several factors. First, the student samples used for initial scale piloting, the EFA, and to assess test–retest reliability were relatively homogenous samples of undergraduate
and postgraduate students studying medical and health sciences. This sample is not representative of the general population or patients and medical and health science students specifically may have a different understanding and approach to learning about biological processes in comparison to the lay public. Including patients in scale development may have provided more representative feedback of scale items and appropriateness of wording. The EFA conducted in the patient sample, however, did yield similar results. Second, we assessed convergent but not predictive validity for the Health VIPS. It would have been interesting to see if Health VIPS scores also predicted health information preferences assessed at a later point in time. Third, the amount of variance explained by the factors of the Health VIPS in the EFAs performed in Study 1 could be considered low (between 57% and 64%). This could be the result of smaller sample sizes; however, it has been noted that in social science research it is not uncommon to consider lower amounts of variance explained satisfactory (Hair, Black, Babin, & Anderson, 2014). In this instance, decisions regarding factors to retain should also include considerations of theoretical content.

Despite these limitations, there are clinical implications for the tool. Firstly, delivering visual health information to those with increased preferences could improve patient understanding and subsequent health behaviours. Research on health risk information suggests that the format of information may influence actual medical decision-making, by influencing patients' knowledge attainment (Hawley et al., 2008). Visual information can increase patient attention, comprehension, and retention (Brotherstone et al., 2006; Mintzer & Snodgrass, 1999), making patients more likely to adhere correctly to physician recommendations. These effects could be heightened further if patients prefer receiving health information visually. Our results did reveal that a match between format preference and experience was associated with greater health confidence, which may be an important factor in patient engagement and adherence.

The Health VIPS is brief and quick to complete, meaning it could easily be administered before a clinical consultation. The second study demonstrated that patients could complete the tool while waiting for an outpatient appointment. Health care providers could use the Health VIPS to screen patients and identify those who would benefit most from receiving supplemental visual aids during clinical consultations. Visual tools could be easy to incorporate into the clinical setting due to their low cost and portability (Jones et al., 2016, 2017). Furthermore, diagnostic scans and images are often available in certain specialities (such as cardiology) but are underutilized as tools for patients (Devch et al., 2014). Visual materials may therefore already exist that could be easily incorporated into explanations for patients with a visual preference. The scale may also be useful to inform clinical staff
what the proportion of their patient group is who would prefer visual information and how their patient information aligns with this group.

The Health VIPS may also be particularly useful in the health care setting for patients with low literacy levels. Patients are unlikely to disclose literacy problems for fear of embarrassment (Parikh, Parker, Nurss, Baker, & Williams, 1996). Importantly, patients with literacy problems are likely to be those most in need of health advice (Michielutte, Bahnson, Dignan, & Schroeder, 1992), but least likely to adequately comprehend traditional written material (Kessels, 2003). The Health VIPS could therefore be a way to sensitively measure preferences for visual health information, without relying upon patient disclosure of literacy problems or issues with understanding material. Furthermore, future research could also assess whether the Health VIPS is associated with the comprehension of health information, as this would highlight the importance of this tool for improving the utilization of health information.

Notable, when looking at all three samples, is the positive skew of scale responses suggesting a general preference for visual health information. This is perhaps unsurprising, yet an important consideration seeing as the default format for health information has been written material (Ngoh & Shepherd, 1997). Patient health information often neglects the inclusion of visual aids (Fagerlin et al., 2004), although patients appear to prefer this format. Clinicians should therefore consider the format of supplementary health materials, and more broadly how incorporating visual aids and tools into their practice may improve patient education and outcomes.

To conclude, the Health VIPS is a short, reliable scale which appears to validly measure patient preferences for visual information about health. Clinically, this tool could be especially useful for increasing understanding and promoting health behaviour. Understanding patient preferences is an important aspect of health care, as aligning patient preferences with information delivery may also increase satisfaction and promote autonomy within the medical consultation. Further research should aim to replicate these results to understand if this construct can be reliably measured in other health populations.
References


Appendix G: Revised and accepted manuscript of Study 4

Citation
Abstract

Objective. Enhanced Recovery After Surgery (ERAS) programmes fast-track recovery for surgical procedures, including colorectal and gynaecological oncology surgery. Early mobilisation is a postoperative ERAS module that can be self-managed by patients, but poor adherence is common. Visualisation is increasingly being used to improve patient understanding of pathological and treatment processes, and adherence to health behaviours. This study tested whether an animated visualisation intervention could improve adherence to postoperative mobilisation. Methods. 100 colorectal and gynaecological oncology surgery patients were randomised to intervention, active control, or standard care groups. Intervention participants saw an animated intervention on a computer tablet at day one post-surgery. All patients wore fitness trackers from day of discharge to seven days post-discharge, and completed psychological measures at baseline, day one post-surgery and seven days post-discharge. Results. Step count data was available for 57 colorectal surgery participants. There was a main effect of group, whereby intervention participants had a significantly higher average daily step count from discharge across the following week ($M_{adj}=2294.60$, CI [1746.11, 2744.89]), compared to control participants ($M_{adj}=1347.25$, CI [826.51, 1871.20], $p=.05$). At post-surgery, intervention participants reported significantly greater perceived quality of recovery, and less difficulty in being mobile compared to control participants. There were no between group differences in self-reported exercise, or perceptions of surgery and recovery. Conclusion. This brief intervention appears effective in improving perceptions of early mobilisation, and initial evidence suggests improvements in adherence to postsurgical mobilisation. This intervention has high clinical applicability and could be incorporated into postoperative standard care.
Introduction

The surgical postoperative recovery period is vital in determining return to good health and functioning for patients. Delayed or problematic postoperative recovery not only increases medical care and burden, but can also indirectly negatively impact the patient and their wider support network emotionally and financially (Lee et al., 2014). Over the last decade, Enhanced Recovery After Surgery (ERAS) programmes have been introduced into hospitals worldwide for a number of surgical services, including colorectal and gynaecological surgery (Gustafsson et al., 2013). ERAS programmes encompass a multi-disciplinary care pathway preoperatively to postoperatively, to reduce surgical trauma and metabolic stress on the body, and to optimise patient outcomes and a faster recovery (Lee et al., 2014; Varadhan, Lobo, & Ljungqvist, 2010). The ERAS items cover biological and medical recommendations (e.g. preoperative fasting, anaesthesia, intraoperative technique, postoperative analgesia) to instructing pre-admission information, education and counselling, and postoperative nutrition and mobilisation (Gustafsson et al., 2013). ERAS programmes have been adopted as standard practise in hospitals worldwide and within New Zealand.

In comparison to standard care, ERAS patients are typically discharged faster with fewer illness-related complications, while experiencing no increased rates of hospital readmission or mortality (Varadhan et al., 2010). However, optimal recovery is reliant upon adherence to the components of the ERAS pathway. Despite the widespread introduction of ERAS recommendations and guidelines worldwide, non-adherence to ERAS that cannot be explained by major surgical and medical complications is common (Smart et al., 2012).

One key postoperative ERAS module is early mobilisation. Combining early mobilisation with early oral nutrition can help prevent postoperative loss of muscle strength (Henriksen, Jensen, Hansen, Jespersen, & Hessov, 2002), as the improved blood circulation resulting from early mobilisation allows the nutrients received from oral nutrition to be transported more efficiently around the body. Despite this, adherence to early mobilisation remains poor (Bergman et al., 2014; Fiore et al., 2017). Failure to complete early mobilisation is a common reason for ERAS deviation and is associated with poorer recovery (Vlug et al., 2012) and increased hospital stay (Smart et al., 2012). Efforts directed at getting patients to mobilise early can conflict with lay beliefs about bed rest and limited activity being necessary for the body to recover following a major operation (Brieger, 1983). Indeed, the difficulties of attempting to change these perceptions have been highlighted by staff (Pearsall et al., 2015).

There is limited evidence regarding the optimal methods for enhancing postoperative mobilisation. Previous research with colorectal patients has found that staff-facilitated mobilisation
(dedicated walking assistance) can improve step count during in-hospital recovery but this is not maintained once the patient leaves hospital (Fiore et al., 2017). A recent systematic review of studies examining the impact of early mobilisation on postoperative recovery all used similar one-on-one style training with patients (Castelino et al., 2016). These staff-facilitated interventions require considerable resources and the efficacy of these interventions in improving mobilisation is inconsistent (Castelino et al., 2016). Staff-directed interventions may force patients to mobilise in hospital, but may not promote self-directed behaviour from the patient once discharged. Finding ways to increase patient self-adherence to postoperative mobilisation could therefore improve patient outcomes, without increasing staff burden.

Enhancing patient understanding of the biological mechanisms and purpose of early mobilisation in improving recovery time could help reduce anxiety and increase adherence to this behaviour. Visual health information or active visualisation is increasingly being used as an intervention technique to improve understanding, motivation, and adherence to health behaviours (Jones, Ellis, Nash, Stanfield, & Broadbent, 2016; Jones, Fernandez, Grey, & Petrie, 2017; Jones & Petrie, 2017; Perera, Thomas, Moore, Faasse, & Petrie, 2014; Stephens et al., 2016). A recent active visualisation intervention for HIV patients failing on treatment in a resource poor area improved adherence as demonstrated by a reduction in the clinical outcome of viral load (Jones, Coetzee, et al., 2018). Visualisation can help patients to understand abstract and conceptual information about how treatments relate to illness by providing a concrete demonstration of processes occurring inside the body. Visualisation interventions are brief and portable, and have successfully been delivered to patients in hospital using technology (Jones et al., 2016).

Clinical staff provide patients with information regarding the importance of early mobilisation as part of preoperative care, and additionally encourage ERAS patients to be mobile postoperatively, however, adherence to that recommendation is largely determined by the patient. A visualisation intervention may therefore help patients to establish a concrete link between the purpose of early mobilisation and their recovery. This understanding may further drive maintenance outside the hospital environment and improve both patient adherence and recovery.

The current study aimed to assess whether a visualisation intervention explaining the purpose of early mobilisation could increase adherence to this behaviour postoperatively. Therefore, the primary outcome of this study was adherence to postoperative mobilisation, operationalised as step count from day of discharge to seven days post-discharge. Secondary outcome measures included changes in perceived quality of recovery from surgery and beliefs about ERAS recovery behaviours.
This study also aimed to assess whether this visualisation intervention would be more effective than receiving the same information verbally. To assess this idea, an animated visualisation intervention was developed to deliver to ERAS patients following colorectal and gynaecological oncology surgeries.

Methods

Trial Design and Participants

This study was a parallel, 3-arm, randomised controlled intervention trial with blinded assessors. A sample of 100 ERAS patients undergoing colorectal surgery (n=74) or gynaecological oncology surgery (n=26) were recruited. The sample size calculation was based on a recent trial protocol to increase postoperative mobilisation in ERAS patients following visceral surgery, which aimed to detect a mean change of 250 steps per postoperative day between the intervention and control group (SD=290 steps per day) (Wolk et al., 2017). This equated to a large effect size. A G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) calculation conducted using a more conservative medium to large effect size of 0.35, suggested that 84 participants would be needed for three groups with 80% power and α= 0.05. A sample of at least 96 participants was needed to account for an estimated 15% attrition rate. Of the 96 participants randomised to the three study groups, 89 completed the post-surgery assessment, and 87 completed the seven day follow-up.

Colorectal and gynaecological oncology pre-admission patients at Greenlane Clinical Centre, Auckland District Health Board, were recruited from July 2017 to July 2018. These surgeries have similar operative procedures (within the lower abdominal/pelvic cavity) and ERAS elements (Abeles, Kwasnicki, & Darzi, 2017). Included participants were having elective gynaecological oncology or colorectal surgery at Auckland City Hospital, Auckland District Health Board, could read and understand English, and were over 18 years of age. Exclusion criteria included having known mobility issues pre-surgery. Reasons for patient dropout included feeling too unwell during hospitalisation and having surgery while admitted for other reasons as an inpatient (see Figure 1). This study was approved by the Health and Disability Ethics Committee (17/CEN/47/AM02) and Auckland District Health Board Research Review Committee (A+7552).

Procedure

At pre-admission clinic, specialist nurses from each service referred patients to the researcher (AJ). Study information was provided and written informed consent was received before participants completed the baseline questionnaire. Randomisation was revealed after participants had a date scheduled for their surgery, which always followed the completion of recruitment and the baseline
assessment. Participants were randomly allocated in a 1:1:1 ratio into one of three study groups, a standard care control group, a visualisation group, or an active control group. Randomisation was created by someone independent of the study, using a random number generator and contained in opaque, sealed envelopes.

At day one post-surgery, participants were seen by one of two study researchers who delivered the active control and intervention presentations to the patient at their bedside (AJ & MK). A script was used to ensure consistency. Both the intervention and active control presentations took up to ten minutes to deliver. Following this, an independent research assistant (blinded to study group) provided participants with the post-surgery questionnaire, fitted the fitness tracker, and provided a pre-paid courier bag for returning the tracker. Control participants completed the post-surgery questionnaire and were fitted with the fitness tracker.

At approximately seven days post-discharge ($M=8.61, SD=3.67$), the blinded research assistant completed a five minute follow-up telephone questionnaire with all participants, and reminded them to return the fitness tracker. Participants were sent a $20 shopping voucher to thank them for their participation after the return of the tracker.

All participants in our study received standard care as part of the ERAS protocol of their respective service. As part of Auckland District Health Board services, there is an ERAS nurse specialist who the patient meets with as part of their pre-admission appointment. During this appointment, the ERAS nurse specialists provide patients with practical information regarding the surgery, including what to expect pre-surgery, during surgery, and postoperatively during recovery. This involves informing them about the behaviours that they will be expected to complete before they leave hospital, as part of the ERAS checklist for discharge. These behaviours include early oral nutrition and early mobilisation (which were used to form the basis of the instructions in the intervention outlined below). Patients are generally given a handbook to keep with them that includes this information. The ERAS nurse specialists also attempt to visit all patients in-hospital following their surgery, and nursing and other treating staff follow the ERAS protocols and encourage these behaviours. To meet discharge criteria, patients are expected to be mobilising near normal to how they were prior to surgery, although there is no strict guideline they must meet. The clinical care team were informed about the study taking place and that some participants may be receiving brief information about their recovery, but they were blind to participants’ group allocation.
Figure 1. CONSORT Diagram depicting flow of participants through study.

- Approached at clinic (N= 128)
  - Excluded (n= 31)
    - Not meeting inclusion criteria (n= 6)
    - Declined to participate (n= 23)
    - No surgery scheduled during study period (n= 3)
- Randomised (N= 96)
- Enrolment
- Allocation
  - Allocated to Intervention (n= 33)
  - Allocated to Active Control (n= 32)
  - Allocated to Control (n= 31)
- Analysis
  - Completed post-surgery assessment (n= 30):
    - Withdrew (n=2)
    - Surgery cancelled (n=1)
  - Analysed at post-surgery (n= 33)
  - Completed post-surgery assessment (n= 29):
    - Withdrew (n=1)
    - No surgery scheduled (n=1)
    - No post-assessment but completed follow-up (n=1)
  - Analysed at post-surgery (n=32)
  - Completed post-surgery assessment (n= 30):
    - Discharged same day as admission (n=1)
  - Analysed at post-surgery (n= 31)
  - Completed follow-up assessment (n= 28):
    - Withdrew (n=1)
    - Not contactable (n=1)
  - Analysed at follow-up (n=33)
  - Step count data analysed (n= 18)
  - Completed follow-up assessment (n= 29)
  - Analysed at follow-up (n=32)
  - Step count data analysed (n=19)
  - Completed follow-up assessment (n= 29):
    - Not contactable (n=1)
  - Analysed at follow-up (n=31)
  - Step count data analysed (n= 20)
**Intervention**

The intervention materials were created by the study authors (AJ, KP & JF) with guidance from clinical collaborators (AM & AM). The intervention described the purpose of early mobilisation, the importance of early oral nutrition, and the link between these two behaviours. The presentation included animations contrasting the internal bodily processes when resting versus when mobile, animations demonstrating digestive processes, as well as real life footage of patient actors (examples in Figure 2). Two versions were created using either a male or female patient actor, and participants saw their gender-match. The intervention was delivered to patients on a computer tablet at their bedside.

The intervention began by addressing common lay surgery beliefs about the need for extended bed rest following surgery, and challenged this by providing information about improved patient outcomes under ERAS. Next, a clip showed the patient actor lying in a hospital bed. The camera zooms in and transitions to an animation showing the resulting effects upon heart rate, blood circulation, and the lungs. These clips were contrasted with the patient sitting upright and walking, and animations showing increases in heart rate, improved blood circulation, and lung function. Following this, participants were given specific instructions about their exercise plan during recovery (from day one to discharge) taken from the ERAS booklet provided as part of standard care.

The intervention also explained the importance of early oral nutrition post-surgery. This information was included as both early oral nutrition and early mobilisation are linked behaviours in enhancing recovery. An animation showed the digestive process from ingestion to the extraction and absorption of nutrients into the bloodstream. This was then linked to early mobilisation and improved blood circulation to establish the importance of both behaviours in promoting recovery. Again, participants received specific instructions about their in-hospital nutrition plan. The final film clip showed the patient actors walking outside once home, and the researcher explained the importance of gentle exercise once discharged.

The intervention ended with an elaborative reasoning task to help participants contextualise how they could incorporate mobilisation into their recovery. Participants were asked to discuss specific examples of ways they could include exercise into their time in-hospital and their daily life once discharged. The active control group received the exact same verbal script as the visualisation group (including the elaborative reasoning task), but saw no animations. The control group received standard postoperative ERAS care as explained above.
Measures

**Demographic and Clinical Information.** At baseline, participants self-reported gender, age, ethnicity, and highest level of education. Clinical information recorded from patient notes included date of surgery, primary surgical procedure, length of hospital stay (days), 30 day hospital re-admission for complications, and cancer diagnosis.

**Step count.** Postoperative mobility was assessed by step count using Jawbone Up Move fitness trackers. Jawbone trackers have been found to have high measurement precision due to the use of triaxial accelerometers (Balto, Kinnett-Hopkins, & Motl, 2016). Up Move trackers were chosen specifically to try and minimise effects upon activity, as these trackers do not display numerical step count. Each participant was instructed to wear the tracker at all times (except showering) until they were contacted seven days post-discharge. The tracker was placed on the participant's non-dominant wrist, except when not possible due to intravenous lines. Participants with larger wrists were given a clip attachment to wear the tracker on their belt or shirt.
Step count data was analysed from the day of discharge to the day before the follow-up phone call was completed (seven days in total), to prevent any inconsistencies in the time that the tracker was fitted and taken off. The Jawbone “UP” mobile application was used to retrieve data through Bluetooth connection. Unfortunately, Jawbone underwent liquidation and removed their application and online servers in May 2018, meaning fitness tracker data was only available if collected before this date (n=57). This sample consisted entirely of colorectal surgery patients who were recruited prior to the gynaecological oncology sample.

**Self-reported exercise.** At baseline, self-reported exercise was answered in a single item with an open-response format in minutes per week. Participants self-reported how many minutes they had spent completing moderate exercise (e.g. going for a walk) during the past seven days. This item has been used in previous research to assess self-reported exercise in another intervention study with a patient sample (Jones et al., 2016).

**Quality of recovery.** The Quality of Recovery short form (QoR-15) was used to assess perceptions of surgical recovery both post-surgery and at follow-up (Stark, Myles, & Burke, 2013). The QoR-15 measures five dimensions of recovery including physical (pain, physical comfort, and physical independence) and mental well-being (psychological support and emotional state). Responses are given on an 11-point scale from 0 (none of the time) to 10 (all of the time). Items 11 to 15 assess physical and psychological symptoms and are reverse-coded. Items are summed to create total scores. The post-surgery questionnaire excluded item 8 (“Able to return to work or usual home activities”) and the follow-up questionnaire excluded item 7 (“Getting support from hospital doctors and nurses”). For this reason, total scores at each time point were analysed separately. This QoR-15 demonstrated good internal reliability at both post-surgery (α=.84) and follow-up (α=.89).

**Perceptions of surgery and recovery.** Items from the Brief Illness Perception Questionnaire (Broadbent, Petrie, Main, & Weinman, 2006) were adapted to assess perceptions of surgery and recovery at baseline and postoperatively. Words “illness” and “treatment” were replaced with “surgery” and “recovery”. Seven items assessed beliefs of treatment control (of surgery), identity (post-surgery symptoms), concerns (for both surgery and recovery), emotional response (to surgery), consequences (of surgery), timeline (of recovery), and personal control (of recovery). The post-surgery questionnaire excluded the concern about surgery item. Each item was scored on an 11-point scale from 0 to 10, where higher scores on each item indicate higher perceived levels of the construct (e.g. more control or more distress).
**Perceptions of ERAS recovery behaviours.** Six items were created to assess perceptions of early mobilisation and early oral nutrition. Participants reported how much they understood each behaviour, how motivated, and how anxious they were about completing each behaviour at all three assessments. At post-presentation and follow-up only, participants also answered how difficult they felt it was to be active and to eat healthily during their recovery. Each item was answered on an 11-point scale from 0 to 10, with relevant anchors for each item in order to ensure response familiarisation. Each item was analysed as a separate outcome in the analysis.

**Traditional Surgery Recovery Beliefs.** Three items at baseline and post-surgery assessed traditional surgery beliefs. These items asked participants how important they felt complete bed rest, extended hospital stay, and intravenous fluids were after surgery. These questions were answered on the same 11-point scale as previous items, with relevant anchors for each item. Items were summed to create a composite total score, which demonstrated good internal reliability (baseline $\alpha= .82$, post-surgery $\alpha= .83$). Higher scores indicated stronger traditional beliefs.

**Health Visual Information Preference Scale.** The Health Visual Information Preference Scale (Health VIPS) (Jones, Kleinstäuber, Martin, Norton, Fernandez, & Petrie, 2019) was included in the baseline questionnaire to assess differences between preferences for receiving supplementary visual health information between groups. The 9-item Health VIPS is measured on a 5-point Likert-type scale (from 1 to 5), with anchors from strongly disagree to strongly agree. Total Health VIPS score is calculated by averaging the items (items 4, 7, and 9 are reverse-coded), and internal consistency was good in the current sample ($\alpha=.79$).

**Evaluation of Intervention and Active Control Materials.** At post-surgery, the intervention and active control group answered seven items evaluating the material they received in-hospital. Items asked how material improved understanding, and whether it increased motivation or anxiety about being active and re-introducing food and drink. One item also asked how interesting participants found the material. Items related to either the “animations” (intervention) or “information” (active control) received. Items were answered on an 11-point scale from 0 to 10 with relevant anchors for each.

**Statistical Analysis**

Data were analysed using SPSS version 25.0. Tests were considered significant at $p< .05$. One-way ANOVAs and Chi-Square tests for independence assessed associations or differences between groups in demographic, clinical, and baseline variables.

A linear mixed-effect model using heterogeneous first order autoregressive covariance matrix and Type III sum of squares was used to assess changes between groups in step count data from
discharge across each day of the following week. This procedure is appropriate for outcomes with multiple repeated measures and is robust against skewed and missing data (Arnau, Bendayan, Blanca, & Bono, 2013; Krueger & Tian, 2004). The effects entered into this model included an interaction effect (group x time) and main effects of group and time. The primary effect of interest was the main effect of group on the step count data.

ANCOVAs (with length of hospital stay as a covariate) were used to assess between group differences in QOR-15 scores at both post-surgery and follow-up, perceived difficulty regarding ERAS behaviours at post-surgery and follow-up, and differences between groups in change scores from baseline to post-surgery in traditional surgery recovery beliefs. An ANCOVA (with baseline self-reported exercise and length of hospital stay as covariates) was also used to assess differences between groups in change scores of self-reported exercise from baseline to follow-up.

A MANOVA (with length of hospital stay as a covariate) was used to assess differences in change scores from baseline to post-surgery between groups in each item measuring perceptions of surgery and recovery. MANOVAs (with length of hospital stay as a covariate) were also used to assess differences in change scores from baseline to post-surgery, and baseline to follow-up, in perceptions of ERAS behaviours. Bonferroni adjustment was used for post-hoc multiple comparisons in all of the analyses conducted. In both the step count data and the psychological outcomes, intention-to-treat analyses were performed and missing data values were imputed using the SPSS multiple imputation procedure. The procedure provides five data sets using the monotone multiple imputation algorithm. Statistical analyses described above were applied and the results were aggregated across the datasets.

Independent samples t-tests were used to assess differences in intervention ratings between the intervention and active control conditions.

Results

Demographic and Clinical Characteristics of the Sample

Figure 1 shows the study CONSORT scheme. Participants ranged from 18 to 91 years old ($M= 58.71$, $SD= 16.48$). Most participants identified as NZ European or European (69/97, 71.1%), were female (61/97, 62.9%), and had completed at least secondary level education (45/96, 46.9%). Participants reported an average of 182 minutes of moderate exercise in the last seven days at baseline ($SD= 186.10$). There were no baseline differences in demographic, clinical, or baseline variables between groups except for length of hospital stay, where the control group had a significantly longer hospital stay than the active control group ($p= .031$) (see Table 1).
As reported above, usable step count data was available for 57 out of 96 participants who completed baseline assessments. Within the sample of participants who did have available step count data, 12% of the data was missing. The mean number of days with missing data was 0.84 days ($SD=1.69$). Data was exclusively available from colorectal patients. Clinical and demographic variables that did differ between those with and without step count data were a reflection of differences between the colorectal and gynaecological oncology patient samples. These differences included a significant association between those who did and did not have data and both ethnicity ($\chi^2=11.59$, $p=.021$, $\phi=.34$), and gender ($\chi^2=17.07$, $p<.001$, $\phi=.42$). There were more male participants with available step count data ($26/30$, 86.7%) than without, and more NZ European participants with available step count data ($42/67$, 62.7%) than without. There was also a significant difference between the groups in length of hospital stay (with step count data $M=6.82$, $SD=4.07$; without step count data $M=4.27$, $SD=3.30$; $t_{(83)}=-3.22$, $p=.002$), which again was a reflection of this difference between the gynaecological oncology and colorectal samples.

Within the participants who did have step count data, there were no significant differences in any demographic and clinical variables between groups, except for a significant main effect of length of hospital stay between groups ($F_{(2, 54)}=3.89$, $p=.026$). Multiple comparisons however revealed no significant differences between any of the three groups ($p>.05$). The sample with step count data were demographically similar to the whole study sample, regarding age ($M=58.96$, $SD=14.96$), gender (45.6% female), ethnicity (80.7% NZ European/European), and education (47.4% completed secondary education). There were also no significant differences between groups in self-reported exercise among those participants who did have available step count data ($p>.05$).
<table>
<thead>
<tr>
<th></th>
<th>Intervention M (SD)</th>
<th>Active Control M (SD)</th>
<th>Control M (SD)</th>
<th>Test statistic (F or χ²)</th>
<th>df</th>
<th>p</th>
<th>Total sample M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline self-reported exercise</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mins)</td>
<td>224.45 (245.29)</td>
<td>168.23 (163.11)</td>
<td>160.71 (135.29)</td>
<td>1.03</td>
<td>2, 87</td>
<td>.361</td>
<td>185.26 (188.75)</td>
</tr>
<tr>
<td><strong>Health VIPS total score</strong></td>
<td>3.66 (0.73)</td>
<td>3.83 (0.54)</td>
<td>3.56 (0.67)</td>
<td>1.38</td>
<td>2, 93</td>
<td>.256</td>
<td>3.68 (0.65)</td>
</tr>
<tr>
<td><strong>Surgery Perceptions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helpfulness</td>
<td>9.42 (1.09)</td>
<td>9.28 (1.22)</td>
<td>9.23 (1.60)</td>
<td>0.19</td>
<td>2, 93</td>
<td>.824</td>
<td>9.31 (1.31)</td>
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<tr>
<td>Post-surgery symptoms</td>
<td>6.27 (1.89)</td>
<td>6.25 (2.27)</td>
<td>6.77 (1.96)</td>
<td>0.63</td>
<td>2, 92</td>
<td>.537</td>
<td>6.42 (2.04)</td>
</tr>
<tr>
<td>Concerns</td>
<td>5.69 (3.18)</td>
<td>6.09 (2.60)</td>
<td>6.25 (3.10)</td>
<td>0.30</td>
<td>2, 93</td>
<td>.739</td>
<td>6.01 (2.95)</td>
</tr>
<tr>
<td>Emotional response</td>
<td>4.72 (3.09)</td>
<td>5.66 (2.46)</td>
<td>5.03 (2.74)</td>
<td>0.95</td>
<td>2, 92</td>
<td>.392</td>
<td>5.14 (2.77)</td>
</tr>
<tr>
<td><strong>Recovery Perceptions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consequences</td>
<td>6.06 (2.26)</td>
<td>6.65 (2.19)</td>
<td>6.48 (2.42)</td>
<td>0.58</td>
<td>2, 93</td>
<td>.561</td>
<td>6.40 (2.28)</td>
</tr>
<tr>
<td>Timeline</td>
<td>4.20 (1.63)</td>
<td>4.13 (1.64)</td>
<td>4.95 (2.54)</td>
<td>1.69</td>
<td>2, 93</td>
<td>.190</td>
<td>4.42 (1.99)</td>
</tr>
<tr>
<td>Personal control</td>
<td>7.45 (2.00)</td>
<td>6.72 (1.76)</td>
<td>6.84 (1.95)</td>
<td>1.39</td>
<td>2, 93</td>
<td>.254</td>
<td>7.01 (1.92)</td>
</tr>
<tr>
<td>Concerns</td>
<td>4.33 (2.35)</td>
<td>4.81 (2.40)</td>
<td>5.77 (3.13)</td>
<td>2.45</td>
<td>2, 93</td>
<td>.092</td>
<td>4.96 (2.68)</td>
</tr>
<tr>
<td><strong>Early Mobilisation Perceptions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding</td>
<td>8.67 (1.98)</td>
<td>8.70 (1.56)</td>
<td>9.03 (1.12)</td>
<td>0.48</td>
<td>2, 91</td>
<td>.622</td>
<td>8.79 (1.60)</td>
</tr>
<tr>
<td>Motivation</td>
<td>8.48 (2.50)</td>
<td>8.56 (1.87)</td>
<td>8.40 (2.07)</td>
<td>0.05</td>
<td>2, 91</td>
<td>.954</td>
<td>8.48 (2.08)</td>
</tr>
<tr>
<td>Anxiousness</td>
<td>3.88 (3.24)</td>
<td>4.47 (2.82)</td>
<td>5.33 (3.13)</td>
<td>1.73</td>
<td>2, 91</td>
<td>.183</td>
<td>4.53 (3.09)</td>
</tr>
<tr>
<td><strong>Early Oral Nutrition Perceptions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding</td>
<td>8.03 (2.58)</td>
<td>8.03 (2.01)</td>
<td>8.66 (1.61)</td>
<td>0.87</td>
<td>2, 91</td>
<td>.424</td>
<td>8.22 (2.12)</td>
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<tr>
<td>Motivation</td>
<td>8.21 (2.07)</td>
<td>7.97 (1.96)</td>
<td>8.25 (2.02)</td>
<td>0.19</td>
<td>2, 91</td>
<td>.830</td>
<td>8.14 (2.00)</td>
</tr>
<tr>
<td>Anxiousness</td>
<td>3.33 (2.99)</td>
<td>3.97 (2.97)</td>
<td>4.87 (3.03)</td>
<td>2.06</td>
<td>2, 91</td>
<td>.133</td>
<td>4.03 (3.03)</td>
</tr>
<tr>
<td><strong>Traditional surgery beliefs</strong></td>
<td>3.72 (2.47)</td>
<td>4.02 (2.09)</td>
<td>4.11 (2.80)</td>
<td>0.22</td>
<td>2, 91</td>
<td>.807</td>
<td>3.94 (2.44)</td>
</tr>
<tr>
<td>Confirmed cancer (Y)</td>
<td>28 [84.8%]</td>
<td>24 [75.0%]</td>
<td>23 [74.2%]</td>
<td>1.34</td>
<td>2</td>
<td>.513</td>
<td>31 [78.1%]</td>
</tr>
<tr>
<td>Length of hospital stay (days)</td>
<td>5.44 (3.37)</td>
<td>4.74 (3.05)</td>
<td>7.29 (4.85)</td>
<td>3.66</td>
<td>2, 91</td>
<td>.030</td>
<td>5.81 (3.94)</td>
</tr>
<tr>
<td>30 day re-admission (Y)</td>
<td>5 [15.6%]</td>
<td>6 [19.4%]</td>
<td>4 [12.9%]</td>
<td>0.49</td>
<td>2</td>
<td>.785</td>
<td>15 [16.0%]</td>
</tr>
</tbody>
</table>
Laparoscopic surgery (Y) (n= 92)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>No (Y)</th>
<th>Yes (%)</th>
<th>Total (%)</th>
<th>M</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14 [43.8%]</td>
<td>22 [71.0%]</td>
<td>18 [58.1%]</td>
<td>4.78</td>
<td>2</td>
<td>.092</td>
</tr>
<tr>
<td>Stoma (Y) (n=92)</td>
<td>3 [9.4%]</td>
<td>4 [12.9%]</td>
<td>3 [9.7%]</td>
<td>0.25</td>
<td>2</td>
<td>.882</td>
</tr>
<tr>
<td>Primary procedure CR (n=66)</td>
<td>9.11</td>
<td>8</td>
<td>.333</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>54 [57.4%]</td>
<td>10 [10.6%]</td>
<td>18 [26.9%]</td>
<td>0.25</td>
<td>2</td>
<td>.882</td>
</tr>
</tbody>
</table>

- **Segmental colectomy**: 4 [19.0%], 9 [39.1%], 5 [21.7%], 18 [26.9%]
- **Anterior resection**: 7 [33.3%], 9 [39.1%], 7 [30.4%], 23 [34.3%]
- **Ileostomy reversal**: 8 [38.1%], 2 [8.7%], 6 [26.1%], 16 [23.9%]
- **Proctectomy**: 0 [0.0%], 2 [8.7%], 2 [8.7%], 4 [6.0%]
- **Other**: 2 [9.5%], 1 [4.3%], 3 [13.0%], 6 [9.0%]

Primary procedure gynae (n= 26)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>No (Y)</th>
<th>Yes (%)</th>
<th>Total (%)</th>
<th>M</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAHBSO + PLND</td>
<td>6 [54.4%]</td>
<td>6 [75.0%]</td>
<td>6 [75.0%]</td>
<td>6.49</td>
<td>6</td>
<td>.370</td>
</tr>
<tr>
<td>RH + PLND</td>
<td>1 [9.1%]</td>
<td>1 [12.5%]</td>
<td>0 [0.0%]</td>
<td>2 [7.4%]</td>
<td>2 [7.4%]</td>
<td></td>
</tr>
<tr>
<td>Ovarian debulking +/- BR</td>
<td>4 [36.4%]</td>
<td>0 [0.0%]</td>
<td>2 [25.0%]</td>
<td>6 [22.2%]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staging laparoscopy</td>
<td>0 [0.0%]</td>
<td>1 [12.5%]</td>
<td>0 [0.0%]</td>
<td>1 [3.7%]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note.** Bolded P indicates significance at p< .05. TAHBSO= Total abdominal hysterectomy with bilateral salpingo-oophorectomy, PLND= Pelvic lymph node dissection, RH= Radical hysterectomy, BR= Bowel resection. Baseline self-reported exercise (mins) refers to week prior to baseline assessment.
An ANCOVA (controlling for baseline self-reported exercise and length of hospital stay) revealed no group differences in change scores in self-reported exercise from baseline to follow-up (p>.05).

The mixed model analysis revealed no interaction effect between group and time in step count data. There was, however, a significant main effect of group ($F_{(2, 67.95)}= 3.58$, $p=.033$, partial $\eta^2 = .10$). Post-hoc comparisons revealed a significantly greater step count in the intervention group ($M_{adj} = 2294.60$, CI [1746.11, 2744.89], range= 12310), compared to the control group ($M_{adj} = 1347.25$, CI [826.51, 1871.20], range= 6872; $p = .05$, $d = .49$). There were no significant differences between the intervention group and the active control group ($M_{adj} = 1504.28$, CI [1078.41, 2038.14], range= 7550.31; $p> .05$), or the active control group and the control group ($p> .05$) (see Figure 3).

There was also a significant main effect of time on step count ($F_{(6, 123.6)}= 2.69$, $p=.017$, partial $\eta^2 = .12$). Post-hoc comparisons revealed a significantly greater step count at day 4 ($M_{adj} = 1934.84$, CI [1503.26, 2366.43], range= 6677) compared to day 2 post-discharge ($M_{adj} = 1180.9$, CI [837.28, 1524.37], range = 8467; $p= .02$, $d= .47$). There were no differences in time for any other days ($p$'s> .05).

Figure 3. Adjusted mean average step count per day between groups from day of discharge for the following week. Error bars depict standard error.
Psychological Outcomes

**Perceptions of surgery and recovery.** A MANOVA found no difference between groups in change scores for perceptions of surgery and recovery outcomes from baseline to post-surgery ($p > .05$).

**Quality of recovery.** An ANCOVA (controlling for length of hospital stay) revealed a significant main effect of group in quality of recovery scores at post-surgery ($F_{(2, 90)} = 3.27, p = .043$, partial $\eta^2 = .07$). Post-hoc comparisons revealed significantly greater QOR-15 score in the intervention group ($M_{adj} = 104.34, CI [97.95, 110.73]$, compared to the control group at post-surgery ($M_{adj} = 92.65, CI [86.01, 99.29]; p = .043, d = .75$). There were no differences between the active control group ($M_{adj} = 96.91, CI [90.35, 103.48]; p > .05$) and the intervention, or the active control and control groups ($p > .05$). Differences between groups were not maintained at follow-up ($p > .05$).

*Figure 4.* Bars represented adjusted mean in quality of recovery scores between groups at post-surgery. Error bars indicate standard error. *indicates significance at $p > .05$.

**Perceptions of early mobilisation and early oral nutrition.** A MANOVA (controlling for length of hospital stay) conducted to assess differences in change scores in perceptions of early mobilisation and early oral nutrition from baseline to post-presentation, found no differences between groups ($p > .05$).
A separate MANOVA (controlling for length of hospital stay) was conducted to assess differences in change scores in perceptions of early mobilisation and early oral nutrition from baseline to follow-up. Although the multivariate test did not reach significance ($p = .053$), univariate tests revealed a between groups difference in change scores from baseline to follow-up in anxiety about re-introducing food and drink ($F(2, 88) = 4.27, p = .017$, partial $\eta^2 = .09$). The intervention group had a significantly greater reduction in anxiousness ($M_{adj} = -1.92, CI [-3.05, -0.79]$) compared to the control group ($M_{adj} = 0.53, CI [-0.68, 1.75], p = .016, d = .73$). There were no significant differences between the active control ($M_{adj} = -0.74, CI [-1.90, 0.42]$) and intervention ($p > .05$), or the active control and control group ($p > .05$). There were no significant differences between the other univariate tests ($p > .05$).

MANOVAs (controlling for length of hospital stay) were also conducted at post-surgery and follow-up respectively, to assess between groups differences in difficulty being active, and eating and drinking during recovery. At post-surgery, there was a significant difference found between groups in the dependent measures ($F(4, 178) = 2.60, p = .038$, Wilks’ Lambda = .89, partial $\eta^2 = .06$). Univariate tests revealed a significant between groups effect in anticipated difficulty regarding being active ($F(2, 90) = 4.02, p = .021$, partial $\eta^2 = .08$), but not eating and drinking ($p > .05$). Post-hoc comparisons revealed significantly greater anticipated difficulty with being active in the control group ($M_{adj} = 5.32, CI [4.40, 6.24]$) compared to the intervention group ($M_{adj} = 3.64, CI [2.76, 4.53], p = .037, d = .80$). There were no differences found between the active control and intervention group ($M_{adj} = 5.05, CI [4.14, 5.96], p > .05$), or the control group ($p > .05$).

At follow-up, there was also a significant difference between groups in the dependent measures ($F(4, 178) = 3.10, p = .017$, Wilks’ Lambda = .87, partial $\eta^2 = .07$). Univariate tests revealed a significant difference between groups in difficulty eating and drinking during recovery ($F(2, 90) = 4.96, p = .009$, partial $\eta^2 = .10$), but not for difficulty being active ($p > .05$). Post hoc comparisons revealed significantly greater difficulty with eating and drinking during recovery for the control group ($M_{adj} = 4.42, CI [3.44, 5.40]$), as compared to the intervention group ($M_{adj} = 2.33, CI [1.38, 3.27], p = .010, d = .86$). There were no significant differences between the active control group ($M_{adj} = 2.80, CI [1.83, 3.77]$) and the intervention group ($p > .05$), or the control group ($p > .05$).

Traditional Surgery Recovery Beliefs. An ANCOVA (controlling for length of hospital stay) found no differences between groups in change scores of traditional surgery recovery beliefs from baseline to post-surgery ($p > .05$).
Evaluation of intervention and active control materials

There were no significant differences between the intervention and active control group in their ratings of the information received (p > .05). Overall, both intervention and active control participants rated the presentation high in helping to improve their understanding of ERAS behaviours, as being interesting, and in improving their motivation regarding ERAS behaviours (Ms range from 7.64 to 9.17). Both forms of information also did not make either group highly anxious regarding being active and eating and drinking post-surgery (Ms range from 1.48 to 2.66).

Discussion

This study is the first to examine how an active visualisation intervention could improve adherence to early mobilisation following surgery. Although limited by a reduced sample size, our study found that intervention participants, consisting of colorectal surgery patients, showed greater step count across discharge and the following week post-surgery compared to those who received standard care only.

The intervention also produced changes in psychological outcomes regarding postoperative ERAS behaviours and patients’ perceived quality of recovery. Intervention participants had more positive perceptions of recovery at post-surgery and found mobilization less difficult than control participants. Intervention participants also had a decrease in their anxiety about eating and drinking at follow-up compared to the control group, and found eating and drinking during their recovery less difficult.

Overall, these findings provide initial evidence for the intervention to improve adherence to early mobilisation. It may be that seeing the physiological processes of early mobilisation provides a link between the information and behaviour, as compared to standard care or only receiving this information verbally. These results align with visualisation theory which suggests that visual information has increased salience, is easier to understand (Brotherstone, Miles, Robb, Atkin, & Wardle, 2006), and therefore can increase intentions to change behaviour (Williams, Anderson, Barton, & McGhee, 2012).

As highlighted above, previous studies with ERAS patients have relied upon one-on-one staff-directed methods to increase adherence to mobilisation (Castelino et al., 2016). To the authors’ knowledge, this is the first intervention with ERAS surgery patients that has not used staff-direction and monitoring to increase adherence to early mobilisation. These findings suggest that this brief intervention may be useful in encouraging patients to self-manage their mobilisation effectively.

The changes in psychological outcomes also demonstrate a shift in mindset that would promote adherence and support the objective data. It has been suggested that changing traditional
recovery beliefs can be challenging (Pearsall et al., 2015). If traditional recovery beliefs are associated with hesitations to mobilise, simply instructing a patient to undertake ERAS behaviours will likely be ineffective. This intervention demonstrates how these beliefs can be modified. Furthermore, the intervention was able to not only increase adherence to mobilisation, but also appeared to reduce anxiety and difficulty with eating and drinking post-surgery, which is an important complementary ERAS behaviour to early mobilisation.

No previous visualisation studies have reported objective improvements in a health behaviour other than adherence to medicine. A similar animated intervention successfully improved seven week self-reported exercise in patients recovering from acute coronary syndrome (Jones et al., 2016). Our findings provide initial objective evidence that visualisation can improve postoperative mobilisation, a behaviour important to recovery from any surgery.

The findings of the current study also suggest that visual information appears to be more effective than receiving verbal information only, as demonstrated by a lack of significant differences between the control and active control groups in outcomes. This is an finding, as previous visualisation interventions have only compared receiving visualisation with standard care. The results of this study are the first to suggest that visual information appears to provide an important, additive effect in changing outcomes that is not achieved by providing the same information verbally.

There are strengths of the current study and findings presented. First, the study used a randomised controlled design. The primary outcome was assessed using an objective, continuous, non-invasive measure of physical activity, which has been a limitation of previous ERAS research (Abeles et al., 2017). Nearly all studies included in a recent review of post-surgical mobilisation (Castelino et al., 2016) assessed outcomes such as complications and length of stay, which are not direct measures of adherence to mobilisation. Furthermore, the current study assessed mobilisation at and following discharge. This provides an indication of how participants’ self-managed their recovery behaviour in the home environment. Finally, another strength of the study is the use of a three-arm trial and an active control group, to ascertain the additive effects of visual information in comparison to receiving the same information verbally.

This intervention has high clinical applicability to be incorporated into post-surgical care. The intervention is not resource-intensive, and is brief and portable. Any staff member could deliver the presentation on a computer tablet at the patients’ bedside. This could be useful before initial mobilisation. The intervention seems particularly worthwhile if it can increase patient self-management
of their mobility without additional staff input. The intervention could also be utilised by ERAS nurse specialists as part of the preoperative education materials provided during surgical pre-admission.

Limitations of the study findings should also be taken into consideration. First, although all participants wore our trackers, data was not retrievable for over 40% of our sample. This issue was uncontrollable as the company suddenly removed their online servers and application preventing access to data received later in the recruitment period. This had clear implications for statistical power and ability to detect significant results. Regardless, the significance found provides initial evidence with a reduced sample size that the intervention appears efficacious in objectively increasing adherence to early mobilisation.

A related limitation is that step count data was only available from colorectal surgery patients. As discussed above, there are clinical and demographic differences between the two samples, meaning that results cannot be generalised to gynaecological oncology patients. It is uncertain whether the intervention would also have been effective in this group. The psychological outcomes, however, do suggest that the intervention is effective in improving perceptions of ERAS behaviours and traditional surgery beliefs for both patient groups.

It may also have been useful to measure patients’ step counts pre-surgery, to assess whether there were differences between the randomised study groups in general exercise levels. The self-report measure used to assess this at baseline however found no differences between groups.

Another important consideration is that simply wearing a fitness tracker can influence patient behaviour (Low et al., 2018). Attempts to limit this influence included selecting a fitness tracker without numerical display of step count. Step count average was only visible around the perimeter of the tracker face by pushing a button. Participants were not informed about this function and were instructed not to push any buttons on the tracker. Furthermore, study participants in all groups wore trackers to account for any influence upon mobilisation.

Finally, potential limitation of the intervention and active control information delivery is the lack of an evaluation of intervention fidelity and participant engagement between the two researchers delivering these materials. However, a standardised script was used by both researchers to ensure that intervention content was matched.

Future research should attempt replication of our findings within a larger trial. The same presentation could be used with other ERAS patients or any surgery patients who would benefit from increasing early mobilisation. Future research should also attempt to understand the underlying mechanisms of improved adherence to early mobilisation. Theoretically, these may include improved
understanding of these behaviours, decreased anxiety, increased social support, or lack of symptoms such as fatigue and pain. Although the current study was not adequately powered to perform mediation and moderation analyses, future research should focus on deducing these mechanisms to further inform intervention design and increase potential efficacy. This brief intervention, however, provides initial promise of a new strategy for promoting patient self-management to post-surgery mobilisation.
References


