Continuing education for optometrists

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Continuing Education for Optometrists

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A thesis in fulfillment of the requirements for the degree of Doctor of Philosophy

School of Optometry and Vision Science

Faculty of Medicine

March 2021

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Thesis Title

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Thesis Abstract

Abstract

Effective continuing professional development (CPD) has the potential to yield better health outcomes for optometrists and their patients. A conceptual model of CPD provided a framework to characterize CPD and its outcomes. A mixed-method approach was chosen for this thesis. Across three studies this thesis measured optometrists' perspectives of CPD, the effectiveness of a specific CPD activity, and optometrists' capability in critically appraising the most frequently presented statistical methods in articles published in relevant ophthalmic scientific journals.

An in-depth study of the perspectives of optometrists towards CPD via focus groups and interviews was conducted and responses coded to the Cabana determinant framework. Optometrists' attitude towards CPD was modulated by their outcome expectancy, self-efficacy, the inertia of previous practice and their desire for self-improvement. A Likert scale measure of 46 optometrists' attitudes towards CPD revealed positive attitudes with mean score of 72% (Mean=20.27, SD=3.81, Range 0-28). Meanwhile, the self-efficacy of these optometrists on the topic of Choroidal lesions was moderate (59%) or often times weak.
A quasi-randomized controlled trial comparing the online experience of an Adaptive (n=22) to a Traditional (n=24) CPD intervention demonstrated that Traditional learners lost significantly more knowledge at 12 weeks compared to those optometrists randomized to the Adaptive CPD arm of the intervention (T=3, p=0.01, r=-0.52). Adaptive learning was also seen as more fun.

The final study evaluated the alignment between the level of statistical knowledge required to successfully appraise the ophthalmic literature and optometrists' self-reported knowledge, attitudes, and practices (KAP) of statistics. The most used tests were: descriptive, t-tests, contingency tables, non-parametric tests and ANOVAs. Together these tests were present in 61% of the 358 articles audited. Optometrists demonstrated very poor knowledge of t-tests, contingency tables, and ANOVAs (averages of <50% correct).

Overall, the findings of this mixed-method thesis indicated that optometrists have a positive attitude to CPD and wish to maintain and expand their learning across a lifetime. CPD specifically focused on statistics would enable more effective lifelong learning in optometrists. Any gaps in knowledge or practice cannot be attributed to a lack of desire to learn more.

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ABSTRACT

Effective continuing professional development (CPD) has the potential to yield better health outcomes for optometrists and their patients. A conceptual model of CPD provided a framework to characterize CPD and its outcomes. A mixed-method approach was chosen for this thesis. Across three studies this thesis measured optometrists' perspectives of CPD, the effectiveness of a specific CPD activity, and optometrists' capability in critically appraising the most frequently presented statistical methods in articles published in relevant ophthalmic scientific journals.

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PUBLICATIONS

Journal Articles

*Gyawali R, Toomey M, Stapleton F, Zangerl B, Dillon L, Ho KC, Keay L, Liew G, **Alkhawajah SM**, Jalbert I. Quality of clinical practice guidelines for diabetic eye disease: a systematic review and critical appraisal. J Clin Epidemiol 2021; Under Review.*

*Ho KC, Stapleton F, Wiles L, Hibbert P, **Alkhawajah S**, White A, Jalbert I. Systematic review of the appropriateness of eye care delivery in eye care practice. BMC Health Serv Res 2019; 19: 646.*

Conference Papers

*Gyawali R, Toomey M, Stapleton F, Zangerl B, Dillon L, Ho KC, Keay L, **Alkhawajah SM**, Liew G, Jalbert I. Eyes on guidelines: evaluating the quality of diabetic eye disease clinical practice guidelines. Invest Ophthalmol Vis Sci 2021; Submitted for presentation.*

***Alkhawajah, S. M.,** Wei, K., Lee, J., Challinor, K. L. & Jalbert, I. (2020) Statistics–What do optometrists need to learn and understand? Investigative Ophthalmology & Visual Science, 61 (7), 5108-5108; abstract accepted.*

*Gyawali R, Toomey M, Ho KC, **Alkhawajah SM**, Zangerl B, Dillon L, Keay L, Stapleton F, Liew G, Jalbert I. Quality of the National Health Medical Research Council (NHMRC) Clinical Practice Guidelines for the management of diabetic retinopathy in Australia. Invest Ophthalmol Vis Sci 2020;61: 1607.*

Protocol Registration

*Ho KC, Stapleton F, Wiles L, Hibbert P, **Alkhawajah S**, White A, Jalbert I. Systematic review of the appropriateness of eye care delivery in eye care practice. PROSPERO. 2016: CRD42016049974. Available from http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42016049974/*

The candidate contributed to research studies that are not the subject of this thesis (someone else's thesis) as it is listed in the Publications section in this page.

The candidate took the lead on all of the research aspects for the experiments of the three chapters: Optometrists' Perspectives of Continuing Professional Development (CPD): A Qualitative Study, Adaptative versus Traditional CPD in Optometry: A Quasi-Randomized Trial, and Statistics in Optometry from conception, literature review, experimental design, data collection, analysis, discussion, and conclusion.

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Chapter 1. Introduction

Chapter 2. Optometrists' Perspectives of Continuing Professional Development (CPD): A Qualitative Study

Chapter 3. Adaptative versus Traditional CPD in Optometry: A Quasi-Randomized Trial

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DEFINITIONS

Adaptive Learning is the delivery of custom learning experiences that address the unique needs of an individual through just-in-time feedback, pathways, and resources, rather than providing a one-size-fits-all learning experience (Smart Sparrow, 2019).

Audit and Feedback is a process where an individual's professional practice or performance is measured and then compared to professional standards or targets. The results of this comparison are then fed back to the individual, with the aim to encourage the individual to follow professional standards (Ivers et al., 2012).

Authentic Learning is a pedagogical approach that situates learning tasks in the context of real-world situations, and in so doing, provides opportunities for learning by allowing students to experience the same problem-solving challenges in the curriculum as they will in their future daily endeavors (Herrington et al., 2014).

Clinical outcomes are any change in the health status, health-related behavior, or attitudes of patients about the physicians for whom the continuing education intervention was directed (Marinopoulos & Baumann, 2009).

Continuing Professional Development (CPD) is the maintaining, improving, and broadening of a health practitioner's knowledge, skill, and expertise throughout their professional career (Toomey & Jalbert, 2021).

Dissemination is the communication of information to improve knowledge and skills; it is more active than diffusion (Cabana et al., 1999).

Electronic learning (e-learning) is the training, learning, or education delivered online through a computer or any other digital device (Lawless, 2018).

Evidence-Based Practice (EBP) Is the practice of integrating best available evidence with practitioner expertise and the patient's preferences and circumstances within the context of the clinical environment (Satterfield et al., 2009).

Framework is a system of rules, ideas, or beliefs that is used to plan or decide something (Cambridge University Press, 2021).

Interactive learning includes all methods of purposeful learner engagement with data supported by learners interacting with others (instructor or colleagues) and themselves (Baylor University, 2021).

Interprofessional Education (IPE) is the teaching and learning of individuals from different professions together during all or part of their professional training – and in practice – in order to promote collaborative working in their professional practice (CAIPE 1997).

Knowledge Translation (KT) is the process that includes the synthesis, dissemination, exchange, and ethically sound application of knowledge to improve health, provide more effective health services and products, and strengthen the health care system (CIHR, 2020).

Learning means the way in which individuals or groups acquire, interpret, reorganize, change, or assimilate a related cluster of information, skills and feelings, and a means by which individuals construct meaning in their personal and shared organizational lives (AAMC, 2010).

Lifelong learning (LLL) is the voluntary and self-motivated pursuit of knowledge for either personal or professional reasons (wikipedia, 2021). An approach to learning whereby health professionals continually engage in learning for personal goals (IOM, 2010).

Online learning is learning which takes place in front of a computer that is connected to the Internet (Shute & Towle, 2003).

Practice behavior referred to any type of physician/healthcare practitioner behavior (Marinopoulos & Baumann, 2009).

Professional Competencies are skills, knowledge and attributes that are specifically valued by the professional associations, organizations and bodies connected to your future career (UVic, 2020).

Reflection is a learning tool in which an individual evaluates how experiences can guide action (IOM, 2010).

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ABBREVIATIONS

AAO	American Academy of Ophthalmology
AHPRA-RU	Australian Health Practitioner Regulation Agency’s Research Unit
AMD	Age-related Macular Degeneration
BOptom	Bachelor of Optometry
BPsych	Bachelor of Psychology
CE	Continuing education
CEO	Clinical and Experimental Optometry
CfEH	Center for Eye Health
CI	Confidence interval
CONSORT	Consolidated Standards of Reporting Trials
COREQ	Consolidated Criteria for Reporting Qualitative Research
CPD	Continuing Professional Development
e.g.,	for example
et al.	and others
etc.	Et cetera
FAAO	Fellow of the American Academy of Optometry
i.e.,	that is to say
IQR	Inter Quartile Range
JBI	Joanna Briggs Institute
KSU	King Saud University
M	Mean
Mdn	Median
MMM	Modified Monash Model
MOptom	Master of Optometry
MPH	Master of Public Health
NA	not applicable
No.	number

NSW	New South Wales
OA	Optometry Australia
OBA	Optometry Board Australia
OCT	Optical Coherence Tomography
OD	Doctor of Optometry
OPO	Ophthalmic & Physiological Optics
OVS	Optometry and Vision Science
PhD	Doctor of Philosophy
QLD	Queensland
SA	South Australia
SD	Standard deviation
SPSS	Statistical Product and Service Solutions
UK	United Kingdom
UNSW	University of New South Wales
USA	United States of America
VIC	Victoria
vs	versus

Chapter 1. Introduction

This chapter defines and summarizes the literature on continuing professional education. It will examine theoretical models of professional education, review its significance, and examine its effectiveness before focusing on reviewing the specific literature on continuing education in optometry.

1.1. Continuing Professional Development or CPD

Continuing professional education is defined as educational activities that serve to maintain, develop, or increase the knowledge, skills, performance and relationships a professional uses to provide services (or care) to patients, the public or a profession (Marinopoulos & Baumann, 2009). An accepted singular definition of continuing professional education does not exist in the literature (Gould et al., 2004). It is readily acknowledged by many but not all that the terms development and education are synonymous (Lawton & Wimpenny, 2003), such that continuing professional education and continuing professional development (CPD) are often interchangeable terms.

CPD has been defined as the continuing supply, achievement and expansion of knowledge, skills and concepts to enable practitioners to improve in their career (Sriharan et al., 2009). For health professionals, CPD can be defined as post registration acquisition of skills or knowledge related to healthcare (Brown et al., 2002). The term CPD encompasses a wider range of modalities that aim to develop professionals' skills rather than just education. In line with recommendations from the *Lifelong Learning in Medicine and Nursing Final Conference Report*, this thesis adopts a broad definition of CPD that incorporates both formal or traditional education, as well as other types of activities (AAMC, 2010). This contemporary definition includes formal educational programs, as well as use of guidelines, mentoring, and independent study. CPD can also integrate content and educational design for individual practitioners in the practice setting (IOM, 2010).

Continuing professional education or CPD occurs when healthcare professionals' access, attend and interact with a mixture of events and techniques, for example evaluating, training, discussing, investigating, to ensure that their learning process is ongoing throughout their career. This may for example include training, audit, management, team building and communication (Boulay, 2000). However, there is not always a clear sharp division between continuing education and CPD (IOM, 2010), since continuing education has recently come to include administrative, public and subjective skills, as well as taking account of themes beyond the traditional clinical ones. Continuing education and CPD are not independent terms as continuing education has included topics beyond the traditional clinical health subjects, such as social, managerial and personal skills (Peck et al., 2000). Whilst acknowledging that the terms continuing education and CPD may have slightly different meanings in some contexts, for the purpose of this thesis we treat the terms interchangeably. For convenience, the term continuing professional development (CPD) will be used predominately in this thesis.

Health educational programs are expected to instill a belief in the value of, and skills in lifelong learning (AAMC, 2010). In medicine, continuing medical education is an established term used to define activities that facilitate lifelong learning with a focus on maintaining and developing knowledge, skills and attitudes, to ensure delivery of a medical care which is up-to-date, evidence based, safe and patient centered (AMA, 2017; Nazim et al., 2018). This process of lifelong learning begins after the formal process of education has ended and is distinct from higher education such as Master's or PhD degrees. Continuing education spans the duration of a professional's career, from graduation to retirement (IOM, 2010). CPD has also been defined as the system for maintaining, improving, and broadening knowledge and skill throughout one's professional life. It is focused squarely on promoting effective practice and is better positioned than other stages of learning to effect change because it occurs when professionals are most likely to be aware of their needs. It is the process by which health professionals keep updated to meet the needs of patients, health service, and their own professional development. It includes the continuous acquisition of new knowledge, skills, and attitudes to enable competent practice. Since CPD is a process of lifelong learning in practice, countries are integrating continuing education as a component of CPD programs and larger quality improvement initiatives (Sriharan et al., 2009).

Continuing education also helps to integrate new research findings into practice in a process called knowledge translation (CIHR, 2020; Toomey & Jalbert, 2021). For health professions an important goal of CPD is to bridge the gap between the best available evidence and practice behavior such that patients have the best health outcomes. Continuing education is considered essential for healthcare professionals in order for them to stay current with new knowledge developing in their area of expertise, sustain their proficiency for any new procedures and for new medications being constantly introduced to the marketplace, maintain high-quality patient care, and sometimes even to allow them to successfully manage their professional skills and knowledge in order to progress and specialize to the expert level in a chosen specialty field. Professional expertise has been described as the gradual transition from novice or competent (at graduation) to the level of expert within a profession (Faucher, 2011; Guest et al., 2001). CPD is integral to the process but is not the only factor involved in professionals developing to an expert level (Faucher, 2011).

Continuing education contributes to CPD, whereas maintenance of certification or revalidation certifies the CPD of health care workers (Ahmed et al., 2013). Healthcare professionals are often legally required to participate in CPD activities to meet regulations of their specific professional organization and to maintain their registration, license, or certification. Established revalidation and recertification of practitioners are driving the health professions towards mandatory CPD programs internationally, covering a spectrum of clinical, professional, and managerial activities. Approaches differ widely around the world, but most rely on self-regulation. Whatever system is adopted or legislated, however, every professional retains a personal responsibility to participate in CPD and has a choice of a wide range of educational activities to fulfil that responsibility (Peck et al., 2000).

1.2. Significance of CPD

Billions of dollars are spent every year on continuing education or CPD events worldwide. For example, in 1999-2000 the direct National Health Service (NHS) in the UK spent approximately $1.6bn on CPD (Brown et al., 2002; Levin, 2001; Vaughn et al., 2006), on the assumption that continuing education improves health professional practice and health care quality. Individually, health practitioners can easily spend a minimum of $2,000 and up to $10,000 Australian dollars per year towards CPD (McGilvray, 2013).

Scientific knowledge is growing faster than our ability to effectively absorb and utilize it. As an example, Densen, describes a ‘doubling time of medical knowledge’, referring to the time it takes for a given volume of knowledge to double in size. In the year 1950, this doubling time was estimated at 50 years; by 1980, this was reduced to 7 years and in 2010, 3 and a half years (Densen, 2011). Densen predicted the doubling time would be 0.2 years by the year 2020. This corresponds to a doubling in the amount of facts, information, and skills that practitioners need to “know” every 73 days (Densen, 2011). CPD theoretically helps professionals to keep up to date with the huge volume of knowledge pumped into their field of practice. On that basis, the need to deliver and develop effective CPD will continuously increase.

Conversely, it may take up to 17 years for a newly published study to be incorporated in healthcare practices; this delay between the establishment of new evidence and its adoption in clinical practice can be modulated by many factors including the strength of the scientific evidence, professional rules and guidelines, accessibility to and budget support for new treatments, and associated training requirements (Green, 2009). CPD could theoretically speed-up this process by demonstrating the examined, appraised and produced data to healthcare practitioners (Green et al., 2009).

The volume of information produced yearly is growing just as fast in the ophthalmic field. The need for lifelong learning or CPD in eyecare specifically is perhaps best evidenced by the explosion in the number of scientific articles published in the fields of optometry and ophthalmology over the last fifty years (Figure 1.1). A search was conducted on the PubMed database (https://pubmed.ncbi.nlm.nih.gov) using the keywords “optometry” OR “ophthalmology”. The number of published articles related to these keywords were then plotted by decade (Figure 1.1).

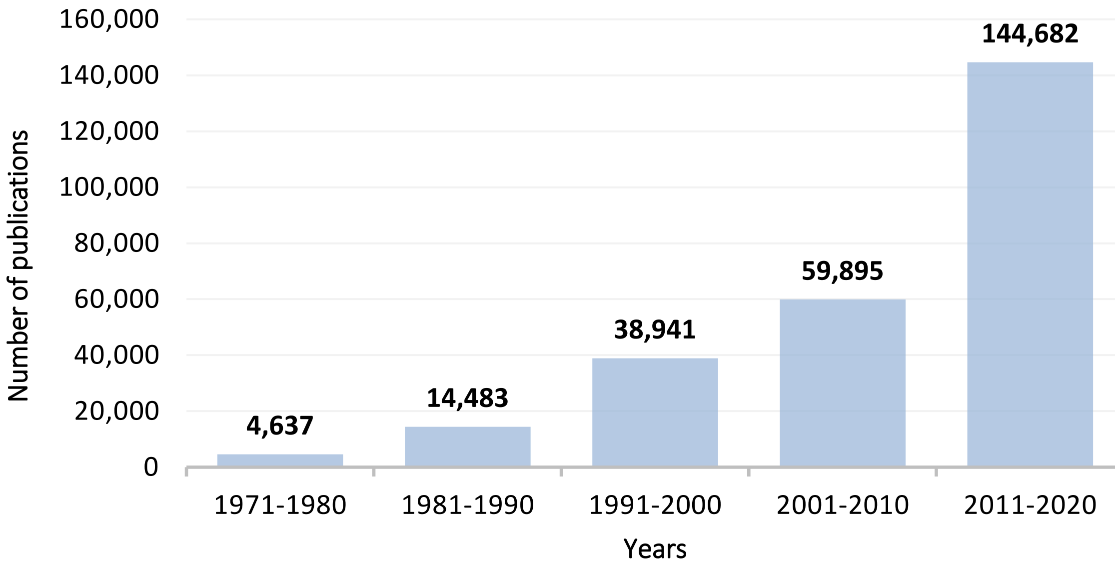

Figure 1.1 Exponential Growth of Published Ophthalmic Research

Number of articles published with key words ‘Optometry’ or ‘Ophthalmology’ between 1971 and 2020. Data extracted from PubMed® database (http://pubmed.ncbi.mlm.nih.gov).

As evidenced in Figure 1.1, there has been a marked increase in the volume of ophthalmic literature published, starting 50 years ago in 1971, with the pace of this increase appearing to grow exponentially over time. For example, more than 140,000 articles related to optometry and ophthalmology have been published in the last 10 years. This represents close to 40 new pieces of information every day (38.3), suggesting that a large volume of potentially relevant new knowledge is generated daily. A number of these new publications each day, month or year may be likely to necessitate or require changes to practice and/or to support the adoption of new diagnostic tests or new treatments that optometrists will have to incorporate in their everyday clinical routine. Ultimately, this means that at the close of an optometry student's graduation ceremony, their current knowledge of the ophthalmic field is already becoming outdated. Because information is increasing at a fast exponential rate, there is a need for post-graduate education or CPD so that professionals stay up to date.

1.3. A Conceptual Model of CPD

CPD may not be effective enough to completely or significantly bridge the gap between what is done in clinical practice and what should be done based on the best available evidence. Understanding the tools and techniques which are most effective in disseminating and retaining knowledge is critical to improving the effectiveness of CPD and thus diminishing the gap between evidence and practice. Relatively little has been done to synthesize evidence comprehensively and systematically regarding the effectiveness of CPD and the comparative effectiveness of differing instructional designs for CPD in terms of impact on knowledge, attitudes, skills, practice behavior, and clinical practice outcomes. The American College of Chest Physicians nominated CPD effectiveness as a topic to the Evidence- based Practice Center (EPC) Program of the Agency for Healthcare Research and Quality. As a result, the Johns Hopkins Evidence-based Center performed a systematic review to address key questions pertaining to the effectiveness of CPD (Marinopoulos, 2007). As part of this review a panel of experts from education and clinical medicine produced a conceptual model of continuing (medical) education or CPD to provide a framework for their systematic review. As the model was made with medicine in mind, it refers to physicians and medical education.

Other possible models are numerous, but these are often too narrow or specific in their application or focus or too wide. For example, the medical model of education ignores the complex interacting dynamics that impact and influence learning (Slavin, 2008). The design of CPD that follows the Framework for Action on Interprofessional Education and Collaborative

Practice would require health professionals from multiple professions to attend CPD together and learn with and from each other (WHO, 2010); this is unlikely to align with much of the contemporary CDP provided to optometrists. Miflin's conceptual framework for fostering self-direction was specifically designed for educational contexts that had exclusively adopted problem-based approaches to learning (Miflin et al., 2000). A recent proposal to use the adaptive expertise conceptual framework to support lifelong learning may focus attention on the solving of new and difficult-to-anticipate problems at the expense of continuous consolidation of everyday routine care (Steenhof, 2020).

In the following description and presentation of the Marinopoulos model, it is adapted to be aligned with the optometric focus of this thesis. For example, 'physician' is replaced with 'optometrist'. The modified conceptual model of continuing education (Marinopoulos & Baumann, 2009) in Figure 1.2 has been chosen, although it is not the only model, because it is focused on practice outcomes which suited our work because we were practice focused, characterizes factors that influence a learner's outcomes of knowledge, attitudes, skills and practice. The downstream outcome is clinical practice. Influential factors on the learner are grouped into four inter-relating categories: educator, CPD activity, external factors, and audience characteristics. Aspects of the CPD educator influence the learner such as the educator's university, industry, or government position, etc. The educator has a bi-directional relationship with a given CPD activity. Aspects of the activity include type of media used (e.g., online, offline, audio, video, print), the nature of the educational technique such as didactic, interactive or team based, and the specific activity content (e.g., facts, updates, and breath of information). The setting of the activity could be a university educator, a CPD conference, home, or a practice setting for example. The activity could be a one off or repetitive in nature. All these components of the CPD activity influence the learner (optometrist) and the learner in turn influences the activity. The leaner of CPD is also working within an external environment, so external factors such as regulation, licensing, financial rewards, and public demand impact the learner and the CPD. These external factors also guide the activities and the educators in the provision of effective CPD. Lastly the individual audience characteristics of the learner such as their age, setting, years from training and motivation also directly interact with the learning or CPD.

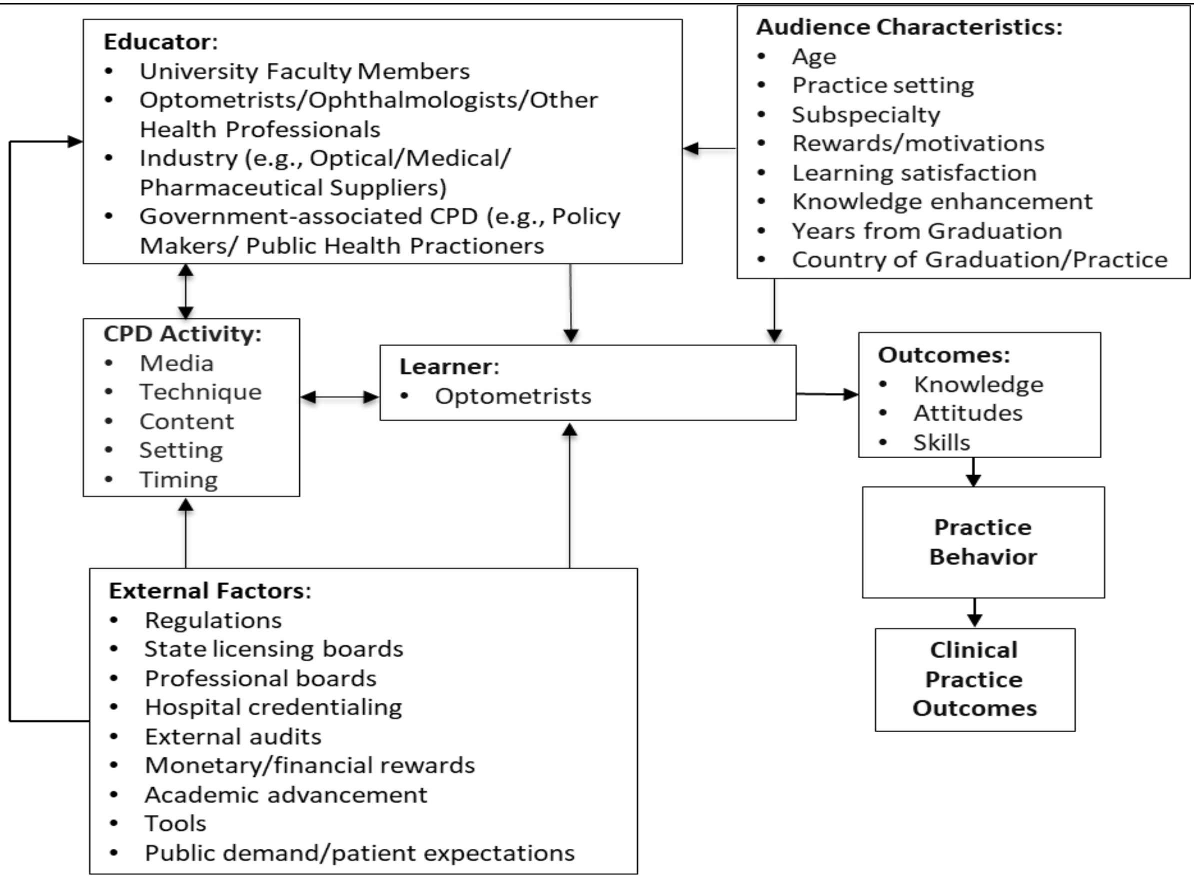

Figure 1.2 Conceptual Model of CPD

In the model of effectiveness if CPD the learner is the optometrist, and the outcomes of the education are knowledge, attitude and skills that hope to produce practice behaviors which result in optimal clinical practice outcomes. CPD = Continuing Professional Development.
(Adapted from (Marinopoulos & Baumann, 2009)).

1.4. Effectiveness of CPD

Reviewing the evidence elucidating the value of CPD (and ways the learning activities could be improved, if appropriate) could yield tremendous value to policy makers and professional organizations seeking to make recommendations regarding the optimal delivery of health care. The conceptual model in Section 1.3 above presents many factors such as the context and delivery of CPD that interact together to modulate the outcomes of CPD. It proposes that effectiveness can be measured as any or all of the three boxes on the right-hand side of the of the model: Outcomes, Practice Behavior and Clinical Practice outcomes. Outcomes refers to a practitioner's knowledge, attitudes, and skills, which result in practice behaviors. Based on this, for CPD to be effective it has to demonstrate that the competence and performance of practitioners has been improved as a result of the education, and or that the healthcare received by the patients was optimal (Forsetlund et al., 2009; Lloyd & Abrahamson, 1979). So, whilst health outcomes are the ultimate desired outcome, there are several possible levels at which to measure effectiveness of CPD education in this conceptual model.

These effectiveness factors align very well with Miller's (1990) pyramid of clinical competence with its four levels from bottom to top of "knows, knows how, shows how and does" (Miller, 1990). The bottom two levels of the pyramid refer to cognitive components of competence. The lowest level of the hierarchical pyramid is 'knowledge' as could be assessed by multiple choice questions. The second level is 'application of knowledge' as demonstrated in clinical problem-solving exercises. The third and fourth tiers of Miller's pyramid account for the behavioral components of clinical competence, which involve assessment in simulated and real clinical settings. Specifically, the third tier of the pyramid represents 'clinical skills competency', assessed in clinical exams. The peak of the pyramid represents 'clinical performance', assessed by direct observation in real clinical settings, or 'practice behaviors' as referred to in (Marinopoulos & Baumann, 2009).

Therefore, the sequence of outcomes in the conceptual model of CPD presented in Figure 1.2 (e.g., knowledge, attitudes, and behavior) towards practice behavior and ultimately to patient health outcomes parallels the stepped journey from the lower levels to the top level of the Miller pyramid of clinical competency. In summary, both models move from cognitions to a peak outcome of behavioral performance as an "trained" or "educated" health professional.

In the last two decades a number of reviews have systematically summarized the effectiveness of continuing education (Akl et al., 2013; Cervero & Gaines, 2015; Forsetlund et al., 2009; Ivers et al., 2012b; JBI, 2012; Marinopoulos, 2007; O'Brien et al., 2007; Scott et al., 2012). These papers are summarized in Table 1.1.

The Johns Hopkins evidence-based practice center synthesized evidence regarding the effectiveness of CPD and differing instructional designs in terms of knowledge, attitudes, skills, practice behavior, and clinical practice outcomes (Marinopoulos, 2007). Specific questions were drawn from the conceptual model presented in Figure 1.2. Synthesizing across 136 articles and nine systematic reviews, they found that continuing education or CPD is effective, at least to some degree, in not only achieving, but also in maintaining the objectives studied. The Australian Health Practitioner Regulation Agency's Research Unit (AHPRA-RU) and the Joanna Briggs Institute (JBI) in Australia also both conducted systematic reviews of the literature to identify the attributes of effective CPD and to review the evidence for the effectiveness of mandatory requirements of CPD for healthcare professionals (AHPRA, 2018; JBI, 2012; Tivey et al., 2012). As shown in Table 1.1, both concluded that CPD is effective in improving practitioner's knowledge, however, there were less evidence that the acquired knowledge would influence their practice behavior and even less evidence that continuing education events or CPD result in enhanced patient safety or clinical practice outcomes.

The systematic reviews summarized in Table 1.1 are primarily focused on the characteristics of the CPD activities included in the review. There is little research investigating how other elements of the conceptual model presented in Figure 1.2 such as for example external factors, and educator or audience characteristics might affect the outcomes, behaviors, and clinical health outcomes of CPD. As can be seen in the conceptual model above (Figure 1.2), the characteristics of CPD activities can be broken up into the five areas of media, technique, content, setting, and timing. Each characteristic of CPD activities is briefly discussed in turn below, considering both the results of the systematic review from which the conceptual model in Figure 1.2 was derived as well as the other systematic reviews summarized in Table 1.1.

1.4.1. Characteristics of CPD Activities (Media, Technique, Content, Setting, Timing) and Effectiveness

CPD activities can be delivered using different media formats, including but not limited to live, online, blended, video, audio, or print (Marinopoulos & Baumann, 2009). In the John Hopkins review (Marinopoulos, 2007), when assessing the effectiveness of CPD across domains, print media seemed less effective than live media, and multimedia activities generally seemed more effective than single media. This was true for Knowledge, Skills, Attitudes, Behavior, and Clinical outcomes. There were both short and long term (>30days) effects on behavior. Audit and feedback was most effective when feedback was given both verbally and in written format (Ivers et al., 2012a). CPD was shown to have greater effects if an event used multiple methods (Cervero & Gaines, 2015). In lines with this, the JBI review concluded that interactive CPD that included multimedia were more effective than learning tasks created and presented using a single instructional method.

When it comes to delivering CPD, possible techniques include but are not limited to didactic, interactive, self-directed, team-based, simulation and experiential learning techniques (Marinopoulos & Baumann, 2009). Interactive techniques have been shown to be more effective than non-interactive ones (Marinopoulos, 2007). Forsetlund and colleagues (Forsetlund et al., 2009) calculated a risk difference in compliance with desired practice of 6% (interquartile range 1.8 to 15.9) in favor of CPD versus no intervention. Mixed interactive and didactic education meetings (median adjusted risk difference 13.6) were more effective than either didactic meetings (risk difference 6.9) or interactive meetings (risk difference 3.0) alone (Forsetlund et al., 2009). The JBI review was found that interactive CPD events that included multiple-instructional methods were more effective (JBI, 2012). The JBI review also found that interactive CPD events that included multimedia, multiple-instructional methods, and repetition, like online learning, audit and feedback, face to face educational meetings (e.g., conferences and workshops), public health campaigns, etc., were more effective than learning tasks created and presented using a single instructional method. CPD yielded greater effects if the event was adaptive (Cervero & Gaines, 2015).

The content of the CPD activities can vary greatly, depending on whether it is presenting facts, or methods, or disciplines, or updates versus relearning, depending on whether content is regulated or based on the breadth and depth of content that one wishes to cover (Marinopoulos & Baumann, 2009). Audit and feedback was most effective when the feedback it offered contained instruction (goals, targets, and action plans) which can then be used to guide future content (Ivers et al., 2012a). Continuing education was shown to have greater effects if the event was focused on outcomes that were important from the perspective of the healthcare practitioners (Cervero & Gaines, 2015).

The setting of a CPD activity varies and can be and is not limited to a university, conference, professional meetings, home, or a practice setting (Marinopoulos & Baumann, 2009). In terms of timing, CPD activities can be delivered once or repeated multiple times (Marinopoulos & Baumann, 2009). Multiple exposures to a CPD activity appeared more effective than a single exposure (Cervero & Gaines, 2015; Marinopoulos, 2007). The effect of a single delivery CPD activity was more variable (Bero et al., 1998). For example, audit and feedback was more effective when feedback was delivered at least monthly (Ivers et al., 2012a). In fact, audit and feedback was most effective if feedback was continuous and given by peers. (Scott, 2009).

Taken together, the summarized evidence above in Table 1.1 viewed through the lens of the conceptual CPD model (Figure 1.2) suggests that print media may be less effective than live media, multimedia CPD activities generally seemed more effective than single media, interactive CPD activities seemed to be more effective than non-interactive ones, and multiple exposures to the CPD activity seemed more effective than a single exposure. It can thus be concluded that interactive CPD events that included multimedia, multiple-instructional methods, and repetition, like online learning, audit and feedback, face to face educational meetings (e.g., conferences and workshops), public health campaigns, etc., are more effective than learning tasks created and presented using a single instructional method.

1.4.2. Effective Delivery Modes

When it comes to the effective facilitation of knowledge no single intervention has been shown to be successful overall, but rather a few that have been shown to be moderately effective. Three specific delivery modes of CPD have been found to be thus effective and they are audit and feedback, educational meetings and educational outreach (Bloom, 2005; Costa et al., 2016; Ivers et al., 2012a; O'Brien et al., 2007).

Audit and feedback is an educational intervention where practitioners' current performance is measured, and feedback provided over a specific time period. In an audit and feedback process, an individual's professional practice or performance is measured and then compared to professional standards or targets. That is, their professional performance is "audited". The results of this comparison are then fed back to the individual. There is a lot of different ways to measure professional performance (clinical practice) as described in Shah et al paper (2007): medical record abstraction, interview with practitioners, using clinical vignettes (response to written case scenarios), using unannounced or announced standardized patient, direct observation of patient consultation by an expert, or questionnaire about current practice

(Shah et al., 2007). However, a common way to measure an individual's professional performance in an audit and feedback process is to do self-audit (Gocuk et al., 2021). Audits of care and self-reflection are increasingly recognized as essential professional development activities, including in optometry (Downie & Keller, 2015; Van Hout et al., 2018).

The aim of this process is to encourage the individual to follow professional standards. Early assessment of the effectiveness of audit and feedback interventions was not very encouraging (Bero et al., 1998); however, those earlier variable outcomes have been attributed to poor design. It is now agreed that well designed audit and feedback type interventions have moderate effects on professional practice and healthcare outcomes (Ivers et al., 2012b) (Table 1.1). Researchers are now enthusiastically pushing for the field to pursue research in this area (Colquhoun et al., 2017; Ivers et al., 2014). The effectiveness of audit and feedback also appeared to be modulated by the characteristics of the intervention. Audit and feedback has been shown most effective when feedback is given by supervisor or senior colleague, delivered at least monthly (i.e. repeated), both verbal and written, aimed at decreasing behaviors rather than increasing behaviors, and offered instruction (i.e. goals, targets and action plans) (Ivers et al., 2012b). It has been suggested that audit and feedback type interventions owe their success to the fact that they force practitioners to reflect on their performance. According to learning theory, reflection is a learning tool in which individuals evaluate how their own experiences can guide their actions. The use of self-reflection and supervision and feedback as a part of the interactive learning process, enhanced learning outcomes and reduced feelings of "professional isolation" (AHPRA, 2018; JBI, 2012; Tivey et al., 2012).

Educational meetings are another educational method which can improve the quality of care. Educational meetings are commonly used for CPD with the aim of improving professional practice and, thereby, patient outcomes. Educational meetings include courses, conferences, lectures, workshops, seminars, and symposia. In the 2009 Cochrane review, all types of CPD meetings were moderately effective whether they were didactic, interactive, or mixed, but meetings that were mixed yielded the biggest improvements in professional practice and the achievement of treatment goals by patients (Forsetlund et al., 2009).

Educational outreach visits involve trained people visit clinicians where they practice and provide them with information to change how they practice. The information given may include feedback about their performance or may be based on overcoming obstacles to change. This type of face-to-face visit has also been referred to as university-based educational detailing, academic detailing, and educational visiting. A Cochrane review (O'Brien et al., 2007) found that educational outreach visits improved the care delivered to patients. When trying to change how health care professionals prescribe medications, outreach visits consistently provided small changes in prescribing. For other types of professional practice, such as providing screening tests, outreach visits also provided small to moderate changes in practice.

Whilst this has not been formally demonstrated, a recent summary report review of CPD has strongly suggested that CPD that supports authentic learning is likely to be more effective (AHPRA, 2018). Authentic learning is a pedagogical approach that situates learning tasks in the context of real-world situations, and in so doing, provides opportunities for learning by allowing students to experience the same problem-solving challenges in the curriculum as they will in their future daily endeavors (Herrington et al., 2014). The review identified that authentic learning required a change in professional understanding, active engagement in professional practice, interconnection of experiences over time, and openness to possibilities for doing things differently (AHPRA, 2018). Finally, measuring the effect of CPD on patient outcomes continues to present significant challenges, due to the complexity of other intervening variables including societal, policy, health systems, and patient factors (AHPRA, 2018; Al-Azri & Ratnapalan, 2014; Bloom, 2005; Cervero & Gaines, 2015; Davis & Galbraith, 2009; Forsetlund et al., 2009; Lowe et al., 2009; Mansouri & Lockyer, 2007; Marinopoulos, 2007; Mazmanian et al., 2009).

Table 1.1 Summary of Eight Systematic Reviews Concerning the Effectiveness of Continuing Education

Reference	*Population*	*Intervention*	*Outcome Measure*	*Result*	*Effect size*
Obrien (Cochrane) (2007) (O'Brien et al., 2007) Educational outreach visits: effects on professional practice and health care outcomes (Review)	Health care professionals	Educational outreach visits	Objectively measured professional performance in a healthcare setting or healthcare outcomes	Risk difference (RD) in compliance with desired practice was 5.6%. The adjusted RDs were highly consistent for prescribing (median 4.8%).	Small
Forsetlund (Cochrane) (2009) (Forsetlund et al., 2009) Continuing education meetings and workshops: effects on professional practice and health care outcomes (Review)	Health care professionals	Continuing education meetings and workshops Interactive, didactic, and mixed	Compliance with desired practice Patient outcomes Objective measure of professional practice or healthcare outcomes	Good results for education RD= 6% Mixed interactive and didactic education meetings (median adjusted RD 13.6) were more effective than either didactic meetings (RD 6.9) or interactive meetings (RD 3.0).	Small to moderate
John Hopkins (2009) (Marinopoulos, 2007)	Physicians	Continuing medical education	Knowledge, Attitudes, Skills, Practice Behavior and Clinical Practice Outcomes	CME was effective, at least to some degree, in achieving and maintaining the objectives studied, including knowledge (22 of 28 studies), attitudes (22 of 26), skills (12 of 15), practice	Mixed

				behavior (61 of 105), and clinical practice outcomes (14 of 33) Live media was more effective than print, multimedia was more effective than single media interventions, and multiple exposures were more effective than a single exposure.	
Scott (2012) (Scott et al., 2012) Systematic review of knowledge translation strategies in the allied health professions	Allied health professionals	Knowledge Translation	Professional/process outcomes, patient outcomes, and economic outcomes	Outcome reporting bias was common and precluded determination of effectiveness. In most studies, the interventions demonstrated mixed effects on primary outcomes; only four studies demonstrated statistically significant, positive effects on primary outcomes.	Mixed
Ivers (Cochrane) (2012) (Ivers et al., 2012a) Audit and feedback: effects on professional practice and healthcare outcomes	Health professionals	Audit & Feedback (continuous/peer)	Objectively measured health professional practice or patient outcome	RD 4.3% increase The effect appears to be larger when baseline performance is low, the source is a supervisor or senior colleague, delivered both verbally and written, provided more than once, aims to decrease current behaviors, targets prescribing, and includes both explicit targets and an action plan.	Small to moderate
AHPRA (2012)	Health professionals	Any	professional competence, competency, risk management, patient safety, law, legislation, malpractice, impaired practice,	individual CPD methods can improve learning, multiple methods of CPD, including reflective practice in the workplace, are more effective.	Mixed

			and criminal law		
Akl (Cochrane) (2013) (Akl et al., 2013) Educational games for health professionals (Review)	Healthcare workers	Educational games	Patient outcomes, professional behavior (process of care outcomes), and professional's knowledge, skills, attitude, and satisfaction.	2 studies only The findings of this systematic review do not confirm nor refute the utility of games as a teaching strategy for health professionals.	n/a
Cervero (2015) (Cervero & Gaines, 2015)	Physicians	Continuing medical education	Physician Performance and Patient Health Outcomes	CPD can be effective, with greater effects if adaptive, used multiple methods, involved multiple exposures, was longer, and was focused on outcomes that were important from the perspective of the healthcare practitioners.	Small to moderate

Note: The adjusted risk difference (RD) is the difference in the effect on compliance between the intervention and control group means. A positive risk difference indicates that compliance improved more in the educational intervention group than in the control group, for example an adjusted risk difference of 0.09 indicates an absolute improvement in care (improvement in compliance) of 9%.

1.5. CPD for Optometrists

A non-exhaustive list of health professionals in Australia would include chiropractors, dentists, dieticians, general practitioners, nurses and midwifes, osteopaths, pharmacists, physiotherapists, podiatrists, psychologists, speech pathologists, and optometrists. From here on, this thesis will focus on the profession of optometry. Whilst there is no evidence to suggest that the fundamentals of CPD, in other words its definition, significance, and effectiveness would vary between health professions, the CPD literature may focus on different aspects of CPD for each profession. Very few studies have investigated CPD in optometry. Ten articles were found related to CPD in optometry (Adler et al., 2005; Bullock et al., 2014; Cui et al., 2011; Faucher, 2011; Gocuk et al., 2021; Jacobs & Scott, 1990; Kleinstein et al., 1985; McDonnell & Crehan, 2012; Nguyen et al., 2020; Yoshioka et al., 2015). A brief descriptive summary of the findings from these articles is provided in Table 1.2.

Most studies originated from Australia and New Zealand and are self-report of changes in practice. Very few had objective measures of improvement or changes in practice. No study measured patient outcomes. A range of different types of CPD intervention were tested including face-to-face or online lectures, workshops, clinical placements, self-audit tools and cased-based peer discussions. Topic areas ranged widely with only a single study focusing on optometrists' perspectives of CPD. There is a need for more high-quality studies of CPD in optometry to be conducted.

Table 1.2 Studies of CPD in Optometry
AMD: Age-related macular degeneration.

Author, date	*Country / Region*	*Topic area*	*CPD characteristics*	*Audience characteristics*	*Outcomes / Findings*
Gocuk, 2021	Australia	AMD	Clinical Care Audit tool	20 optometrists	Improved clinical record documentation of AMD risk factors, clinical examination, AMD severity classification, management advice
Nguyen, 2020	Australia	Migraine	Online educational resource	31 optometrists	45% self-reported changed behavior (now use the ID-Migraine diagnostic tool).
Yoshioka, 2015	Australia, New Zealand	Glaucoma	3 face-to-face teaching modules (total 4 hours)	54 optometrists	Education improved diagnostic ability with multimodal imaging only No impact for other parts. Very small effect
Bullock, 2014	United Kingdom (Wales)	Pre-prepared case records and referral letters on iritis and corneal abrasions	Cased-based peer discussion (lecture + group discussion)	75 groups, 379 optometrists, 2 ophthalmic medical practitioners	73% self-report changed practice 3-4 months post workshop
McDonnell, 2012	Ireland	Punctal plugs and lacrimal syringing, binocular vision	1-hour workshop	73 optometrists	11% to 37.5% self-report changed practice 4-6 months post workshop #1 barrier: Not enough practice #1 enabler: Hands on / practical
Cui, 2011	Australia, New Zealand, China, India, Indonesia,	Prescribing progressive addition	Lectures and/or workshops and/or	5,658 ophthalmologists,	Average improvement of 19.4 ± 3.3 in test score ($p<0.001$)

	Hong Kong, Taiwan, Malaysia, Singapore, Korea, Thailand, the Philippines, United States Emirates	lens designs	tutorials and/or practical activities Customized to the country and audience (e.g., translated to local language)	optometrists, opticians, refractionists, sales personnel	
Adler, 2005	United Kingdom	Examination of people with intellectual disabilities	Lecture alone versus lecture + supervised clinic at Special Olympics	71 optometrists vs 39 optometrists	Improvement in self-assessed knowledge in both groups (p=0.013) Larger improvement in confidence in those received supervised clinic training
Jacobs, 1990	New Zealand	Optometrists' perspective of CPD	1-hour written questionnaire + focus group	87 optometrists	Interaction with colleagues perceived as most effective (28%) followed by conferences and seminars second (18% each)
Kleinstein, 1985	United States of America	Optometric hypertension screening	2-day CPD program followed by reporting on 100 consecutive patients	211 optometrists	84% reported sustained change in practice 5 years later, where they were continuing to screen for hypertension. Rural practice and practices with older, nonwhite, low SES status patients more likely to have sustained change

1.6. Thesis Aims and Objectives

CPD refers to learning that occurs once professional education is completed. CPD helps to bridge the gap between new evidence and clinical practice, however its effectiveness has not been fully characterized. A conceptual model of CPD where effectiveness of CPD can be measured at the practitioner (knowledge, attitudes, skills), practice behavior, or patient outcome level was put forward (Marinopoulos & Baumann, 2009). When the literature on CPD is considered in light of this model, it is revealed that most of the literature has focused on the type of CPD activity. CPD is most effective when the activity includes mixed media, mixed interactive delivery techniques, and multiple exposures. Audit and Feedback, educational meetings and outreach visits are successful activities and probably so due to the fact that they include many different delivery types. Considering the scarcity of high-quality information highlighted in section 1.5 above, this thesis aims to characterize CPD in the context of optometry.

1.6.1. The Specific Objectives for This Thesis Include:

1. Evaluate the perspectives of optometrists towards CPD (**Chapter 2**).
2. Compare the effectiveness of interactive (adaptive) versus traditional CPD (**Chapter 3**).
3. Evaluate the alignment between the level of statistical knowledge required to successfully appraise the optometric literature and optometrists' self-reported knowledge, attitudes, and practices (KAP) of statistics (**Chapter 4**).

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Chapter 2. Optometrists' Perspectives of Continuing Professional Development (CPD): A Qualitative Study

2.1. Background

Based on the literature reviewed in Chapter 1, CPD is likely to have varying effects on optometrists' knowledge, skills, and practice behaviors, likely ranging from no effect to a moderate improvement at best. Despite the existence of regulations, CPD may thus have a limited effect on optometrists' knowledge and their clinical practice outcomes. CPD in Australia is overseen by the Australian Health Practitioner Regulation Agency (APRHA www.ahpra.gov.au) and regulated by the Optometry board of Australia (www.optometryboard.gov.au). Very little is known about how optometrists perceive and use CPD, and the processes that may occur to change their behavior in practice as a result of CPD activities. Debates on the effectiveness of CPD center on issues regarding compulsory participation in CPD events for ongoing certification, or the obligatory attending of a CPD event when required by an authorized institution (DeWitt et al., 2004). The reason behind this might include health professionals' attitudes and many other associated determinants (barriers and enablers) towards CPD events, including for example the perceived importance of CPD, the practitioner's level of experience, their gender, working hours, and the practice location (e.g.; rural areas) (Jacobs & Scott, 1990).

2.1.1. Current perspectives of Optometrists

Ali and colleagues (2018) found that the most common reason for physicians to participate in CPD events was to update their knowledge, skills and expertise (67.3%), while reasons preventing physicians from participating in CPD events included lack of knowledge (32.66%) and time restrictions (24%) (Ali et al., 2018). A previous study on the effect of training on optometrists concluded that optometrists were likely to attend CPD events based on previous experiences and interests, however, the researchers felt that optometrists should be encouraged to participate in CPD in order to gain confidence in new areas of practice, where continuing education was said to maintain existing skills, and CPD was said to develop new skills (Adler et al., 2005a; McDonnell & Crehan, 2012). A similar conclusion was reached by Faucher in identifying the importance of a positive attitude (including motivation and deliberate practice) of practitioners toward their personal development in their progression from novice to expert level (Faucher, 2011).

Studies have suggested that the CPD participation behavior of healthcare practitioners can be influenced by factors like the quality and accessibility of existing evidence and guidelines and their applicability to clinical practice, the individual enthusiasm of health practitioners and their capability to keep-up with existing developments, the clarity of roles and practice requirements, and the practice experience of specific healthcare systems (Cane et al., 2012; McKenna et al., 2004; Newman et al., 1998). As seen in Chapter 1, the effectiveness of CPD activities in improving professional practice is at best very small and little data exist for CPD in the context of optometry (Forsetlund, 2009; Jacobs, 1990). Little is known regarding what factors might underpin this lack of CPD effectiveness. The reasons behind this could be attributed to a complex interaction of social, organizational, political, economic, and cultural factors, including optometrists' attitudes towards CPD events (Green, 2009; National Institute of Clinical Studies, 2006).

Table 2.1 Four determinant frameworks considered for qualitative analysis coding of optometrists' perspective of CPD

CPD: Continuing Professional Development.

	Framework (citation)			
Definition	**<u>Cabana:</u>** Framework describes barriers to physician adherence to practice guideline according to their effect on physician knowledge, attitudes, or behavior (Cabana et al., 1999).	**<u>Theoretical Domains Framework (TDF):</u>** Theoretical domains and model questions for use in interviews or focus groups to provide a comprehensive theoretical assessment of implementation problems, used by researchers within numerous healthcare systems to describe implementation interventions in a way to simplify and combine several behaviors change theories and make theory more accessible to/ usable by other fields (Cane et al., 2012).	**<u>Promoting Action on Research Implementation in Health Services (PARIHS):</u>** An impact or explanatory framework refined over time based on concept analyses and exploratory research (Stetler et al., 2011). **<u>Integrated-PARISH:</u>** Positions facilitation as the active ingredient of implementation, assessing and aligning the innovation to be implemented with the intended recipients in their local, organizational and wider system context (Harvey & Alison, 2016).	**<u>Consolidated Framework for Implementation Research (CFIR):</u>** A framework, which reflects a professional consensus within a scientific community. It incorporates, combines, standardizes, and joins concepts shown to be associated with implementation from other published implementation theories. It presents an overarching typology to help implementation theory growth and confirmation about what works where and why across multiple settings. Made by combining concepts across published theories that had different domains' labels but were overlapping in definition and explained apart theories that conflated main concept. So, it basically supports, not substitutes, the important and meaningful role of current research (Damschroder et al., 2009).

Domains	Knowledge • Lack of awareness • Lack of familiarity Attitudes - Lack of agreement with: • Specific Guidelines • Guidelines in General • Lack of self-efficacy • Lack of outcome expectancy • Lack of motivation/ inertia of previous practice Behavior • External barriers • Guideline factors • Environmental factors	Knowledge Skills Social/professional role & identity Beliefs about capabilities Optimism Beliefs about consequences Reinforcement Intentions Goals Memory, attention & Decision processes Environmental context & resources Social influences Emotions behavioral regulation	Context Innovation Recipient Facilitation (in the i-PARIHS)	Intervention Inner setting (features of structural, political, and cultural contexts through which the implementation process will proceed) Outer setting (economic, political, and social context) Individuals Process of implementation
Validity	Validated by three examiners and then created based on a format that describes a general standard system of actions for guidelines "the knowledge, attitudes, behavior framework (Woolf, 1993)".	Validated through a three-step validation process.	PARIHS: four studies were analyzed to test this framework. i-PARIHS: the authors noted that future work is required to test and refine the proposed i-PARIHS"(Harvey & Alison, 2016).	The authors noted that the best assessment of the CFIR's efficacy and validity can be detected by merging answers to the following questions, and that answering "Yes" to these 3 questions means that the researcher is on the right direction: 1. Is terminology and language coherent? 2. Does the CFIR promote comparison of results across contexts and studies over

		time? 3. Does the CFIR stimulate new theoretical developments?(Damschroder et al., 2009; McCormack et al., 2008).

2.1.2. Choice of framework

Cabana et.al., (1999) examined the reasons why physicians were not following the clinical practice regulations and recommendations. They organized these reasons or barriers into a determinant framework (Cabana et al., 1999; Woolf, 1993). Table 2.1 summarizes four key determinant frameworks that can be used to analyze practitioner, patient, and health system barriers and enablers to various desired health practices (Cabana et al., 1999; Cane et al., 2012; Damschroder et al., 2009; Harvey & Alison, 2016; Kitson et al., 1998). The purpose of a determinant framework is to recognize and describe the impacts on application or the implementation effects on a situation or an intervention. These frameworks help to identify categories or domains and individual factors, which might act as barriers and enablers and potentially affect implementation results including effectiveness of CPD. It should be noted that determinant frameworks do not report how change happens or any contributing processes (Nilsen, 2015). As our study was interested in observing and characterizing optometrists' perspectives of CPD rather than changing behaviors or implementing a guideline, we selected the Cabana et al. (1999) framework as the most suitable for our purposes. The Cabana framework describes the barriers to physicians' adherence to professional practice guidelines by grouping these barriers into common sequency of 3 behavior change based on whether they affected the physician knowledge, attitudes, or behavior (Cabana et al., 1999). Each of these three sequenced behaviors then have several related constructs each attached to them (Table 2.2). These were adapted for our study as described below in the methods section.

Table 2.2 Cabana et al. (1999) framework domains and constructs

Domain (theme)	*Constructs related to each domain*
Knowledge	Lack of awareness Lack of familiarity
Attitudes	Lack of agreement with: Specific Guidelines Guidelines in General Lack of self-efficacy Lack of outcome expectancy Lack of motivation/ inertia of previous practice
Behavior (CPD participation behavior)	External barriers Guideline factors Environmental factors

2.1.3. Aim

This study aims to explore the perspectives of optometrists toward continuing education with a view to identify the factors that may influence their perspectives and beliefs towards continuing education. This research identifies and characterizes understanding, attitudes, beliefs, practices and barriers and enablers to continuing education in optometrists.

2.2. Methods

2.2.1. Study design

As the aim of the study was to providing an in-depth and interpreted understanding, qualitative methods were best suited to addressing this investigation (Ritchie & Lewis, 2003). Focus groups are chosen because of their ability to learn what individuals think and why they think the way they do (Kitzinger 1995; Barbour 2008; Hennink 2008). In contrast to individual interviews, focus groups are able to generate participant practices and perspectives that may not be achievable without group interaction (Liamputtong, 2013). A combination of semi-structured face to face or online focus groups and semi-structured individual interviews were used to collect data from optometrists. Focus groups were chosen as the qualitative research method so as to benefit from the insights that are gained from the interactions found in the focus group setting. It was felt that listening to other's experiences was likely to stimulate ideas and sharing of experiences by optometrists. Individual interviews were also conducted however in instances where participants could not be accommodated in a focus group setting. Thus, semi-structured interviews and focus groups were conducted in parallel and combined in a process known as method triangulation where there was mutual enhancement of the understanding of optometrists' perspective of continuing education of each method by the other. A completed COREQ checklist for this study is provided in Appendix 2-1.

2.2.2. Ethics Approval

The study received ethics approval number HC17629 from the Human Research Ethics Advisory Panel (HREAP) of the University of New South Wales (UNSW Sydney) in February 2018, in advance of the study start date. A Participation and Information Statement and Consent form (PISC) was emailed to all eligible volunteers (Appendix 2-2), and verbal consent obtained prior to the start of the focus group or individual interview. Optometrists were offered either refreshments or a $20.00 gift voucher as a financial incentive for participation in the discussions, to reimburse them for the time involved. Optometrists were also eligible to claim CPD points for the activity. The study endeavored to comply with the Consolidated

Criteria for Reporting Qualitative Research (COREQ) (Tong et al., 2007).

2.2.3. Recruitment of participants

Convenience (snowball) sampling was used to recruit optometrists registered for practice in Australia. Optometrists were recruited by posting an announcement and letter of invitation to relevant university and professional organizations' email lists, websites, and social media platforms (e.g., Facebook) to inform them of the study. Recruitment also occurred by word of mouth. Volunteer participants were screened by email to ensure that they met the inclusion criteria. Optometrists were asked to choose their preferred method (focus group versus individual interview) and mode (face to face versus online) of discussion prior scheduling a time. Online meetings were held on Skype (Skype Communications SARL, Luxembourg). Recruitment continued until no new themes emerged and data saturation was achieved.

2.2.3.1. ***Inclusion criteria***

Volunteers who self-identified as an optometrist registered for practice in Australia and were 18 years and over were eligible to participate in this study.

2.2.4. Data collection

Demographic information was collected. Two experienced and one novice facilitator conducted the focus groups and individual interviews. Facilitator/interviewer information is presented in Table 2.3. Facilitators made sure to withhold any expression of their personal views and opinions throughout the duration of the study, to avoid potentially biasing the research results. Facilitators independently controlled the discussions and ensured that all questions (Table 2.4) were addressed and that all participants in the focus group were offered the opportunity to contribute to discussions.

Table 2.3 Information of the Facilitators/interviewers of the conducted focus groups and individual interviews

Interviewer	*Gender*	*Credentials*	*Occupation*	*Experience and training*
Sally Alkhawajah (SK)	Female	MOptom, BOptom	PhD Candidate, UNSW Sydney Lecturer, King Saud University	Optometrist 2-day NVivo workshop, School of Public Health & Community Medicine, UNSW Sydney Experience conducting 9 focus groups in Saudi Arabia
Isabelle Jalbert (IJ)	Female	OD, MPH, PhD, FAAO, GradCertOcTher	Associate Professor, School of Optometry and Vision Science, UNSW Sydney Associate Dean International and Engagement, Faculty of Science, UNSW Sydney	More than 10 years of experience conducting focus groups and interviews (Alnahedh et al., 2015; Jalbert et al., 2020; Suttle et al., 2015a)
Kirsten Challinor (KC)	Female	B Psych, PhD	Lecturer, School of Behavioral and Health Sciences, Australian Catholic University Adjunct Lecturer, School of Optometry and Vision Science, UNSW Sydney	10 years of experience conducting focus groups and interviews (Suttle et al., 2015a)

2.2.5. Interview guide

A semi-structured interview guide consisting of open-ended questions was used to lead the focus group and individual interview discussions (Table 2.4). The semi-structured guide was designed based upon an extensive literature review and continuously adapted based on any issues raised during the discussions. The guide covered the following key areas: understanding and experiences of continuing education, determinants (barriers and enablers) of continuing education, perceived effectiveness and opinions on how continuing education could be improved. Follow-up probe questions were used when needed to increase the depth of the discussions. Participants were allowed to explore any issues they judged relevant.

Table 2.4 Semi-Structured Interview Guide

Topic	*Guiding Questions*	*Possible follow-up questions*
Definition	Can you tell me, in your own words, what CPD is?	What is the aim of CPD? Why do we need it? Probe for difference between CPD and university education Can you list the stakeholders?
Motivation	Can you talk to me about your reasons to attend CPD?	Probe for understanding of their own CPD requirements (e.g., is it compulsory? how many hours are required?) Are all types of events the same? Who sets up these requirements?
Characteristics	How do you select which CPD to attend?	What factors influence your choice? What attracts you? Probe for opinions on types of providers (for example university versus companies) Probe for opinions on types of events (for example face to face versus webinar versus self-directed learning)
Significance	How important is CPD and why?	Can continuing education change practice? Probe for examples from own practice or from colleagues
Effectiveness	Is CPD effective?	Probe for benefits and disadvantages of CPD Who benefits from CPD? Can you share an example of a

		good and a bad CPD experience?
Regulatory environment	Thinking about the current CPD system for optometrists in Australia, what works well, what does not work well, what needs to change?	Probe for opinions on the volume of CPD, quality of CPD, ease of access of CPD. Probe for opinion on CPD type and hours required currently.
Summary	Thank you for taking the time to talk about your perspectives of CPD. Is there anything else you think should be discussed?	

Interviews were audio recorded using two external recording devices wherever possible to provide adequate back up and coverage of what is said by participants in any location of the interview rooms (if face to face).

All focus group and individual interview discussions were conducted in English. The researchers took notes during and after the discussions. Data collection and analysis proceeded in parallel, with emerging findings informing further focus group and interview sessions to the point that data saturation was reached, thus satisfying the terms of qualitative methodology. All recorded sessions were transcribed verbatim using a professional transcription service (Way With Words Ltd, Australia) not involved in the research study. Transcripts were checked for accuracy by the researchers and missing words and gaps were filled in wherever possible. Transcripts were not returned to participants for checking or feedback. Participants' names were removed and replaced with a unique code to preserve anonymity.

2.2.6. Data analysis

Transcribed focus group/individual interview discussions were analyzed and deductively coded by three trained and experienced coders simultaneously (see Table 2.3) using the framework method (Cornish et al., 2014; Gale et al., 2019; Richards & Hemphill, 2017). Collaborative coding allowed researchers to bring the following dimensions of difference in collaboration to the analysis and interpretation of the data: interdisciplinary (optometry, psychology), academic-practitioner, international (Australia, Saudi Arabia), and senior-junior (experts versus novice qualitative researcher, supervisors versus PhD student)(Cornish et al., 2014). The analytical framework proposed by Cabana et al. (1999) for analysis of barriers to physician adherence to practice guidelines in relation to behavior (CPD participation behavior) change was chosen to help manage and organize the qualitative data (Figure 2.1). As detailed in section 2.1.2, the Cabana framework was selected because it would best enable for exploration of the processes and factors involved in changing practitioner practices in response to CPD. The hope was that this framework would help to create a new structure for the collected qualitative data that would allow the researchers to summarize and reduce optometrists' accounts in a way that would help to understand their perspectives of continuing education. Participants' data was mapped to individual codes from the Cabana framework (e.g., Volume of Information) that were grouped into clusters of similar and interrelated ideas into categories (e.g., Lack of Familiarity). In the Cabana model, categories and codes are arranged in a hierarchical tree structure under a mechanism of action or sequence of behavior change that involves practitioner knowledge, attitudes, and behavior (CPD participation behavior) (Figure 2.1) (Woolf, 1993). Data were simultaneously coded as either a barrier or a facilitator or both.

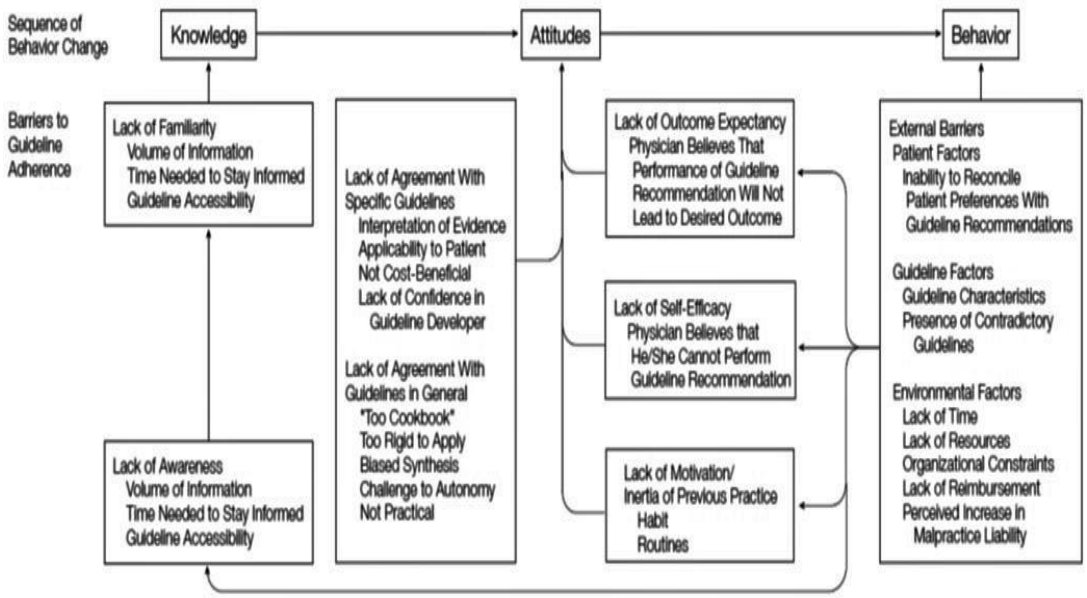

Figure 2.1 The Cabana analytical framework for Barriers to Physician Adherence to Practice Guidelines in Relation to CPD participation behavior Change
Reproduced (permission requested) from (Cabana et al., 1999).

Data were thus deductively coded using "a priori codes" from the framework proposed by Cabana et.al., (1999). Three researchers/ authors performed the primary coding collaboratively, considered agreement and disagreement on the coding process of the collected data to the Cabana framework (Bekelman et al., 2016; Cabana et al., 1999). Emerging new codes were proposed for responses that could not be logically mapped to any of the predefined codes from the Cabana framework; these were also considered, discussed, and confirmed collaboratively by the three researcher coders. Qualitative analysis was conducted using the NVivo software (version 12) (QSR International, Melbourne, Australia). Data was coded simultaneously by three researchers, thus allowing for immediate verification of the coding and for consensus to be reached if or when any disputes emerged.

2.3. Results

2.3.1. Population demographics

Eleven optometrists volunteered and were enrolled but two optometrists were lost to follow-up prior to their scheduled focus group discussions. The 11 participants were the first to volunteer in the study and no subjects were excluded. A total of six discussions (three focus groups and three individual interviews) involving nine registered optometrists (7 Females: 2 Males) were conducted. The reason for the small number of participants in each focus group is because we were unable to recruit more participants to each focus group. The participants' ages ranged from 23 to 58 years old (M=37.3, SD=14.3), and one participant did not provide their age (see Table 2.5). Four out of the nine participating optometrists worked in private practices, another four optometrists worked in corporate practices, and one was a university academic. Table 2.5 presents the demographic characteristics of the participants. Six participants were from the state of New South Wales and three originated from the state of Queensland. The Modified Monash Model (MMM) was used to classify optometrists' geographical location based on the postcode of their primary practice location (Department of Health. Rural Classification Reform, 2015). Seven optometrists originated from metropolitan regions (MM1-3), one reported a primary place of practice located in a regional setting (MM4-5) and one in a rural or remote setting (MM6-7).

Table 2.5 Demographic characteristics of participants

Participant no.	*No. of FG or II they participated in*	*Gender*	*Age*	*MMM*	*Practice type*
1	FG2	F	25	MM 1	Corporate
2	II3	M	58	MM 6	Private
3	II1	F	23	MM 1	Corporate
4	FG2	M	24	MM 1	Private
5	FG3	F	24	MM 5	Corporate
6	II2	F	(Not provided)	MM 1	Private
7	FG3	F	39	MM 1	Academic
8	FG1	F	49	MM 1	Corporate
9	FG1	F	56	MM 1	Private

FG: focus group. II: individual interview

Focus group duration ranged from 38 to 52 minutes and individual interviews duration ranged from 18 to 20 minutes. All participants were registered to practice in Australia as optometrists. One focus group was conducted face to face in Brisbane, Queensland. The remaining two focus groups and two individual interviews were conducted virtually. Details of the focus groups are provided in Table 2.6.

Table 2.6 Characteristics of optometry focus groups and individual interviews

Discussion type	*Participants (n)*	*Gender (F: M)*	*Location*	*Duration (minutes)*
1st Focus group	2	2: 0	Brisbane (face to face)	41 min
2nd Focus group	2	1: 1	Online	38 min
3rd Focus group	2	2: 0	Online	52 min
1st Individual interview	1	1: 0	Online	20 min
2nd Individual interview	1	1: 0	Online	18 min
3rd Individual interview	1	0: 1	Online	18 min
Total number of participants	9 Optometrists			

2.3.2. Overview: Modified Cabana framework

Data analysis was discussed iteratively by the three researchers across multiple meetings with reference to the Cabana framework (Cabana et al., 1999), resulting in a modified Cabana framework (Figure 2.2). Based on the participants' responses and analyzing them using the Cabana et.al (1999) framework, the data remained structured under a sequence of CPD participation behavior that involved knowledge, attitude, and behavior of optometrists towards continuing education in Australia.

The collected data generally mapped well to the modified Cabana framework. One thousand and thirty-two participant quotes were extracted from the transcripts and coded 372 times as barriers and 641 times as enablers. Data was coded to nearly all of the categories and corresponding codes of the original Cabana framework. Only three individual codes from the Cabana framework were not utilized in any of the discussions. These were Interpretation of Evidence, "Too Cookbook", and Reimbursement (e.g., medical coverage).

Some small modifications to the framework were made to fit all the data as follows:

- The word Guideline was replaced by CPD throughout the framework.
- Under the category of Familiarity, an additional code termed Memory Loss was added.
- Under the category Awareness, two additional codes termed CPD Accessibility and Stakeholders were added.

- The code Volume of Information under Familiarity and Awareness was modified to state Volume and Breadth of Information
- A new category termed Self-Improvement with the code and explanation personal growth, enjoyment of learning, "self-worth" listed underneath.
- Under the category External Barriers, a new code termed Practitioner Factors with the explanation family commitment, self-commitments, etc. was added.
- Under the category of Continuing Education Factors, a new additional code termed Peer to Peer Interactions was added.
- Wherever possible negative language was turned into neutral or positive language so as to make the framework applicable to both barriers and enablers. For example, "Physician Believes That Performance of Guideline Recommendation Will Not Lead to Desired Outcome" became "Physician Believes that Performance of CPD Recommendation Will Lead to Desired Outcome".

As well as the original 3 sequenced behaviors (CPD participation behavior), the modified Cabana framework thus comprised 11 categories and 32 corresponding codes.

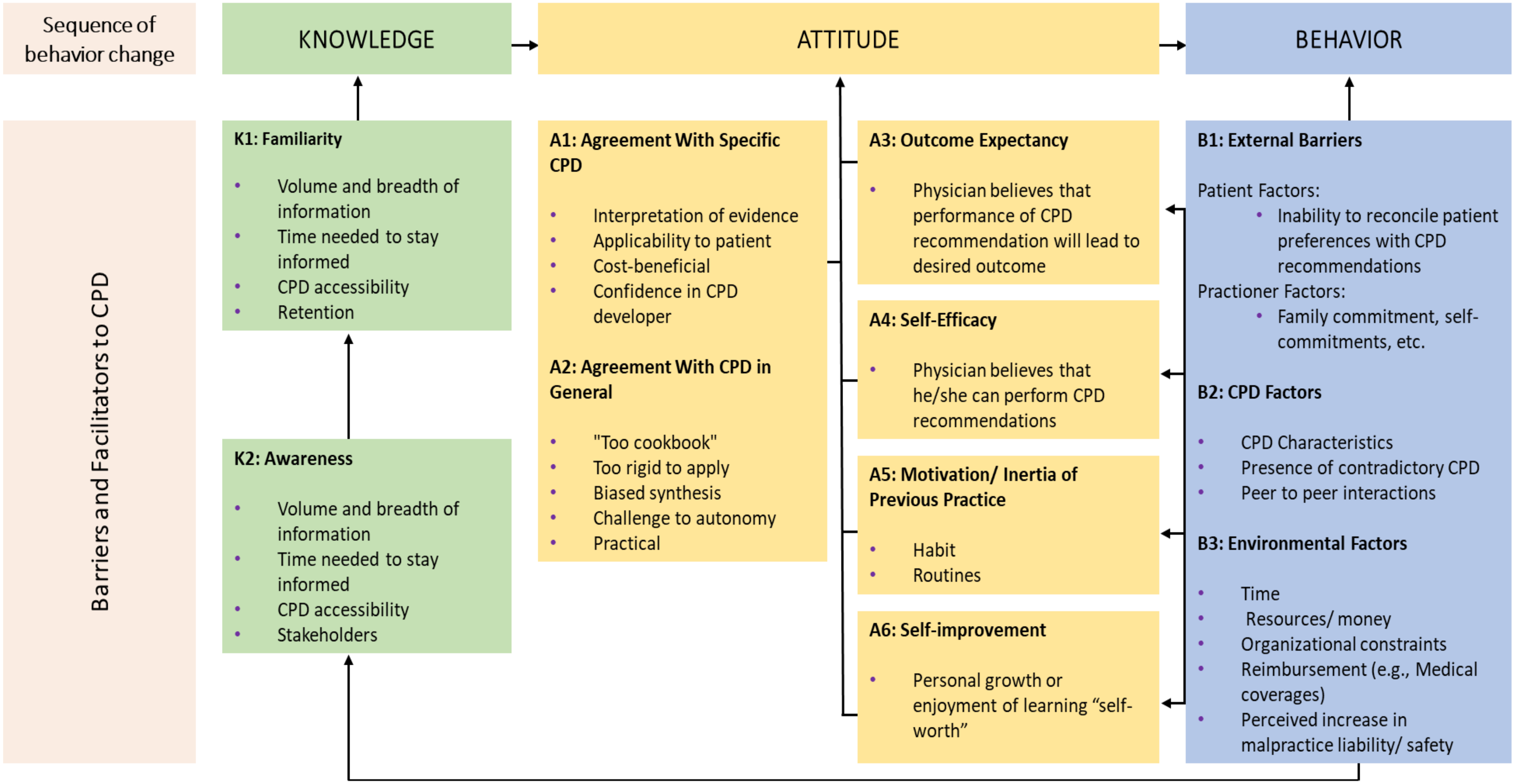

Figure 2.2 Modified Cabana framework for optometrists' perspectives of CPD

Individual codes (bullet points) are grouped into clusters of similar and interrelated ideas into categories (K1 to B3). Categories and their codes are arranged in a hierarchical tree structure under a sequence of CPD participation behavior *change that involved practitioner Knowledge, Attitudes, and Behavior. CPD: Continuing Professional Development.*

2.3.3. Interpretation of Results

Table 2.7 presents illustrative quotations and their associated categorization into barriers and enablers mapped to the code and categories of the modified Cabana framework. In line with the conceptual CPD model described in Chapter 1, the modified Cabana framework used in this study was built upon a premise that before CPD can impact patient outcomes, it must first affect optometrists' knowledge, then their attitudes, and finally their behavior in clinical practice. Inherent to this model was the belief that a sustainable behavior change can only occur as a result of influencing knowledge and attitude and that indirect manipulation of behavior alone was likely doomed to fail (Cabana et al., 1999).

Table 2.7 Codes (with illustrative quotes) identified from optometrists' perspectives of CPD mapped to the Modified Cabana framework categories and corresponding structured behaviors (dark grey shading)

Categories and codes are in their order of presentation from the Modified Cabana framework. Quotes were classified as a barrier, enabler, or both. Quotes mapped to a category without being assigned to a code are indicated as n/a.

Category	*Code*	*Barrier/Enabler/Both*	*Illustrative quotes (focus group, participant)*
KNOWLEDGE			
Familiarity	**n/a**	Enabler	*Um, with CPD events I feel like it is more of a revision kind of thing just to keep us on the ball with, um, how we practice and stuff like that. (FG3, P5)*
		Barrier	*I think, off the top of my head, it is, um, 80 points over a two-year period and 24 of those points for therapeutic optometrists have to be face, oh I know, 24 points has to be face-to-face and then I think over half have to be therapeutic based [laughter]. (FG3, P6)*
			So, if you are not up to date, then you might not know, like, the proper or more updated treatment methods that could be better for the patient, yeah (II3, P9)
	Volume and breadth of Information	Enabler	*I think I would tend to focus on something that I think I can use to grow my scope of practice. (FG2, P3)*
			Um, with CPD events I feel like […] it is also new research or any like, um, new technology that might have come out recently, that, uh, we were not taught back in uni (FG3, P5)
			Just keeping your knowledge up to date, um, making sure that like even in practices where you are not actively practicing about certain areas, um, you can keep up to date in those, uh, sectors (FG3, P6)
		Barrier	*Yeah. Yeah. There is plenty of choice and because you cannot go to a conference every week because you have got work to do (II3, P9)*
			I think I do... I do sometimes decide to go to something because I know a little bit about it, and I want to know more about it. Or I will... And I will also avoid going to a certain session for example, um, if I know nothing about it and have no interest in knowing anything else about it (FG2, P3)
			No, there is no downside, but there are occasions where you listen to a lot of lectures, and most of the stuff you have heard before, and you have got to wait for 20 minutes until you get a new snippet of information that adds to your, uh, collective. But you cannot pick and choose, you do not know how much information is redundant, how much is new (II3, P9)
	Time needed to stay informed	Barrier	*I guess, I guess it is the time away. So you, you do obviously have to give up your personal time to attend the event (II2, P8)*
			Because time…. Time is also valuable. I mean if you go on a night, it is a night I am not home (FG1, P2)
			I guess for practicing clinicians it is really hard for them to get to events, um, if they're too early after work. Um, and we have experienced this at the start of the year, we have our alumni events, if you start too early, um, you only get the optoms from the Eastern Suburbs. People from other parts of Sydney cannot get to them. Um, so, time of day's important, um. Um... [FG2, P3?)
	CPD accessibility	Enabler	*In Optometry Australia, uh, back when I had a learnership [laughter], um, you could log into, uh, the, the account and then there would be a calendar of CPD events that were going on (FG3, P6)*
			Before continuing education were coming in, I was downloading journals from America about issues that I have not come across. (II3, P9)
		Barrier	*There were some things that, um, I do not know how to remedy this, but, um, there are some things that do not come up automatically. Um, like, um, if you attend a conference overseas for example, you... Obviously that is not going to come up automatically (FG2, P3)*
			Like, there is, there is probably an event, I do not know, once, once a week at least, and it is quite a lot of time away (II2, P8)
	Retention	Enabler	*Um, with CPD events I feel like it is more of a revision kind of thing just to keep us on the ball with, um, how we practice and stuff like that (FG3, P5)*
			Uh, no just learning, you are just learning. You keep improving and reminding yourself, because the brain has got to get better, all the neurons are synapsing more when you go to conferences. (II3, P9)
			Yeah. Um, I, always remember the workshop (II2, P8)

Category	*Code*	*Barrier/Enabler/Both*	*Illustrative quotes (focus group, participant)*
		Barrier	*When you have been out for a while you start to forget things. So, there is the maintenance side of it. Just maintaining knowledge, maintaining your skills, remembering how to manage certain diseases and so on. So that is the maintenance side of it. And then you have got changes that are happening (FG2, P3)* *Like, there is still a lot of things that we forget over time. Um, even at CPD events and meeting other optometrists, I realize how much they have forgotten that they are after […] there is a few of my [….] ten years. Like, I just, kind of, feel like, um, my knowledge of particularly, I guess, uncommon or rare conditions, kind of, slipping away from me (FG3, P6)*
	n/a	Enabler	*Um, yeah. I think, off the top of my head, it is, um, 80 points over a two-year period and 24 of those points for therapeutic optometrists have to be face, oh I know, 24 points has to be face-to-face and then I think over half have to be therapeutic based [laughter] (FG3, P6)*
		Barrier	*The course itself, as in like the optometry course itself was pretty full on. So, I feel like with all the information that we have, we already have all of that information, to an extent (FG3, P5)*
	Volume and breadth of Information	Enabler	*We owe it to our patients to be up to speed and um, current, um, with the current research. So, um, it is absolutely critical that we're up to date (FG2, P3)* *Um, yeah, I guess I see it more from a, a like keeping up with, uh, the current research, soft of, perspectives and making sure that we always give the best like evidence-based practice for our patients (II3, P9)* *And, but there's numerous occasions where you just collect information in your files, put them in your library, in case you come across the use of it later on. I mean, I subscribe to about ten journals from the US. I peruse them every month, and then, and then a month or two later information comes across to Australia and then they go through it, so uh…. (II3, P9),*
Awareness		Barrier	*You know, the thing is you go, there is, there is plenty of topics covered. So, I can go to any area I want to and there's eventually a, a, a, a conference that 70% of the topics, uh, I am interested in. The other 30% as I just sort of put up with it because I do not see patients, for instance, for scleral lens fitting, and I have got to sit through that to make the day go by (II3, P9)* *Um, I would say it is really important, um, even right after finishing uni I'm already behind. Um for example, the myopia course they came out in…. Was it 2017 or something? So, it was just a little bit, um, different. A little bit, um, further along that when I had been in my studies. So, what I learnt about […] is a little bit earlier than that and then I was focused on something else and then I just completely missed all of that. And then they are already coming out with a second LAMP study this year. And I think it is important to yeah, definitely keep on top of everything because it's moving so fast. And so many people are doing different research that if you do not keep up you are not, um, doing right by your patients. Yeah, they could go to someone else. And then they have found the most recent solution that is easiest for them that you did not even realize existed (FG2, P4)*
	Time Needed to Stay Informed	Enabler	*Situation it would more be about integrating the newest practice. So, uh, maybe a course, I mean, maybe like a CPD event that would be like good with… Lay out what the recent research is, what the findings are, and what is most pertinent to clinical practice and how we can integrate that into our clinical practice. That sort of format (FG3, P6)*
	CPD accessibility	Enabler	*Yeah, so it is a combination. So, for the face-to-face events by local optometrists [?], they generally send out an email to all the local optometrists. So that is how we know about it. And they also send us, like, mailed letters to like our practice [inaudible]. And then the ones that are a bit more broad like, like OA, like online modules and stuff, I'll know about it because they'll email us. And like more, like further away OA then. So, I have attended two [?] by like more, like ophthalmologists that are further off, like they are not local then I would search for them through the OA list. But these kinds of [?] events are listed in the OA, so I will just look it up that way. And they have, like, the contact details, like who to contact to, to register your attendance as well, yeah (II1, P7)* *Um, I think the good thing is how much variety they have, coz, there is so many different CPD events on, like, different topics that people can, kind of, select the one that is relevant to them, or, um, and then also the different modes as well. Because obviously, there's gonna be some people who prefer a bit more of a face-to-face, um, interaction. And there's gonna be, like, people who are more into, like, contact lenses […] Whereas other people would prefer like online modules […] So, yeah, I think that the good things about what we currently have is just the variety and that just makes it useful for a broad range of optometrists across Australia, yeah (II3, P9)*
		Barrier	*Um, I think most of the topics there is a sufficient amount. The only thing I would say is the therapeutics, I feel like is a little lacking […] But there is not that many that specifically just on using, like, and prescribing eye drops (II3, P9)*

Category	Code	Barrier/Enabler/Both	Illustrative quotes (focus group, participant)
	Stakeholders	Enabler	*Various groups, off the top of my head, Optometry Association of Australia provides a lot. Uh, Ophthalmological associations provide quite a few. and, uh, companies that, uh, manufacture products and contact lenses, they have a few (II3, P9)* *So, like, there was, um Young, actually, I used to be involved with Young Optometrists. I used to actually help organize their event as well (II2, P8)*
		Barrier	*And, um, it has made compulsory by AHPRA, I think, to ensure that everyone keeps up to date to a sufficient amount (II3, P9)* *You know how you have companies that make presentations? That is fine. But I do not think that's necessarily CPD. Um, I think that is informing people of what new products are available. But it is not necessarily presenting the evidence for those products (FG2, P3)*
ATTITUDE			
Agreement with Specific CPD	**n/a**	Enabler	*Yeah, it is, it is live, you can attend [virtually]. It is in the United States and, uh, because there's lecturers and ophthalmologists there, you feel as if you are with a higher level of intellect and then you have to really get your best skill (II3, P9)*
	Applicability to patient	Enabler	*So it if was, like myopia control, this is, um, I guess, I guess something I'm not really treating like, macular degeneration new treatments. I guess I would go to the myopia management because that is more relevant to me into practicing, yeah (II2, P8)* *So, like, I consider it effective if I remember it and I start to apply it to practice, yeah (II2, P8)* *There is some CPDs that are more hands on, and I find that to be quite useful. Like, for example, in Super Sunday you can sign up for the workshop, um… And because it is hand on, hands on, you get definitely more of a, a perception of how you can use it in clinical practice (FG3, P6)*
		Barrier	*I do not see patients, for instance, for scleral lens fitting, and I have got to sit through that to make the day go by (II3, P9)* *But I would not go to, for example, like if it was a CPD event on, like, IPL because we don't have an IPL. So there is, kind of, not much point learning about it coz you can't use it anyway (II3, P9)*
	Cost-beneficial	Enabler	*Like, I know all the ones that I attend have either been, either is no cost to attend, or instead of low cost, like…. Um, I guess the most expensive one would be Super Sunday and that will be like, but it is, like your entire points for the year, that is, I mean, that is quite different (II3, P9)* *Um, and also the amount of [CPD] points. So if, like, there's more points, usually I'd like to go more, I guess, yeah. Sometimes it does not necessarily, like sometimes I will even go if there is like a 2 point. But then, um, it is like, an ophthalmologist who is close by (II2, P8)*
		Barrier	*Um, and I feel that the quality of, um, American conferences is just so much higher. Um, and the amount that is on offer is just so much more (FG2, P3)*
	Confidence in CPD developer	Enabler	*Quality, yes, I mean, um, I, yes, the speakers know a lot more than I do. So, I cannot be unhappy because they are there and because they spend their time, so I am happy with the quality and the contents (II3, P9)* *I could not really think of disadvantages, but I guess it is true and that is where it comes into what you were saying before about, you would choose a CPD event based on the speaker. If it is someone you trust and you know has done the research properly, then anything that they say, you are just like, yeah that sounds right. I will trust you because you know everything about this topic much more than I do (FG2, P4)* *But then, um, it is like, an ophthalmologist who is close by. So I, I like how they're going coz, like, they're treating my patients as well. So I mean, I wanna make sure that, um, that, yeah, they're still [laughs] keeping up with everything too. I like to, you know, also meet up with them too, yeah (II2, P8)* *In America there's a, um, they do liver webinar case studies for a hospital, a hospital, Wills eye Hospital. […] Over there, that webinar that ophthalmologists challenge other ophthalmologists, that is at a much higher level (II3, P9)* *Yeah, or you believe in the product or you believe in what the technology is, yeah (II2, P8)*
		Barrier	*Companies which are actively trained to sell their products (FG3, P6)* *I guess, providers. But after that would probably be the ophthalmologists because sometimes their CPD can be hit or miss. Sometimes it ends up being too surgical. Other times they underestimate what we know and just really beat the [….] tell us at day six and I do not learn anything new, um (FG3, P6)*
Agreement with CPD in general	**Too Rigid to Apply**	Barrier	*So, how can we learn. But I think the big thing is to try to not make it sound like it is a big stick approach (FG1, P2)* *I like those case study stuff just because you can ask any questions that pop up, um, when they are going through the case, um, to do with anything. It could be testing, diagnosis, you know, just, or even just how they, they, they were thinking when, um, they were going in, um, going through the*

Category	*Code*	*Barrier/Enabler/Both*	*Illustrative quotes (focus group, participant)*
			case (FG3, P5)
	Biased synthesis	Barrier	*You know how you have companies that make [CPD] presentations? That is fine. But I do not think that's necessarily CPD…. Um, I think that is informing people of what new products are available. But it is not necessarily presenting the evidence for those products (FG2, P3)* *Um, I guess you are, um, you are a trapped audience basically, in the sense that you are hearing from one person. You are getting the opinion of one…. Potentially an opinion for one person. Um, so, I do not how to word this appropriately, but, um…. Yeah, you are in the hands of the speaker, so you are reliant on them having done the literature review for you (FG2, P3)* *Companies which are actively trained to sell their products (FG3, P6)*
	Challenge to autonomy	Barrier	*Um, I fell that …… I cannot remember what the paperwork involved now. I remember thinking it was just onerous, um, to inform the OA [Optometry Australia]. Maybe it is not, that is just what I remember. Um, so yeah…. I have. I was audited in 2015. Um, so that was a while ago and I am still traumatized. Speaking of PTSD, that is traumatizing. [Laughing]…. Ah, year, it was not fun. All the paperwork like, you had to pull out. Um, so yeah, I have been audited (FG2, P3)*
	Practical	Enabler	*I think it is important because it is a way to ensure that everyone that is registered and practicing as an optometrist can be up to date with what is current so that they can give the best standard of, of care for their patients, basically (II1, P7)* *It depends on the area of practice. So, if I am, if I am practicing in an area which have a lot of eye disease, I want to go to eye disease conferences. It is an area that has a lot of children, so I got to children, blah, blah, blah, that sort of thing, because that is the most likely need you're going to need the next day (II3, P9)* *I think it [CPD] works if you have access to the, the things that, the, the topics that you attend to are, like, relevant to your practice (II3, P9)* *But, yeah, particularly workshops, there was a foreign body workshop […] We, there is a lot of hands-on learning, and, sorry, lecture first and we are doing, like theory and then we actually practiced how to do it on […], yeah (II2, P8)*
		Barrier	*I guess, providers. But after that would probably be the ophthalmologists because sometimes their CPD can be hit or miss. Sometimes it ends up being too surgical (FG3, P6)*
Outcome expectancy	**n/a**	Enabler	*About, um, just tiny little things that you think, do I need to really worry about that when I am going to send it to the ophthalmologist anyway and he is gonna do the exact same scans that I have just done. (FG2, P4)* *So, I am happy with the quality and the contents. It is just that you cannot predict how much of the half an hour you already know. […] How much is new, you can't predict that. Uh, yeah (II3, P9)* *Uh, continuing education is, um, to attend events where information is transmitted to you. Some of it is a revision of university stuff, some of it is new development on what you already know, so you can actually be a much better practitioner with more up to date information to give to patients (II3, P9)*
Self-Efficacy	**n/a**	Both	*Even if it is quality though, I do think that there is a difference between opthal-led talks and optometry-led talks. Because often... And it... It... It... And it is not necessarily that it lacks the quality, but, often, the opthal. ones, when you go to those ones out near the, um, the suburbs, there's a... A... A restriction on the scope of practice because the opthal is wanting you to refer to them. And so, there's often that kind of talk where it is, well, you do not need to do... You do not need to go to that extension, and you are going to just send them to MT anyway. As opposed to, you know, if you go... Sometimes have a talk that is optometry-led by a... A colleague in the field who is doing this stuff, it will be more about, you know, broadening your scope of practice (FG1, P1)* *[Talking about workshops] And, um, you really learnt how to, how to do it properly and I felt a lot more confident in doing that even though I was already out practicing, like, it is always good to practice your skills even more (II2, P8)*
Motivation/Inertia of previous practice	**n/a**	Enabler	*But for those people who are, do not have the discipline, I think for them to force them to get some points, maybe, uh, you know, they will find that they are safer practitioners. (II3, P9)* *I guess it is also as brush-ups if we, um, are going from university where we are learning every day, to go into practice, we're not learning every…… We are, we are learning but it is a different setting, I suppose (II2, P8)*
		Barrier	*I used to have lots of optometrists say to me, back when I was working at Lux, um, optometry is boring. And then you would explore and... Yeah, what was going on. And these were people that had never done anything... Never taken it beyond what they walked out of uni... And you think, well, of*

Category	*Code*	*Barrier/Enabler/Both*	*Illustrative quotes (focus group, participant)*
			course it is boring, all you are doing is saying one or two all day, where the richness comes afterwards (FG1, P2)
Self-improvement	**n/a**	Enabler	*Just go from that to that one, and then... You know, and I am probably different. Um, this is really going, you know, esoteric. Um, there is some self-actualization, you know, um, going to, you know, CPD. A really good CPD night, the motivation that you... You get from it. So, you go along and, um, it can reinvigorate you. And so that is often, as well, why you do it because it recharges you. It gets you excited about... Into what you are doing, you know. Which is beyond just, you know... Because sometimes a straight learning or... (FG1, P1)* *I enjoy what I am doing because I just enjoy what I do. […] It is all, maybe I'm weird, but I enjoy people, I enjoy new things, and even if it's a repeat, there's the social side is great. (II3, P9)* *I personally want to know a lot more than I know already and to put it into practice. So, to me continuing education is just a normal thing, you want to keep knowing more stuff. [….] Its personal satisfaction is my criteria, basically. (II3, P9)* *Uh, no just learning, you are just learning. You keep improving and reminding yourself, because the brain has got to get better, all the neurons are synapsing more when you go to conferences. (II3, P9)*
BEHAVIOR (CPD participation behavior)			
External Barriers	**Patient factors**	Enabler	*Oh, well because, um, I guess they are invested in us investing in our knowledge because that way they get the best patient care (FG3, P6)*
	Practitioner factor	Barrier	*I think it is [CPD] moderately important, but I think it is more important more so for optometrists who have graduated a long time ago. Because, like, when it comes to things like, like, like newer OCT's and things like that, they are not as familiar with it (II3, P9)* *So, like, the ones that are face-to-face or like really far away, like, it becomes hard to attend those ones, especially with balancing work and, I guess, life commitments (FG3, P6)* *Every time it, it seems like I want to go to a CPD event, it is like six o'clock after work and it is not exactly, um, my favorite thing to do (FG3, P6)*
CPD Factors	**CPD characteristics**	Enabler	*Um, and I think [throat clearing] because so many events are at no cost here, I can get CPD here at no cost. (FG2, P3)* *Yeah, well, no, the cost I think, I do not think anyone's gonna complain about the cost, a weekend, it is, uh, we can all afford that (II3, P9)* *I like to go to face to face, actually, that is how, and workshops. That is how, that is, I guess personally, that is how I learn. So that is why I prefer that. Actually, I very rarely go in online learning, very, actually, very rare (II2, P8)* *I think I prefer online the most, simply because it is the easiest to attend to. Because you can just watch, watch it from home. Or if you are not home, you can just watch it from wherever you are. (II3, P9)* *But, um, ah, maybe, I guess, um, maybe just the way that they do the points. Like, I know that some… Like, for example, I have been to a lot of conferences and I have got an overload of points. But then some people it is, um, they only just scrape through so I do not know whether they are getting the same amount of, like, education that say other optometrists would be getting. I do not know, maybe, yeah (II2, P8)* *In America there's a, um, they do live webinar case studies for a hospital, a hospital, Wills Eye Hospital. They are amazingly fascinating, easy to listen to, and one of the best CPDs because they are real cases. And they go through the differential diagnosis. Um, I get more out of that than anything else because it is um, it is, uh, it's short snippets, 20-minute cases, but you learn a hell of a lot (II3, P9)* *Interaction is best, interaction is best […] Because you have to be active. You may immerse yourself, you thought about it, but, uh, it is, um, you're, you get all your […], sorry, your critical capacity, and then that's the where the best learning curve is. Um, you hear, you contribute, and you realize, hold on as second, that is not right or that is right (II3, P9)* *Yeah, uh, you mean how do I choose which one to prefer? [….] Social amenities. Uh, the social amenities around that area and your friends who are going. (II3, P9)* *Um, it wasn't, it, like, it was at the uni so it wasn't exactly a nice venue or anything. But, like, it was a very, I thought it was intimate coz there was not that many people as well, maybe a list of 30 in the whole event (II2, P8)* *I like the journals as well because I, I go and study, read the [unclear]. Journals are good for me. (II3, P9)* *Um, I think I do more often the, the ones where it's just, kind of, like, the reading ones coz that's the, it's the most convenient time-wise, because I can just read it when I like and I'll just answer the questions (II3, P9)*
		Barrier	*That sounds pretty good, um, as in, I do not, I do not know too much about it. I would assume that it's like a, like a small, kind of, tutorial based, kind of, thing (FG3, P5)*

Category	*Code*	*Barrier/Enabler/Both*	*Illustrative quotes (focus group, participant)*
			And the third factor will be price as well, because I know a lot of, like, especially the bigger events can be like, can cost hundreds and they can be interstate (II3, P9) *And then, um, um, then I know one of the […] online modules, like I tried to open it and then it did not open so I couldn't access it properly. Like, that was not good either. But I think that's some kind of online technical issues thing (II3, P9)* *The only one I can really think of is, I guess if you live in like a really rural area or you're like a remote rural town optometrist, then it'll just be really hard to access the face-to-face ones so you wouldn't […] But like, if you're like, in like, rural, like Western Australia or Northern Territory or something, it might be quite hard to access (II3, P9)*
	Peer to peer interactions	Enabler	*Even if you did talk to your peers, obviously they work in separate rooms from you and so you might not realize that what you are doing is no longer the best thing to do… Well, actually it wouldn't be a bad idea. Like, for example, um, on Facebook there is the, um, Simon and Colin face, uh, like Facebook ophthalmology page and basically, it is just, um, uh, Tom sharing case studies and, um, giving examples of what sort of management to do (FG3, P6)* *Uh, well, uh, what other things is just camaraderie, seeing colleagues go through the same challenging patients. This makes you feel you are not isolated in what you are doing, and it gives you more enjoyment for your work (II3, P9)* *Also, to build rapport with, um, I guess, our like, um, referring, um, professionals as well (FG3, P5)* *And they also get to see the people who have, for example, doing or they have designed the product or they've they are doing the surgery for your patients. So, you get to see who they are. I like to personally, like, see who they are. If there is like, like, once, I think one of the ophthalmologists took us to, um, ah, this cruise (II2, P8)*
Environmental Factors	**n/a**	Enabler	*I think I am also quite lucky that I am central in Sydney, so I can just travel after work. And it is, um, I do not mind doing it either. As long as I am free that night, I guess so (II2, P8)* *If there is like, like, once, I think one of the ophthalmologists took us to, um, ah, this cruise (II2, P8)* *Free, free CPD events, um, I will probably prefer to go to those, um, with dinner included [laughter] (FG3, P5)*
		Barrier	*I guess, like, location (FG3, P6)*
	Time	Enabler	*It was really attractive to a lot of people because they were... Sunday, you know, hubby can look after the kids, you don't miss a day of work. They could get a big... And... And... And she was running them because there was a need (FG1, P2)* *And then there, there is enough weekends and a lot happening at night times (II3, P9)*
		Barrier	*Oh, um, I would prefer if they did it like not everything on like, on week, weeknights. Every time it, it seems like I want to go to a CPD event, it is like six o'clock after work and it is not exactly, um, my favorite thing to do [laughter]. So, yeah. Maybe some more on like, um, during the, maybe like a weekday, or like, um, on Sundays, something like that (FG3, P6)*
	Resources/ money	Enabler	*Uh, I went to an ophthalmology, um, conference, and they use a special lens to look at their far periphery portion of the retina. Uh, uh, the outcome was I spent $1,000 and bought that special lens. […] Hence, I could see a great, with greater view of the peripheral retina and, uh, came up with some, uh, good findings, which ophthalmologists in our local area was quite impressed with, so it does work. (II3, P9)* *Um, and I think [throat clearing] because so many events are at no cost here, I can get CPD here at no cost (FG2, P3)*
		Barrier	*No, there is no downside, but there are occasions where you listen to a lot of lectures, and most of the stuff you have heard before, and you have got to wait for 20 minutes until you get a new snippet of information that adds to your, uh, collective. But you cannot pick and choose, you do not know how much information is redundant, how much is new (II3, P9)* *It's a very fishy business. Um, so there are events that have a high cost associated with them and they should honestly because they are a big thing to run (FG2, P4)*
	Organizational constraints	Enabler	*It is risk mitigation. So, from the point that's... That is why the association likes it because it reduces their, um, professional indemnity... Lux loved it and... And I am sure Specsavers were the same, but the fact that we had our own, um, inhouse, um, CPD department was yeah, mitigated our risk. And allowed us to reduce our premiums (FG1, P1)*
		Barrier	*So, like, the ones that are face-to-face or like really far away, like, it becomes hard to attend those ones, especially with balancing work and, I guess, life commitments (FG3, P6)*

Category	*Code*	*Barrier/Enabler/Both*	*Illustrative quotes (focus group, participant)*
			Un, personally, it is, ah, the main reason is just to ensure that I am registered (II3, P9)
			Hmmm-mm. I guess that comes with like experience as well, um, as I said at the beginning, um, you know, I am just going to whatever I can get my hands on-ish. I feel like, um, because I am working at an independent place and where I am working, um, I, I am by myself. So, I do not have any colleagues or anything (FG3, P5)
			There is like optoms work late, so it is a bit hard in retail (FG3, P6)
	Perceived increase in malpractice liability/ safety	Enabler	*Yes, for others it is good to force some people to go, to turn up, and hopefully at least they will be safe, safer (II3, P9)*
			But for those people who are, do not have the discipline, I think for them to force them to get some points, maybe, uh, you know, they will find that they are safer practitioners (II3, P9)
			Uh, to be, and the secondary fact is you become much safer as a practitioner, and you can diagnose more stuff, you know. (II3, P9)
		Barrier	*Um... But I think the whole thing about safety, about public safety, is not necessarily, uh... That message, I do not think is getting through (FG1, P2)*
			I just do not know how they come up with 45 hours or 60 hours, and if they have done any peer review studies to see which is better, to make a safer practitioner. But it is up to them to come up with their studies (II3, P9)

2.3.4. Sequence CPD participation behavior: Knowledge

In their framework for improvement, Cabana and colleagues considered that factors limiting adherence to guidelines through a cognitive component would affect knowledge (Cabana et al., 1999). Lack of familiarity was intended to include the inability to correctly answer knowledge questions as well as self-reported lack of knowledge, for example an inability to correctly acknowledge the existence of a guideline or piece of published evidence. Categories that impacted behavior related to knowledge included familiarity and awareness.

Australian optometrists participating in this qualitative study were familiar with the meaning of CPD, describing it as an enabler of knowledge associated with the concept of lifelong learning or keeping "up-to-date" with new knowledge and skills that has arisen since their initial training as a practitioner. There was a recognition that new knowledge is constantly being generated and that learning needs to continue always *"As health practitioners, we accept the fact that health is always changing […] I don't think that we, we shouldn't be always learning" (II2, P8).* Optometrists also felt that CPD was an important vehicle for imparting specialty knowledge, in those areas of practices where a practitioner might want to specialize or, conversely, might need further education because they do not actively practice in those areas. Many mentioned CPD as an enabler of breadth of information, allowing them to grow to their full scope of practice. Some saw a role for CPD in the maintenance of *"public safety"* and in ensuring that optometrists can give *"the best standard for care"* to their patients.

Time Needed to Stay Informed intersected with CPD characteristics. Optometrists suggested that CPD structured to highlight most recent research findings, their applicability to clinical practice, and provide advice on this could be integrated into clinical practice would enable Knowledge. Optometrists recognized that attending to CPD required a sacrifice of personal time. Whilst CPD was generally described as readily available in positive terms, one optometrist perceived the large volume of CPD as a barrier because of the unreasonable amount of time that would be required to attend all CPD events on offer *"once a week at least, and it's quite a lot of time away" (II2, P8)*.

Optometrists felt that CPD accessibility was much improved by the availability of a centralized, clear calendar of CPD events such as that provided by the professional association Optometry Australia, but some recognized that this would miss potentially important events (e.g., overseas conferences).

Familiarity and awareness of CPD intersected with the CPD regulatory environment (listed under the CPD participation behavior sequence of change). Many were not familiar with the requirements in existence at the time interviews were conducted. Many optometrists reporting that they were aware but not familiar with a recent change in the CPD regulations for optometrists in Australia (Optometry Australia, 2020b).

Optometrists were generally familiar with the large volume and wide breath of information that they need to keep pace with. Many spoke about being *"out of date"* a few years out of their university training.

A new code labelled Retention was introduced under the sequence of behavior Knowledge, category Familiarity. This code was related to the process of retaining or forgetting information over time. Practitioners felt that without CPD, they would start to forget knowledge they had learnt during their training. Within this sat the concept of repeating information and maintenance.

Optometrists identified many stakeholders of CPD, with the professional association Optometry Australia recognized as a key stakeholder of CPD by many. Intersecting with knowledge and awareness of the regulatory environment, very few participants identified other important stakeholders including the Optometry Board of Australia and the Australian Health Practitioner Regulatory Agency. Participants tended to identify those stakeholders that provide CPD for optometrists and thus included other health professionals (e.g., ophthalmologists) and manufacturers of products relevant to optometrists (e.g., contact lenses). Provision of CPD by optometrists and ophthalmologists was generally viewed favorably whereas CPD provision by manufacturers was at times viewed negatively with concepts such as lack of evidence and conflicts of interest raised by participants.

2.3.5. Sequence CPD participation behavior: Attitude

In their framework for improvement, Cabana and colleagues considered that factors limiting adherence to guidelines through an affective component would affect attitude (Cabana et al., 1999).

Optometrists reported a positive or negative attitude towards CPD because of a lack of agreement with specific characteristics of CPD but had less opinions on their agreement or disagreement with CPD in general. Optometrists overall favored CPD events where the material delivered was applicable to patient care (including *'hands-on'* education), novel and challenging, relevant to their specialty practice, low cost and high CPD points and delivered by a trustworthy speaker. The balance between the cost of CPD and the number of CPD points attributed to it was discussed by optometrists as a factor influence decision regarding specific CPD attendance. The rigorous processes surrounding accreditation of university training courses for optometrists were contrasted with the minimal quality assurance processes surrounding other types of CPD providers (Optometry Australia, 2020a). Trust or confidence in the speaker was mentioned as key to agreement with a particular CPD. Even when optometrists discussed CPD in terms of biased synthesis, they related this to the characteristics of individual speakers. Manufacturers were generally recognized as having vested interests in promoting their products and thus were often spoken about as less *"reliable"* or *"trustworthy"* than other types of speakers. An interesting example was provided by an optometrist who described attending CPD events offered by the local ophthalmologist he or she referred to, with the specific intent to gage the ophthalmologist's trustworthiness, whether they were "up-to-date" and could be safely trusted to manage the patients referred by the optometrist to them. Applicability to patient and applicability to clinical practice was mentioned as an enabler, "*I consider it effective if I remember it and I start to apply it to practice"*. This type of changed CPD participation behavior was viewed as confirmation of the effectiveness of a given CPD. High price was at times mentioned as a disadvantage of CPD and optometrists highlighted that CPD was readily available at no cost in Australia. However, some optometrists felt that a high price could be justified if a CPD event had high-quality content, innovative delivery method and quality speakers.

Outcome expectancy refers to a health practitioner's belief that their action or practice behavior will lead to a given (positive or negative) outcome or consequence. Optometrists generally believed that they would benefit or "learn" from CPD but discussed the challenges associated with selecting the right type of CPD that would add to their knowledge rather than just restating what they already know. The ability of CPD to lead to a changed or *"better"* practitioner that can give *"up to date"* information to their patients was highlighted in the discussions.

Self-efficacy has been defined as a perceived capability to perform a behavior. In the current context, self-efficacy referred to a health practitioner's belief that they are able to perform an action or practice behavior necessary to deliver appropriate health care. (Carey & Forsyth, 2009; Taveras et al., 2009). In this study self-efficacy intersected with CPD characteristics. Optometrists expressed strong belief in their ability to manage various eye conditions and felt that the type of provider delivering the CPD (for example ophthalmologist versus optometrist) impacted on the relevance of the CPD offering, with optometrists being more likely to believe in a potential independent role for optometrists. Workshops were described as particularly useful in increasing *"confidence"* in difficult techniques such as for example foreign body removal. Ophthalmology-led CPD was characterized by some optometrists as less relevant but conversely it was described as more challenging by others. Such differences in descriptions may be related to individual optometrist's self-efficacy.

CPD was recognized as a good enabler or motivator for learning, for breaking habits and routines and enabling changed practice behavior, with optometrists likening it to university education. Optometrists talked about CPD allowing them to "go back into student mode". Lack of motivation and inertia of previous practice was recognized as a barrier to CPD. This interacted with the regulatory environment, with the need to meet certain requirements or "points" seen as an enabler of CPD.

2.3.6. Sequence CPD participation behavior: Behavior

In their framework for improvement, Cabana and colleagues considered that factors limiting adherence to guidelines through a restriction of practitioner ability would affect behavior (Cabana et al., 1999). An optometrist with appropriate knowledge and attitude may still be limited in his ability to use CPD to deliver care (practice behavior) because of external barriers (patient and practitioner factors), CPD or environmental factors. Although these behavioral CPD participation factors are in theory independent from optometrists' knowledge and attitude, their persistence could eventually impact on optometrists' outcome expectancy, self-efficacy, or motivation, as indicated by the arrows in Figure 2.2. For example, a new graduate may be well trained and confident in performing dilated fundus examination for the detection diabetic retinopathy in people with diabetes but may be unable to perform these as recommended in CPD because of short consultation time or lack Medicare funding (Gyawali et al., 2019).

External barriers related to optometrists' family and self-commitments were perceived as important external barriers to CPD, much more so than patient related factors which were seldom mentioned. Work-life balance was frequently mentioned, and this interacted with the CPD characteristic timing of event (during day versus evening, during week versus weekend), amount of travel required, etc. Those that lived outside major urban centers were perceived to be at a disadvantage when it came to accessing face-to-face CPD events. CPD was perceived to be of increased value for older practitioner, because of their likely increased need to stay "up-to-date". Examples of fields of practice where significant changes to practice have occurred were given my optometrists such as the advent of OCT.

CPD factors were a relatively important code sitting the behavior side of the tree structure. Most optometrists appeared to conceive CPD as presentations, be they face-to-face or webinars, however, one optometrist mentioned scientific journals as another important source of CPD. Cased- based CPD offerings that involved *"ground rounds"* or *"real cases"* were valued. Interactivity of CPD was also mentioned as an important aspect that enabled optometrists to optimize their learning. Many optometrists stated that they preferred face to face learning but when this was explored further this preference appeared to be grounded in the interactivity that is more readily found in face-to-face learning. When stated, a preference to online CPD was largely related to the convenience it offered in terms of medium, time, and location it could be accessed from. Workshops were also greatly valued by optometrists who described them positively using words such as *"hands-on"*, "*intimate"*, highlighting the benefit of workshops in terms of practicality and small group size. As mentioned above optometrists also described the cost of CPD events as one of the important factors that would influence their decision to attend a specific CPD event. The relatively common availability of free CPD events in Australia was highlighted as an important factor impacting CPD decisions. Conversely, this was also described as "*fishy business*". Factors such as cost, location and CPD points allocation significantly interacted with each other, appearing to be very influential in optometrists' decisions of which CPD event to attend.

Peer-to-peer interactions were a valued aspect of CPD. Optometrists described this as *"camaraderie"*, *"networking"*, felt that this helped to combat isolation, gave them more enjoyment in their work. A specific subset of peer-to-peer interactions that was frequently mentioned was the use of CPD to help establish and/or solidify a referral pathway to ophthalmology. Optometrists viewed events offered by an ophthalmologist that they refer to as a way to optimize interprofessional relations.

Environmental factors were a major determinant of CPD participation behavior. Lack of time including poor timing, access to resources and equipment were commonly mentioned determinants (barriers and enablers) of CPD. Timing of CPD was perceived as an influential characteristic by optometrists but the scheduling of CPD in the evening and on weekends was perceived both positively and negatively by different optometrists. In addition to the learning gained and the CPD points, incentives such as the inclusion of free meals or cruises were mentioned as factors that can influence choice of CPD by some optometrists. CPD was mentioned as a key enabler of introduction and access to new equipment. Optometrists were also concerned with CPD's ability to mitigate the risks for malpractice. The concept of *"public safety"* was frequently mentioned. Examples from corporate and franchise optometry groups where in-house CPD was perceived as a tool to reduce insurance premium were provided.

2.4. Discussion

Continuing development of optometrists through engagement with CPD is critical for the maintenance of evidence-based practice and the translation of health care recommendations into improved outcomes. This study explored Australian optometrists' perspective of CPD and, using the Cabana framework, identified a variety of determinants (barriers and enablers) that can promote or undermine the process of transforming knowledge imparted through CPD into a sustained CPD participation behavior change. Awareness and familiarity of CPD affected optometrists' knowledge. Optometrists' attitudes, that is their beliefs in the value of CPD in general and beliefs in the value of specific types of CPD, their outcome expectancy, self-efficacy, the inertia of previous practice and their desire for self-improvement were described as modulators of CPD. Optometrists' ability to change their practice behaviors by attending and/or using CPD was affected not only by their attitude, but also by external factors including CPD characteristics and environmental factors. Environmental context and resources, knowledge, skills, and belief about consequence were recently identified as important domains in a systematic review of determinants of optometry practice (Toomey et al., 2021). The findings from the current qualitative research study generally aligned well with those identified in the systematic review.

2.4.1. Knowledge

The exponentially expanding volume of research related to optometry and ophthalmology (see Figure 2.1) makes it difficult for optometrists to maintain up-to-date knowledge regarding every possible eye disease and critically apply this in practice (Suttle et al., 2015a). Awareness of knowledge does not necessarily lead to familiarity with knowledge; optometrists in this study were generally more likely to be aware of the need for CPD but felt that they were not necessarily familiar with all knowledge. Many optometrists mentioned a need for a minimum amount of education or "points" to be focused on therapeutic practice for those optometrists endorsed to prescribe therapeutic agents. This was discussed in the context of the regulations surrounding CPD in Australia. Aside from this, optometrists rarely referred to specific areas of eye care when discussing CPD. In contrast to this, the bulk of existing studies on determinants of eye care practice focused on specific areas of care including low vision, age-related macular degeneration, and glaucoma care (representing more than 20% of existing studies each (Toomey et al., 2021)).

2.4.2. Attitude

Optometrists generally displayed a positive attitude towards CPD and expressed general agreement with CPD. Positive attitudes to CPD are not uncommon in other health professions such as for example pharmacy (Saade et al., 2018). Health professionals' attitudes to CPD can influence the CPD methods they select to attend and the effectiveness of CPD activities (IOM, 2010). Lack of agreement was more common in relation to specific CPD, an indication that certain characteristics of the CPD can significantly modulate optometrists' attitude to CPD and its ability to lead to a behavior change. Previous mixed method research from New Zealand indicated that most optometrists (approximately two-thirds) did not want to hear about research results in CPD, particularly those which are perceived to have no direct clinical application or to be "*impractical academic subjects with no clinical relevance*" (Jacobs & Scott, 1990). In contrast, this perspective was not offered by Australian optometrists in the current study where the "Too cookbook" idea from the Cabana framework was not coded to. This could be attributed to a shift in beliefs and values regarding research by optometrists over time or country differences.

The lack of financing for CPD and the likelihood of this giving rise to potential conflict of interests was raised by many optometrists in this study as a barrier to specific types of CPD. Industries including pharmaceutical and medical device companies have long taken a role in financing the provision of CPD in health, including optometry. CPD for optometrists that was directly funded or delivered by these types of providers was described as "*biased*". The findings of this study suggest that as not all optometrists may be able to detect this type of bias, clear guidelines, and clear direction from regulatory authorities for optometry CPD in Australia are urgently required, detailing how CPD providers ought to systematically declare perceived and real conflicts of interest.

2.4.2.1. ***Self-efficacy: Of course, I can do this***

A clinician's ability to learn and/or change practice behavior from engaging in CPD may be related to his or her confidence in his or her own abilities. Optometrists in this study appeared to possess good self-efficacy; they generally expressed high confidence in their ability to appropriately manage eye conditions. In a recent systematic review of determinants of optometry practice, approximately 50% to 60 % of studies coded barriers and facilitators to the

Belief about capabilities TDF domain (Toomey et al., 2021). Conversely, needing more practice and needing a better understanding of when the procedure was required were cited as the main reasons for unchanged practice by optometrists 4 to 13 months following attendance at a CPD workshop (McDonnell & Crehan, 2012). These findings align with a recent clinical audit study where 15 optometrists were moderately confident (reasonably confident, confident, or very confident) in AMD knowledge and clinical care provision (range 80% to 100%) prior to a clinical audit intervention (Gocuk et al., 2021). Similarly, 98 optometrists self-rated themselves as moderately confident (72%) in identifying migraines in their patients (Nguyen et al., 2020). CPD can be used to raise self-efficacy for those areas of care where optometrists report low confidence. For example, the self-efficacy of optometrists towards examining people with intellectual disabilities was improved by an educational program, and more so if the training incorporated a clinical experience component using real patients (Adler et al., 2005b).

At times, optometrists contrasted their self-efficacy with ophthalmologists' differing views of optometry's role and capabilities. This aligns with previous findings regarding the perceptions of the social or professional role and identity of optometrists, and their potential role in providing nutritional and smoking cessation advice to their patients (Jalbert et al., 2020; Zhang et al., 2020).

2.4.2.2. ***Outcome Expectancy: What is in it for me? And for my patients?***

Other research has previously suggested that optometrists need to be convinced of the benefits for them and their patients before they commit to change their practice behaviors (McDonnell & Crehan, 2012). Optometrists in this study expressed positive and negative outcome expectancy towards CPD: some CPD termed "not useful" appeared related to potential overlaps in scope of practice between optometry and ophthalmology, with an expectation that is it unnecessary to conduct some procedures if the ophthalmologist the patient is co-managed with or referred to is expected to conduct these. Conversely, a belief was often expressed that useful advice or education was ultimately contained in any CPD as long as the listener was prepared to wait to hear it or concentrate to find it.

2.4.2.3. ***Self-improvement***

Motivation to attend CPD can arise from regulatory requirements, in which case it is unlikely to yield a positive attitude to CPD. Alternatively motivation to learn may come from an internal place that includes curiosity or a desire to learn. This has been described as a type of intrinsic motivation. A number of theories of motivation from the psychology fields suggest gaps in knowledge as the source of this motivation (IOM, 2010). A new category termed self-improvement was added under the attitude section of the Cabana framework based on optometrists' accounts of CPD. This recognition by optometrists involved in the study of the need for personal growth aligned well with the recommendations from the Joanna Briggs Institute systematic review of literature on CPD in regulated profession commissioned by AHPRA suggesting that activities promoting self-reflection such as the use of portfolios should be fostered (JBI, 2012). It also aligned well with the definition and example of deliberate practice provided by Faucher where optometrists engage in activities for acquisition of new knowledge including CPD lectures and workshops with a view to improving their optometry practice (Faucher, 2011).

There is a tendency for regulatory agencies to talk about CPD in terms of minimum competencies with a focus on making sure that credentialing assessments ensure that a certain minimum level of knowledge and skills are met for the practice of optometry (Backhouse et al., 2021). This is in line with internal data on analyses of notification records by AHPRA which shows an increased likelihood of notification with increasing age (JBI, 2012). A process of progressive professional development from minimally competent to advanced or proficient followed by expert has been described (Faucher, 2011). Optometrists in this study described CPD primarily in terms of maintenance of professional competence and/or development of specialty practice rather than as a means for developing expertise. Based on this, it appeared that CPD was as important for experienced optometrists as it might be for new graduates but may not necessarily yield additional expertise.

2.4.2.4. ***Motivation/ Inertia of previous practice***

High motivation has been said to predict not only what one can learn but also how one learns (Fox & Miner, 1999). At the other end of the spectrum poor motivation has been described as or likened to an inertia of previous practice. The difficulty in breaking routine or habits was recognized as a barrier to CPD in this study. This aligned with findings from a study that identified "Forgot to use" (53% of participants) and "Difficulty changing old routines" (24% of participants) as some of the most important barriers to the implementation of a migraine screening tool into optometric practice (Lipton et al., 2003). Within this category of motivation, a criticism of the regulatory system of CPD in place at the time this study was conducted might be that optometrists could have a tendency to attend CPD based on existing clinical interest and expertise, rather than targeting areas where they have weaknesses. The recent (Dec 2020) regulatory changes to CPD for optometrists in Australia which require optometrists to maintain a portfolio of learning goals might begin to address these potential issues (Optometry Board of Australia, 2020).

2.4.3. Behavior

The context or environment within which optometrists practiced influenced their ability to engage in, learn and change practice behavior through CPD. Processes, systems, and traditions can facilitate or hinder learning and use of new knowledge in practice (IOM, 2010).

2.4.3.1. ***External Barriers***

Optometrists who have been in practice longer, of female gender, and whose practices were in rural areas have previously been shown to have a higher regard for the importance of CPD, a more positive attitude towards CPD (Jacobs & Scott, 1990). The impact of practitioner factors on behaviors related to CPD was similarly discussed in this study. Optometrists felt that CPD was "*more important*" for those who had graduated a long time ago, but rurality was generally discussed as a potential barrier to CPD, and gender was not discussed.

2.4.3.2. ***CPD Factors***

CPD characteristics interacted significantly with the optometrists' attitude and likelihood of engaging with a particular CPD. This is similar to previous reports for example in pharmacists where the location of the CPD activity, constraints from employers, and time limitations were the most important barriers to CPD participation (Saade et al., 2018). In line with previous findings from optometry (Jacobs & Scott, 1990), hands-on workshops and practical training were described by optometrists in this study as enablers of changed practice behavior through CPD. In the optometry literature, comprehensive education programs that involved hands-on workshops, practical and/or patient activities or interactivity demonstrated more clinically significant and sustained changes to optometrists' practice behaviors (Kleinstein et al., 1985) (Cui et al., 2011) (Adler et al., 2005b). Peer interactions was perceived as an enabler of CPD by optometrists in the study. This aligned well with the findings from one of very first published research on CPD for optometrists originating from New Zealand in 1990 which concluded that "*The most effective continuing education was said to be that gained from interactions with colleagues*" (Jacobs & Scott, 1990). A more recent systematic review confirmed that peer interaction reduced feelings of professional isolation (JBI, 2012). When discussing peer to peer interactions, optometrists referred to other optometry colleagues. The term CPD acknowledges not only the wide-ranging competencies needed to practice high quality care, but also the multidisciplinary context of patient care (Peck et al., 2000). Peer to peer interaction in the form of interprofessional CPD, where optometry could or would learn interactively with one or more other health profession (e.g., general practitioners, nurses, dieticians, ophthalmologists), was however not specifically mentioned by optometrists. Yet the most recent Accreditation Standards and Evidence Guide for Entry-Level Optometry Programs include a requirement that principles of inter-professional learning and practice are embedded in the curriculum of any accredited program of study in optometry in Australia (OCANZ, 2017). The enhancement of interprofessional team-based learning and care through CPD education was similarly recommended by the Institute of Medicine in 2010 as a means to improve team-based care for improved patient outcomes (IOM, 2010). Based on the findings of this study, it appears that interprofessional learning has not yet been established as a current or desirable norm by Australian optometrists. Relevant stakeholders including professional organizations and regulatory bodies may need to put more efforts into fostering and enabling the delivery of this type of interprofessional CPD.

2.4.3.3. ***Environmental Factors***

Time was not perceived as a significant barrier to CPD by study optometrists who spoke of time mostly in the context of timing of CPD event (day versus night, week versus weekend) and in terms of external barriers (practitioner factors), where time interacted with the ability to keep family commitments. Lack of time per say was not frequently cited by participants. This contrasts with previous literature suggested time commitment concerns as a major barrier to evidence-based practice and participation in self-improvement interventions (Gocuk et al., 2021; Suttle et al., 2015a). In Suttle et al. study (2015), 35 barriers to evidence-based practice were recognized, where time' was of the top five barriers by most participants and got the top score of all other barrier (Suttle et al., 2015b). The same barrier was reported by Gocuk et al. (2021), where the most frequently reported barrier to clinical audit was time commitment (Gocuk et al., 2021).

CPD was previously rated at a low level compared to other factors when asked to rate its contribution to financial success and this was reflected in the current study where a financial impact for CPD did not form part of optometrists' perspective of CPD (Jacobs & Scott, 1990).

2.5. Strengths and limitations

A strength of this study is the qualitative research approach, minimizing the bias inherent to more quantitative approaches (Lipton et al., 2003).

A very small number of participants were involved in the study and in individual focus groups, however, data collection continued until saturation was obtained. Those optometrists who participated were both young and old, from both sexes, and originated from a wide variety of practice settings (2 states, metropolitan, regional, and rural settings, private and corporate optometry). Selection bias may have been present as optometrists who volunteered for the study may have been those who have a more positive attitude and more frequently attend CPD. The findings presented may thus represent many but not all possible views of Australian optometrists.

This study was conducted prior to the advent of the coronavirus pandemic in 2020 (Kitto, 2020). As everywhere else, the advent of COVID-19 has led to significant changes to the optometric education and optometric CPD landscape in Australia (Schmid et al., 2021) (Efron & Efron, 2020). Face to face conferences were cancelled and a number of meetings were repackaged as web-based events including podcasts and live webinars (Efron & Efron, 2020). What this means for the future of CPD in optometry is uncertain.

2.6. Conclusion

Chapter 1 introduced the CPD model of effectiveness (Marinopoulos & Baumann, 2009). This model outlines the outcomes of effective CPD included knowledge, attitudes and skills, practice behavior and clinical practice outcomes. In this first study we report on Optometrists' perspective of CPD and identified a variety of determinants (barriers and enablers) that can promote or undermine the process of transforming knowledge imparted through CPD into a sustained practice behavior change. Optometrists reported that awareness of knowledge does not necessarily lead to familiarity with knowledge; optometrists in this study were generally more likely to be aware of the need for CPD but felt that they were not necessarily familiar with all knowledge. Optometrists generally displayed a positive attitude towards CPD and expressed general agreement with CPD and appeared to possess good self-efficacy; they generally expressed high confidence in their ability to appropriately manage eye conditions. The context or environment within which optometrists practiced influenced their ability to engage in, learn and change behavior through CPD attitudes and skills, practice behavior and clinical practice outcomes. This research supports the use of the Cabana framework as a determinant framework to explore the concepts, constructs and structures that best describe CPD. In addition to those categories already contained in the Cabana framework, the research highlighted some new areas such as self-improvement, memory loss and peer-to-peer interactions that were necessary to fully explain optometrists' perspective of CPD. These and other findings from this research provide useful insights for policy makers, education providers, professional organizations, and CPD developers wishing to optimize the effectiveness of CPD programs.

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2.8. Appendices

2.8.1. Appendix 2-1: Consolidated Criteria for Reporting Qualitative Research (COREQ)

a 32-item checklist for interviews and focus groups (Tong et al., 2007).

No. Item	*Guide questions/description*	*Response*
Domain 1: Research team and reflexivity		
	Personal Characteristics	
1.Interviewer/facilitator	Which author/s conducted the interview or focus group?	Sally Alkhawajah (SK), Isabelle Jalbert (IJ), Kirsten Challinor (KC)
2. Credentials	What were the researcher's credentials? E.g., PhD, MD	SK: MOptom, BOptom. IJ: OD, MPH, PhD, FAAO, GradCertOcTher. KC: BPsych, PhD.
3. Occupation	What was their occupation at the time of the study?	SK: PhD Candidate, UNSW Sydney IJ: Associate Professor, Deputy Head, School of Optometry and Vision Science; Associate Dean International and Engagement, Faculty of Science, UNSW Sydney Chair, Examination Committee, Optometry Council of Australia, and New Zealand (OCANZ) KC: Lecturer, School of Behavioral and Health Sciences, Australian Catholic University Adjunct Lecturer, School of Optometry and Vision Science, UNSW Sydney
4. Gender	Was the researcher male or female?	All three researchers were females.
5. Experience and training	What experience or training did the researcher have?	SA: Completed NVivo 2-day workshop at School of Public Health and Community Medicine, UNSW Sydney Previously conducted, coded, and analyzed 9 focus groups in Saudi Arabia, supervised by IJ and KC (unpublished) IJ: Master of Public Health that included training in qualitative research methods. NVivo online course

2.1.1.1. ***Appendix 2-1: continued***

		Extensive experience conducting interviews and focus groups (Alnahedh et al., 2015; Jalbert et al., 2020; Suttle et al., 2015a) KC: Experience conducting interviews and focus groups (Suttle et al., 2015a)
	Relationship with participants	
6. Relationship established	Was a relationship established prior to study commencement?	Yes
7. Participant knowledge of the interviewer	What did the participants know about the researcher? e.g., personal goals, reasons for doing the research	Participants read & signed the Participant Information Statement & Consent (PISC) form, which included information about the study aims and objectives. Participants were informed that the research would form part of SK's PhD thesis
8. Interviewer characteristics	What characteristics were reported about the inter viewer/facilitator? e.g., Bias, assumptions, reasons, and interests in the research topic	IJ and KC are academics who may have positive bias towards education
Domain 2: Study design		
Theoretical framework		
9. Methodological orientation and Theory	What methodological orientation was stated to underpin the study? e.g., grounded theory, discourse analysis, ethnography, phenomenology, content analysis	Deductive coding using "a priori" codes and the Framework method
	Participant selection	
10. Sampling	How were participants selected? e.g., purposive, convenience, consecutive, snowball	Convenience (snowball) sampling
11. Method of approach	How were participants approached? e.g., face-to-face, telephone, mail, email	Recruited by email, through websites, social media (e.g., Facebook), and word of mouth
12. Sample size	How many participants	Eleven optometrists who

2.1.1.2. *Appendix 2-1: continued*

	were in the study?	volunteered were enrolled
13. Non-participation	How many people refused to participate or dropped out? Reasons?	Two optometrists were lost to follow-up prior to the scheduled focus group discussion.
	Setting	
14. Setting of data collection	Where was the data collected? e.g., home, clinic, workplace	Data was collected in a university location (e.g., meeting room, restaurant) or via skype
15. Presence of non-participants	Was anyone else present besides the participants and researchers?	No.
16. Description of sample	What are the important characteristics of the sample? e.g., demographic data, date	Nine registered optometrists (7 females, 2 males) ranging from 23 to 58 years in age. Four optometrists work in private and corporate practices, respectively and one was a university academic. Data was collected between 21/05/2019 and 10/10/2019.
	Data collection	
17. Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?	A Semi-structured interview guide was used (Table 2.4). Follow-up questions were allowed. The guide was not pilot tested; it was continuously adapted based on issues raised during discussions.
18. Repeat interviews	Were repeat interviews carried out? If yes, how many?	No.
19. Audio/visual recording	Did the research use audio or visual recording to collect the data?	The interviews were recorded using a laptop and on a mobile phone as backup.
20. Field notes	Were field notes made during and/or after the interview or focus group?	Yes. Fields notes were made and analyzed.
21. Duration	What was the duration of the interviews or focus group?	The focus group durations ranged from 38 to 52 minutes and individual interviews duration ranged from 18 to 20 minutes.
22. Data saturation	Was data saturation discussed?	Yes. Data saturation was discussed and agreed by consensus between the two experienced and one novice researcher.
23. Transcripts returned	Were transcripts returned to participants for	No. Transcripts were not returned.

2.1.1.3. *Appendix 2-1: continued*

	comment and/or correction?	
Domain 3: analysis and findings		
	Data analysis	
24. Number of data coders	How many data coders coded the data?	Three researchers coded the data simultaneously.
25. Description of the coding tree	Did authors provide a description of the coding tree?	Yes. The analytical framework proposed by Cabana et al for analysis of barriers to physician's adherence to clinical practice guidelines was used(Cabana et al., 1999). Data were simultaneously coded as either a barrier or a facilitator or both.
26. Derivation of themes	Were themes identified in advance or derived from the data?	Yes. Emerging new codes were proposed for responses that could not be logically mapped to any of the predefined codes from the Cabana framework.
27. Software	What software, if applicable, was used to manage the data?	NVivo 12.
28. Participant checking	Did participants provide feedback on the findings?	No.
	Reporting	
29. Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g., participant number	Yes. Specific comments were supported with direct quotes attributed to anonymized participants by data collection method (interview or focus group)
30. Data and findings consistent	Was there consistency between the data presented and the findings?	Yes
31. Clarity of major themes	Were major themes clearly presented in the findings?	Yes
32. Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?	Yes. Minor themes are discussed in full.

2.8.2. Appendix 2-2: PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM

PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM

UNSW SYDNEY

Optometrists' Perspectives of Continuing Education or Continuing Professional Development (CPD)

A/Prof Isabelle Jalbert

1. **What is the research study about?**
You are invited to take part in this research study. The research study aims to explore the perspectives of Australian optometrists toward continuing education or continuing professional development (CPD). You are invited to take part in this research study because you are an optometrist registered for practice in Australia.

2. **Who is conducting this research?**
This study is being carried out by the following researchers: Dr Isabelle Jalbert, Dr Kirsten Challinor and Ms Sally Alkhawajah, School of Optometry & Vision Science / The University of New South Wales (UNSW) Sydney.
Research Funder: This research is not funded by any funding organisation and will be supported by Drs Jalbert and Challinor discretionary research funds.

3. **Inclusion/Exclusion Criteria**
Before you decide to participate in this research study, we need to ensure that it is ok for you to take part. The research study is looking to recruit people who meet the following criteria:
   - Optometrists registered for practice in Australia.
   - Any gender, age 18 years and over, any practice type or location, etc.

4. **Do I have to take part in this research study?**
Participation in this research study is voluntary. If you do not want to take part, you do not have to. If you decide to take part and later change your mind, you are free to withdraw from the study at any stage.

   If you decide you want to take part in the research study, you will be asked to:
   - Read the information carefully (ask questions if necessary);
   - Sign and return the consent form if you decide to participate in the study;
   - Take a copy of this form with you to keep.

5. **What does participation in this research require, and are there any risks involved?**
If you decide to take part in the research study, you will be asked to participate in a face to face focus group or individual semi-structured interview. You will be asked questions about your perspectives and beliefs towards continuing education. It should take approximately 45 to 60 minutes to complete.
To ensure we collect the responses accurately, we seek your permission to digitally record the interview using an audio tape. If you would like to participate but do not wish to be recorded, you will need to discuss the options for your participation with the research team.
We don't expect the questions to cause any harm or discomfort, however if you experience feelings of distress as a result of participation in this study you can let the research team know and they will provide you with assistance.

6. **What are the possible benefits to participation?**
We hope to use information we get from this research study to identify beliefs, practices, and barriers to continuing education in Australian optometrists. This may ultimately lead to the development of recommendations on how to maximise the potential for continuing education to be effective.

7. **What will happen to information about me?**
By signing the consent form you consent to the research team collecting and using information about you for the research study. We will keep your data for a minimum of 7 years. We will store information about you at UNSW. Your information will only be used for the purpose of this research study and it will only be disclosed with your permission.
Researchers at UNSW are required to store their aggregated data in UNSW data repository, this is a system called ResData. Once the aggregated data is deposited into this repository it will be retained in this system permanently. It will, however, be retained in a format where your identity will not be known. Your information will only be used for this research study. The information you provide is personal information for the purposes

HC Number:
Version dated: 13 November 2017

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2.8.2.1. *Appendix 2-2: continued*

PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM

UNSW SYDNEY

of the Privacy and Personal Information Protection Act 1998 (NSW). You have the right of access to personal information held about you by the University, the right to request correction and amendment of it, and the right to make a compliant about a breach of the Information Protection Principles as contained in the PPIP Act. Further information on how the University protects personal information is available in the UNSW Privacy Management Plan.

8. **How and when will I find out what the results of the research study are?**
It is anticipated that the results of this research study will be published and/or presented in a variety of forums. In any publication and/or presentation, information will be published, in a way such that you will not be individually identifiable.
You have the right to request access to the information about you that is collected and stored by the research team. You also have the right to request that any information with which you disagree be corrected. You can do this by contacting a member of the research team.
The audiotaped digital recordings are for the purposes of the research study. After the focus group/interview, we will transcribe your digital recordings. We will keep your digital recordings in the form of digital recording and transcription for 7 years. Your confidentiality will be ensured by de-identifying any comments before publication. You have a right to receive feedback about the overall results of this study. You can tell us that you wish to receive feedback by emailing the Chief Investigator Dr Jalbert using the contact details provided below. This feedback will be in the form of a one-page summary which will be made available upon request. You will be able to access this feedback after the study is finished.

9. **What if I want to withdraw from the research study?**
If you do consent to participate, you may withdraw at any time. You can do so by completing the 'Withdrawal of Consent Form' which is provided at the end of this document. Alternatively, you can email the research team and tell them you no longer want to participate. Your decision not to participate or to withdraw from the study will not affect your relationship with UNSW. If you decide to leave the research study, the researchers will not collect additional information from you. Any identifiable information about you will be withdrawn from the research project. The research team will destroy any information about you that was collected during your participation in the study individual interviews.
If, however, you participate in a focus group, your comments along with other participants will be recorded during the group discussions. Because of the way in which the focus group discussions are recorded, the research team will not be able to withdraw or destroy individual participant responses.

10. **What should I do if I have further questions about my involvement in the research study?**
The person you may need to contact will depend on the nature of your query. If you require further information regarding this study or if you have any problems which may be related to your involvement in the study, you can contact the following member/s of the research team:

Research Team Contact Details:

Name	A/ Prof Isabelle Jalbert
Position	Chief Investigator
Telephone	+61 2 9385 9816
Email	i.jalbert@unsw.edu.au

What if I have a complaint or any concerns about the research study?
If you have a complaint regarding any aspect of the study or the way it is being conducted, please contact the UNSW Human Ethics Coordinator:

Complaints Contact:

Position	UNSW Human Research Ethics Coordinator
Telephone	+ 61 2 9385 6222
Email	humanethics@unsw.edu.au
HC Reference Number	HC17629

HC Number:
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2.8.2.2. ***Appendix 2-2: continued***

PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM

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Consent Form – Participant providing own consent

Declaration by the participant

- ☐ I understand I am being asked to provide consent to participate in this research study;
- ☐ I have read the Participant Information Sheet or someone has read it to me in a language that I understand;
- ☐ I understand the purposes, study tasks and risks of the research described in the study;
- ☐ I understand that the research team will audio/video record the interviews; I agree to be recorded for this purpose.
- ☐ I provide my consent for the information collected about me to be used for the purpose of this research study only.
- ☐ I have had an opportunity to ask questions and I am satisfied with the answers I have received;
- ☐ I freely agree to participate in this research study as described and understand that I am free to withdraw at any time during the study and withdrawal will not affect my relationship with any of the named organisations and/or research team members;
- ☐ I would like to receive a copy of the study results via email or post, I have provided my details below and ask that they be used for this purpose only;

  Name: ______________________________

  Address: ______________________________

  Email Address: __________________________

- ☐ I understand that I will be given a signed copy of this document to keep;

Participant Signature

Name of Participant (please print)	
Signature of Research Participant	
Date	

Declaration by Researcher*

- ☐ I have given a verbal explanation of the research study, its study activities and risks and I believe that the participant has understood that explanation.

Researcher Signature*

Name of Researcher (please print)	
Signature of Researcher	
Date	

***An appropriately qualified member of the research team must provide the explanation of, and information concerning the research study.**
Note: All parties signing the consent section must date their own signature.

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2.8.2.3. *Appendix 2-2: continued*

PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM

UNSW SYDNEY

Form for Withdrawal of Participation

I wish to **WITHDRAW** my consent to participate in this research study described above and understand that such withdrawal **WILL NOT** affect my relationship with The University of New South Wales (UNSW) Sydney. In withdrawing my consent, I would like any information which I have provided for the purpose of this research study withdrawn. I understand that the information collected about me during my participation in the focus group cannot be withdrawn given the nature of the focus group.

Participant Signature:

Name of Participant (please print)	
Signature of Research Participant	
Date	

The section for Withdrawal of Participation should be forwarded to:

CI Name:	A/ Prof Isabelle Jalbert
Email:	i.jalbert@unsw.edu.au
Phone:	+61 2 9385 9816
Postal Address:	School of Optometry and Vision Science, UNSW Australia, Sydney 2052

HC Number:
Version dated: 13 November 2017

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Chapter 3. Adaptative Versus Traditional CPD in Optometry: A Quasi-Randomized Trial

3.1. Background

Chapter 1 (Figure 1.2) introduced our conceptual model CPD (Marinopoulos & Baumann, 2009). This model outlined the outcomes of effective CPD, including knowledge, attitudes and skills, practice behavior and clinical practice outcomes. Using qualitative methods and a recognized framework to characterize optometrists' perspective of CPD, Chapter 2 identified and confirmed several factors capable of modulating CPD outcomes. In other words, many external and internal factors have the ability to impact the process of transforming knowledge imparted through CPD into a sustained behavior change. Furthermore, in Chapter 2 Optometrists generally displayed a positive attitude towards CPD and expressed general agreement with CPD; they also appeared to possess good self-efficacy, generally expressing high confidence in their ability to appropriately manage eye conditions. Moreover, optometrists in Chapter 2 reported that awareness of knowledge did not necessarily lead to familiarity with knowledge. Chapter 2 revealed that the context or environment within which optometrists practiced influenced their ability to engage in, learn and change behavior through CPD attitudes and skills, practice behavior and clinical practice outcomes. Therefore, in order to systematically characterize the outcomes box of this CPD model of effectiveness, Chapter 3 collected quantitative data on attitude and self-efficacy. This chapter also sought to quantify these dimensions of attitude and self-efficacy. in addition, knowledge was robustly tested in this chapter for the first time in the context of optometry with respect to comparing the effectiveness of one kind of CPD activity to another. In this Chapter it is hypothesized that if knowledge was retained 3 months after training, it would be more readily translated into practice behavior. Thus, knowledge was tested immediately and 3 months following a CPD intervention.

3.1.1. Attitude to CPD

In Chapter 2, we saw that attitude and beliefs about CPD may be shaped by a health practitioner's knowledge and experience of CPD, and the regulatory environment within which they practice and in turn, these attitudes and beliefs likely shape optometrists' engagement with CPD. Attitude to CPD is concerned with how professionals perceive and interpret the need and importance of CPD (Blunt & Yang, 2002; Efthymios et al., 2010; Hughes, 2005), and what motivates the professionals to be involved in a CPD events (Paloş & Gunaru, 2017).

Attitude to CPD has been shown to impact its effectiveness (Paloş & Gunaru, 2017). Acceptance of CPD among the health professions and in various countries has been heterogeneous, suggesting that it might be important to understand practitioner's attitude towards CPD to enable its successful uptake (Geraghty et al., 2001).

3.1.2. Self-Efficacy

Self-efficacy has been defined as an individual's confidence in performing the required actions to reach a desired outcome. The term "confidence" is distinct from "self-efficacy", which defines levels of belief along with ability, while confidence was a non-specific term that describes someone's belief in something (Bandura, 1997, 1998; Sol et al., 2005; Sol et al., 2008). More specifically in the context of this thesis, self-efficacy referred to the perception that health practitioners have of their ability to perform the actions necessary to deliver appropriate health care (Carey & Forsyth, 2009; Taveras et al., 2009). Self-efficacy is thought to be strongly predictive of effective professional behavior, for instance to achieve organizational objectives and manage work stress, in an extensive range of professional fields (Bandura, 1977, 2012; Bohman et al., 2014). In a recent systematic review of systematic reviews in nursing, it was found that self-efficacy scores can be increased by completion of e-Learning type CPD (Rouleau et al., 2019).

Very few studies have examined self-efficacy in optometrists once they have completed their qualifications but our findings in Chapter 2 and some recent findings highlights that self-efficacy is important and suggested that self-efficacy helps enhancing practice behavior (Adler et al., 2005; Gocuk et al., 2021; McDonnell & Crehan, 2012; Nguyen et al., 2020; Toomey et al., 2021).

Thus, in summary, self-efficacy can impact upon behavior and CPD can raise self-efficacy. We proposed that an optometrist's self-efficacy might change their experience of CPD. We expected this effect to be strongest for CPD which is known to be most effective such as interactive (including adaptive) CPD activities.

3.2. Educational Methods

CPD activities encompass a broad range of possible methods or activities. Many different approaches to the classification of such activities have been proposed in the literature. CPD activities, for example, can be characterised by the type of media involved (e.g., face to face, online, print, etc.), the technique used (e.g., self-directed, problem-based, team-based, etc.), the content that is being delivered, the setting in which the education is being delivered (e.g., in practice, conference, mobile learning, etc.) and the timing of the activity (e.g., one-time versus repeated (Marinopoulos & Baumann, 2009). CPD methods can also be categorized based on the type of delivery, i.e., interactive versus traditional or non-interactive methods (see Table 3.1) (Forsetlund et al., 2009; IOM, 2010; Marinopoulos & Baumann, 2009). A CPD delivery method can be described as interactive when participants and instructors are being mutually active by influencing each other (OED, 2017), while in a non-interactive method the educator is sending information to participants, where they are not supposed to reply or comment on the received information.

Traditional educational methods (e.g., lectures, conferences, clinical experiences etc.) have been said to be very important element of the learning experience because they explain the application of theory and offer practical understanding thus offering the learner a real engagement with the knowledge (Edward, 1997). However, Interactive methods of CPD, as described in Chapter 1, tend to be more effective than traditional methods of CPD delivery (JBI, 2012; Marinopoulos & Baumann, 2009).

Table 3.1 CPD Methods of Delivery

Interactive	*Non-Interactive*
Educational Outreach Visit	Course
Workshop	Lecture
Audit and Feedback	Seminar
Adaptive Learning	Conference/ Symposium
Educational Game	Clinical Experience
Discussion Group	Demonstration
Audience Response System	Mentor
Problem-based Learning	Point of Care
Team-based Learning	Reading
Case-based Learning	Writing/ Authoring
Programmed Learning	
Role-Play	
Simulation/ Standardized Patient	

In a recent study where 88 optometrists were asked to rank their top 3 preferred CPD methods, more preferred education through digital or online resources (webinars 34%; information emailed 19%; downloadable material on a website 11%) than attending face to face CPD (19%) or being physically mailed some information (2%) (Nguyen et al., 2020). Taken together with the evidence summarized in Chapter 1 and viewed through the lens of the conceptual CPD model (see Figure 1.2), it was hypothesized that an interactive CPD event that included multimedia, multiple-instructional methods, and repetition would be more effective than an educational module presented using a single instructional method.

3.2.1. Personalized or Adaptive Learning

Adaptive learning is the delivery of custom learning experiences that address the unique needs of an individual through just-in-time feedback, pathways and resources, rather than providing a one-size-fits-all learning experience (Parsons, 2012; Smart Sparrow, 2019) (Table 3.2). An adaptation can be defined as a variation from an education intervention related to either the course materials or the educator's strategy for teaching that present a practice of specialized knowledge in order to align with the requirements of the learners (Allen et al., 2013). The statements before described the capabilities or possible achievements of adaptive learning; more practically, adaptive learning tools are software systems that have the ability to introduce targeted content to individual learners as a consequence of each learner's performance (Jean-Pierre et al., 2015).

Table 3.2 Key Characteristics of Adaptive Learning
Provides feed back
Personalized/Customized
Technology enabled
Just-in-time
Data-driven

The personalization of an educational program was described as very important as it affects the educational environment that the learner will be involved in, the teaching strategy and the activities used to deliver knowledge, the quality of the educational material delivered to the learner, and the form of "technological infrastructure" that is used to support education (Rich, 2014). Adaptive learning aims to personalize an educational program by using data and technology to increase the learner's engagement with the educational material, allowing educators to utilize the educational program more efficiently (Newman, 2013).

Adaptive learning techniques adjust presentation of common educational material, re-routing content to fit individual learner's profile and characteristics; adaptations can be made based on individuals' preferred learning technique, their past experience, their existing knowledge, and their learning objectives, as well as other characteristics (Schiaffino et al., 2008). This type of learning techniques utilize sets of sequencing processes, with adjusted designs based on each individual performance (Kellman, 2013). Adaptive learning can also enhance the learning experience for each individual, creating objective evaluations throughout the learning process, and guide the learner's effort to where it is needed the most, and therefore, reduce the time consumed in completing the educational activity (Kellman, 2013). These learning techniques enhance learning by adjusting the level, design, and sequencing of learning stages to each individual learner (Kellman, 2013). Adaptive learning tools provide personalized assistance and directed feedback to help learners achieve their goals (Adams BS et al., 2017). This type of learning techniques aims to achieve major impacts by enhancing retention (Newman, 2013).

In a traditional (non-adaptive) educational method, assessments of learners' acquired knowledge are regularly performed at the end of the learning process. However, it rarely includes detailed explanations of what has and has not been understood or gained by the learner at the end of the educational event. These missing links between continuous assessment and the flow of learning is a downside of the non-adaptive learning methods. This learning process could in fact be significantly improved by employing the learner's performance through adaptive learning methods, thus identifying areas for improvement and providing customized content to each learner accordingly (Adams BS et al., 2017; Atkinson, 1968; Kellman, 2013). Polly and colleagues found that diagnostic skills were significantly enhanced by use of adaptive learning (using the online Smart Sparrow platform) in comparison to face to face delivery (Polly et al., 2014). The effectiveness of adaptive learning has not been tested in the context of CPD for optometry.

3.2.1.1. *User-Engagement*

User engagement is a characteristic that describes a "positive human–computer interaction" (Quesenbery, 2003). It has previously been linked with the user-satisfaction (Jacques et al., 1995; Laurel, 1993; Quesenbery, 2003). User engagement during online education is often measured using purpose-designed, unvalidated satisfaction questionnaire, for example using five-point Likert-type scales (Chiu et al., 2009; Fernández Alemán et al., 2011; Horiuchi et al., 2009; Telner et al., 2010). In contrast, a User Engagement Scale developed and validated using large scale exploratory and validation studies involved in excess of 1,000 participants was recently proposed (O' Brien & Toms, 2008; O'Brien & Toms, 2013). Although the scale was designed and validated to evaluate user engagement in online shopping environments, it was subsequently redeveloped into a brief nine items five-level User Engagement Scale and successfully used for the evaluation of user engagement during online learning (O'Brien & Toms, 2013; Wong et al., 2015). We hypothesized that in addition to its personalized characteristics, the effectiveness of adaptive learning would be related to its capacity to engage the user.

3.2.1.2. *Knowledge Retention*

A review commissioned by the American College of Chest Physicians in 2007 asked the question "*Do changes in knowledge, attitudes, skills, practice behavior, or clinical practice outcomes produced by CPD persist over time (greater than or equal to 30 days)?*" (Marinopoulos, 2007). The review concluded that when knowledge retention was measured, a majority of CPD activities (68% to 71%) demonstrated long-term improvements in knowledge, skills, attitudes, and practice behavior (Marinopoulos, 2007). However, less than half (42%) of the studies attempted to knowledge retention past the immediate post CPD evaluation (Marinopoulos, 2007). Certain techniques, methods, or exposure were suggested as being better than others, with a statement that confirmatory evidence was needed (Marinopoulos, 2007). Contemporary studies continue to find that although knowledge declines over time, it is retained for at least 2 months (Courteille et al., 2018; Fordis et al., 2005). The evidence regarding which characteristics of CPD (e.g., online, interactive), the learner (e.g., young or old), or the environment (e.g., regulations) might best optimize knowledge retention remains equivocal (Courteille et al., 2018; Du et al., 2013; Fordis et al., 2005). The effect of adaptive learning on knowledge retention has not been extensively examined, and not in the context of optometry.

3.3. Aim and Hypothesis

This study aimed to evaluate the effectiveness and user engagement of adaptive CPD versus traditional (non-adaptive) CPD in optometry. Secondary aims were:

- to measure optometrists' attitudes towards CPD
- to measure optometrists' self-efficacy
- to investigate retention of knowledge following CPD

We hypothesized that:

- participants in the adaptive online CPD study arm will display better knowledge than those in the traditional online CPD arm of the study;
- participants in both study arms will express a positive attitude toward CPD; and
- participants in both study arms will display low self-efficacy;

- participants in the adaptive CPD study arm will report better user engagement than those in the traditional CPD arm of the study;
- participants in the adaptive CPD study arm will display better knowledge retention than those in traditional CPD arm of the study.

3.4. Methods

3.4.1. Trial Design

A quasi-randomized controlled trial was designed. Optometrists were alternately allocated to receive either a traditional (non-interactive asynchronous online CPD in the form of a recorded narrated PowerPoint presentation) or an adaptive CPD online activity on the topic of choroidal lesions. The primary outcome measure was knowledge score with secondary outcome measures including attitude to CPD, self-efficacy of knowledge, user engagement, and knowledge retention. The traditional and the adaptive CPD interventions have the same learning outcomes, same lecturer transferring knowledge in both interventions, and same voice for both platforms.

The topic of choroidal lesions was chosen based on its importance to optometrists, as previous research suggested that CPD was more effective when it was focused on outcomes that were perceived as important by the learner (Cervero & Gaines, 2015). The most common causes of malpractice claims against optometrists have been reported to be misdiagnosis, delay or failure to diagnose, especially retinal detachment, glaucoma, and tumors or cancers (Classé, 1989; Duszak & Duszak, 2011; Thurman et al., 2019). Uveal melanoma is a relatively rare but deadly cancer that is most commonly found in the choroid (Kaliki & Shields, 2017). It must be differentiated from choroidal naevus, a common intraocular lesion found in up to 5% of Caucasians in the USA and 2.1% of non-indigenous Australians (Keel et al., 2018; Ly et al., 2015; Qiu & Shields, 2015). Whilst they are almost always benign, the rare potential for malignant transformation from choroidal naevus to choroidal melanoma in up to approximately 1 in 4,300 cases illustrates the important of appropriate detection and monitoring of these choroidal lesions by optometrists, to avoid malpractice claims (Damato & Singh, 2019).

The study was conducted from February 2019 to February 2020. The study adhered to the Consolidated Standards for Reporting Trials (CONSORT) guidelines (Appendix 3-1) (CONSORT, 2010b). This study was approved by the Human Research Ethics committee of the University of New South Wales (UNSW) (Approval number: HC180708) (Appendix 3-2).

3.4.2. Participants

3.4.2.1. *Sample Size*

The website https://www.stat.ubc.ca/~rollin/stats/ssize/ created by Professor R Brant (University of British Columbia) was used to calculate a sample size for the primary outcome measure (knowledge score). See (Rosner, 2011) for further detail on the calculator the site employs. Using a mean population value of 7.0, a standard deviation of 1.2 on a 1 to 10 knowledge scale, and a clinically relevant effect size of 1 yielded a calculated sample size of 23 per group. Based on this, a minimum size of 50 participants in total was determined to be sufficient to demonstrate differences between groups and allow for lost to follow-up.

3.4.2.2. *Recruitment of Participants*

Optometrists were recruited through various professional (optometry) websites, newsletters, and mailing lists in Australia and New Zealand over a period of approximately 9 months (Appendix 3-3). Potential volunteers were screened by email according to the inclusion criteria (see 3.4.2.3) before they were emailed a copy of the Participant Information Statement and Consent Form, prior to commencement of the study (Appendix 3-4).

3.4.2.3. *Inclusion Criteria*

Volunteer participants who self-identified as an optometrist, and who were 18 years of age and older were eligible to participate in this study.

3.4.3. Intervention

The adaptive learning platform, Smart Sparrow, presented both arms (online traditional and adaptive) of the study on the topic of “choroidal lesions”. The content of the choroidal lesions online CPD activity was developed by and delivered in collaboration with the staff of the Centre for Eye Health (CfEH) at UNSW, Sydney. Two members of staff of the CfEH, Ms. Michele Clewett and Dr Angelica Ly, designed and delivered the choroidal lesions CPD activity through the CfEH’s online educational platform. The three course learning outcomes for the CPD activity are listed in Figure 3.1.

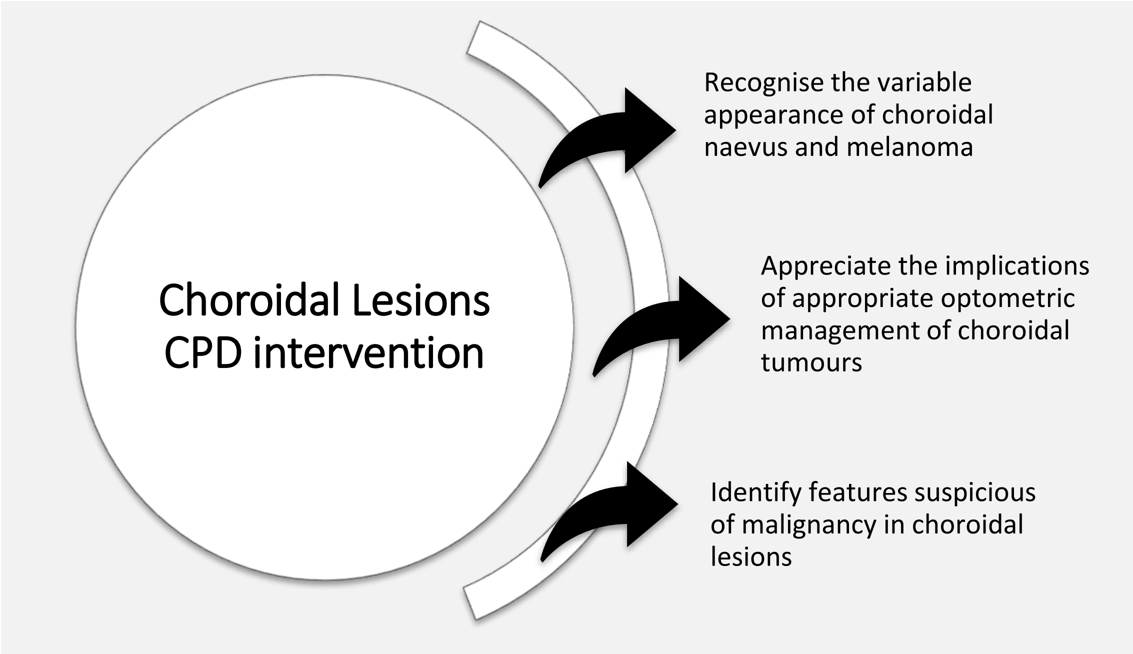

Figure 3.1 Title and Learning Outcomes of the Continuing Professional Development (CPD) Intervention

Optometrists volunteering to participate in the study were randomly allocated to one of the two groups using alternate allocation (quasi-randomized). The first optometrist who expressed interested in participating in this study was allocated to the traditional form of the choroidal lesions' CPD activity, the second optometrist who expressed interest was allocated to the adaptive form of the CPD choroidal lesions' online activity, the third optometrist who expressed interest was allocated to the traditional CPD activity, and so on until no more optometrists expressed interest to participate in the study. Both educational events were delivered online and were approximately the same duration (45 minutes). Following completion of the CPD activity (traditional or adaptive form), optometrists were given a one-month free access to the content of the CPD material in both modes of delivery (adaptive or traditional).

3.4.3.1. *Adaptive CPD Intervention*

The adaptive online form of the choroidal lesions CPD intervention was designed as a flexible, integrated formative activity which combined introductory information, video lectures, and case studies of choroidal lesions cases that optometrist were likely to encounter in their practice with associated assessment. Various embedded multimedia including videos, pictures, and slideshows were included to stimulate critical thinking and enhance optometrists' learning experience. The introductory screen included the course's learning objectives and user instructions, aiming to help optometrists quickly adjust to the online platform (Figure 3.2).

For the assessment, a variety of question formats (e.g., multiple choice, drop-down lists) were utilized, with immediate feedback provided following optometrists' submission of their responses (Figure 3.3, Figure 3.4, and Figure 3.5). Screens that contained questions or case studies did not permit progress unless answers were provided to each question; customized feedback appropriate to each optometrist's answers was provided. Embedded videos and links to supporting references on the presented topic assisted with the presentation of more detailed material on any given topic when needed. For example, when a participant gave an inaccurate response to any of the questions, the adaptive platform would mark the incorrect answer and direct the optometrist to another section, where more detailed information about the specific topic was provided, before requiring the participant to attempt to answer the same question a second time. This guided the learner to the correct answer via their reading of the attached supporting references (Figure 3.3, Figure 3.4, and Figure 3.5).

These components were incorporated to direct individual optometrists to the information that was relevant and needed, and this was specifically personalized for each optometrist, based on their displayed level of understanding of the presented materials on choroidal lesions. In addition, these components of the adaptive CPD intervention had the impact of "activating" the learning material and helped to maintain optometrists' engagement. The design of this adaptive CPD activity assisted in providing optometrists with extra information on a specific topic when needed.

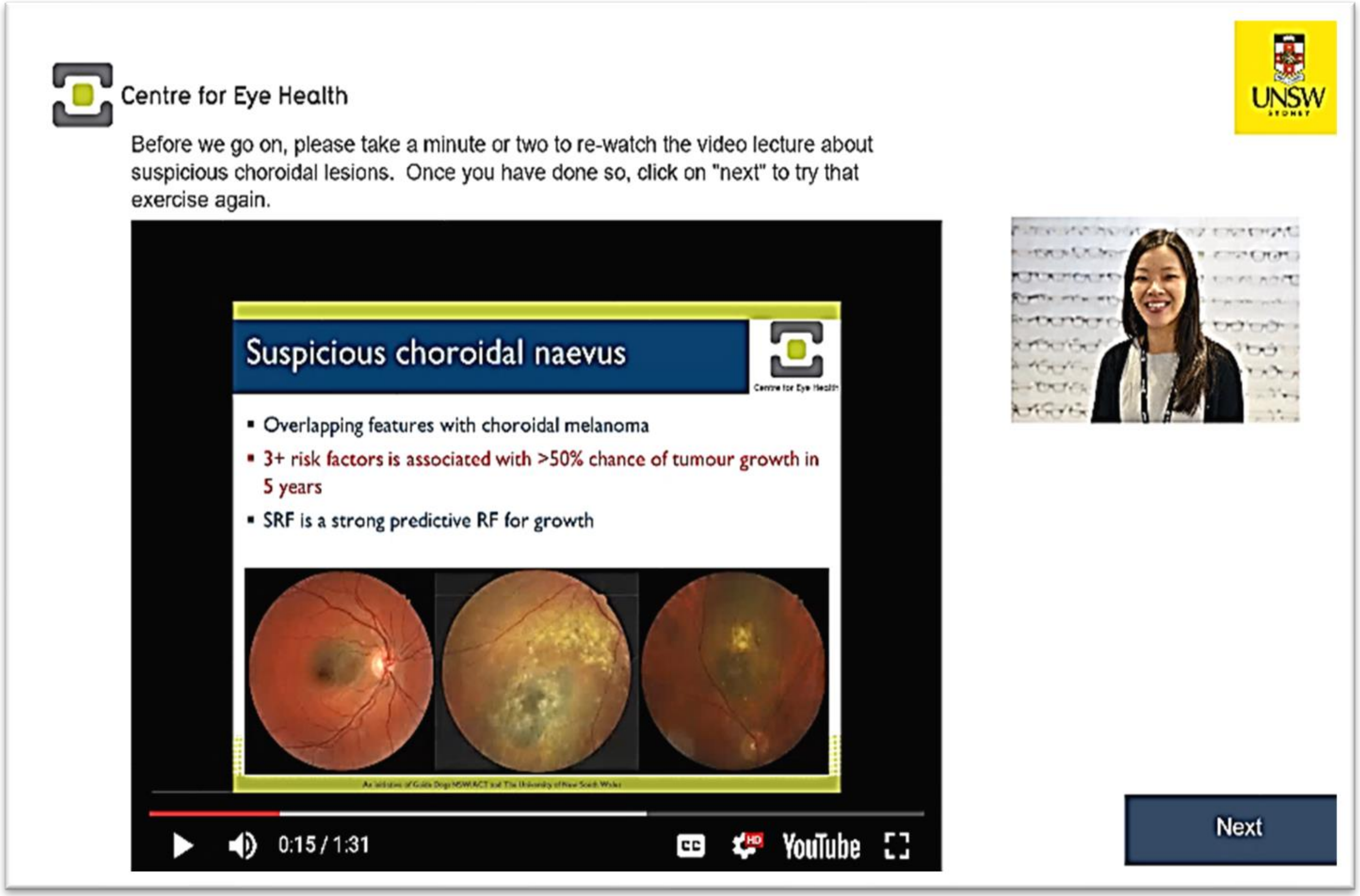

Figure 3.2 Adaptive CPD Intervention Instruction Videos
Short videos explaining the evidence-based diagnosis and management of choroidal lesions were embedded throughout the activity.

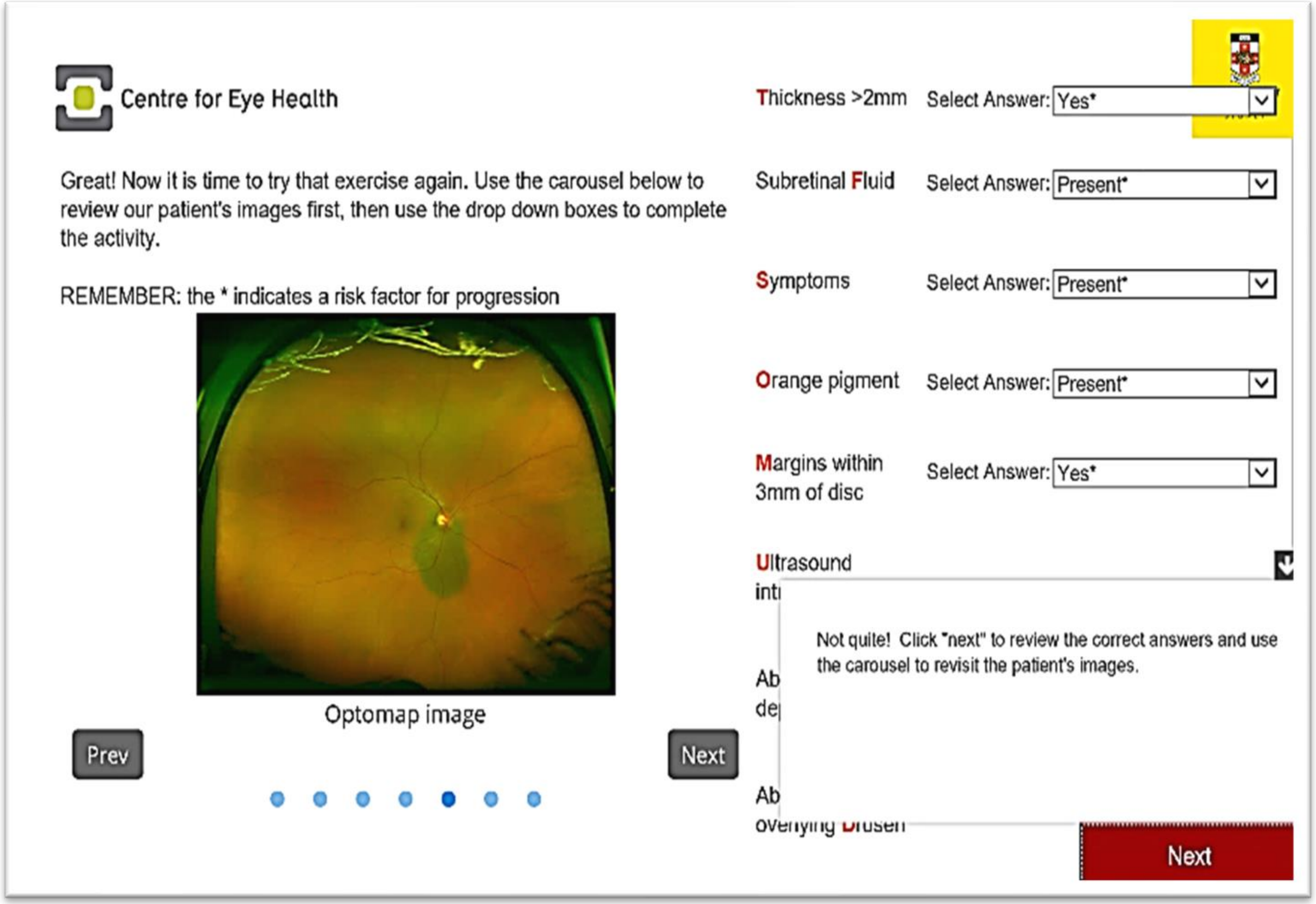

Figure 3.3 Adaptive CPD Intervention Assessment: Multiple-Choice Question Example

Multiple-choice questions with drop-down menus were presented to assess the level of the optometrist's knowledge of the given topic.

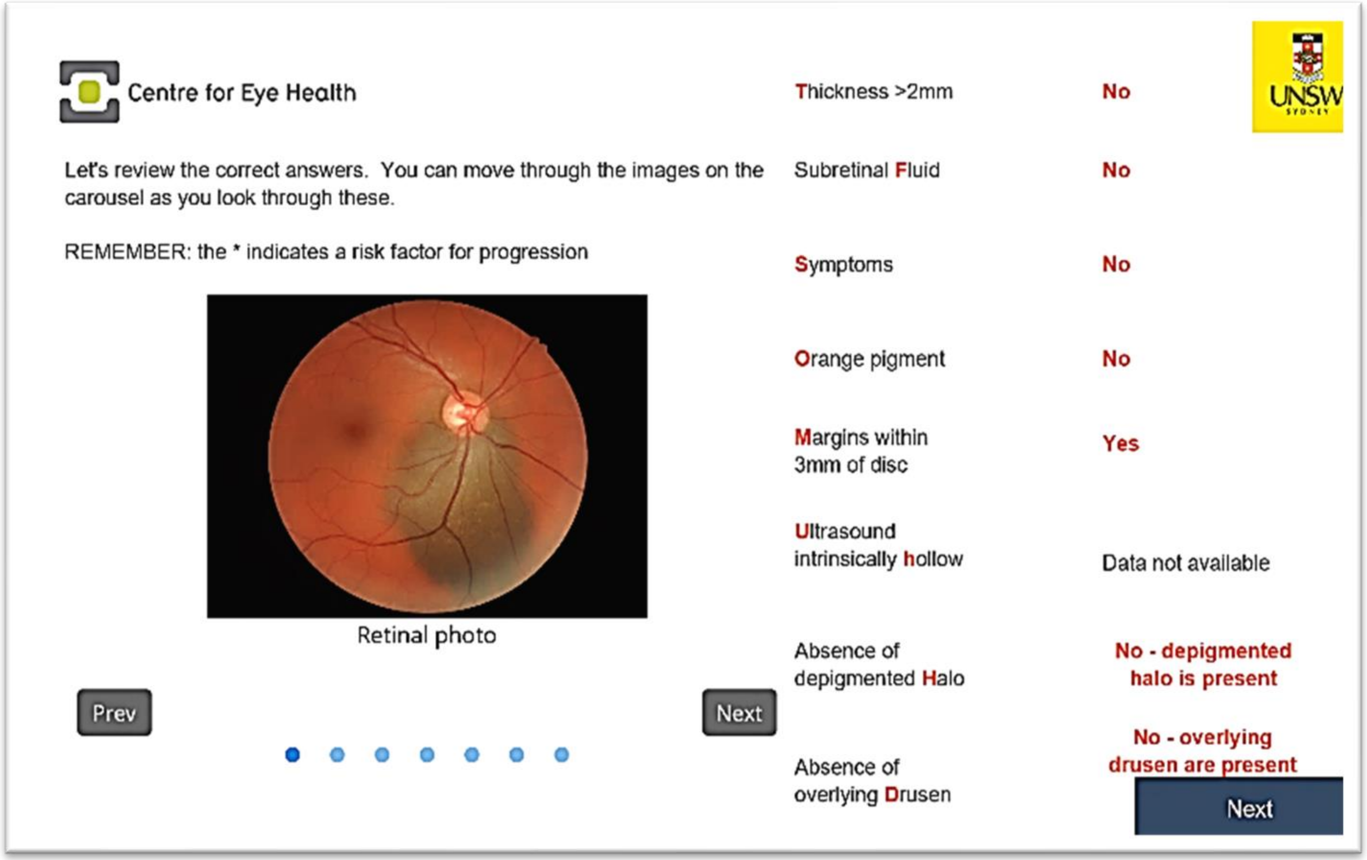

Figure 3.4 Adaptive CPD Intervention Assessment: Example of The Adaptive Feedback

Real-time feedback tailored to the individual optometrist's responses was provided. Red text was displayed when an incorrect response was provided to any of the questions.

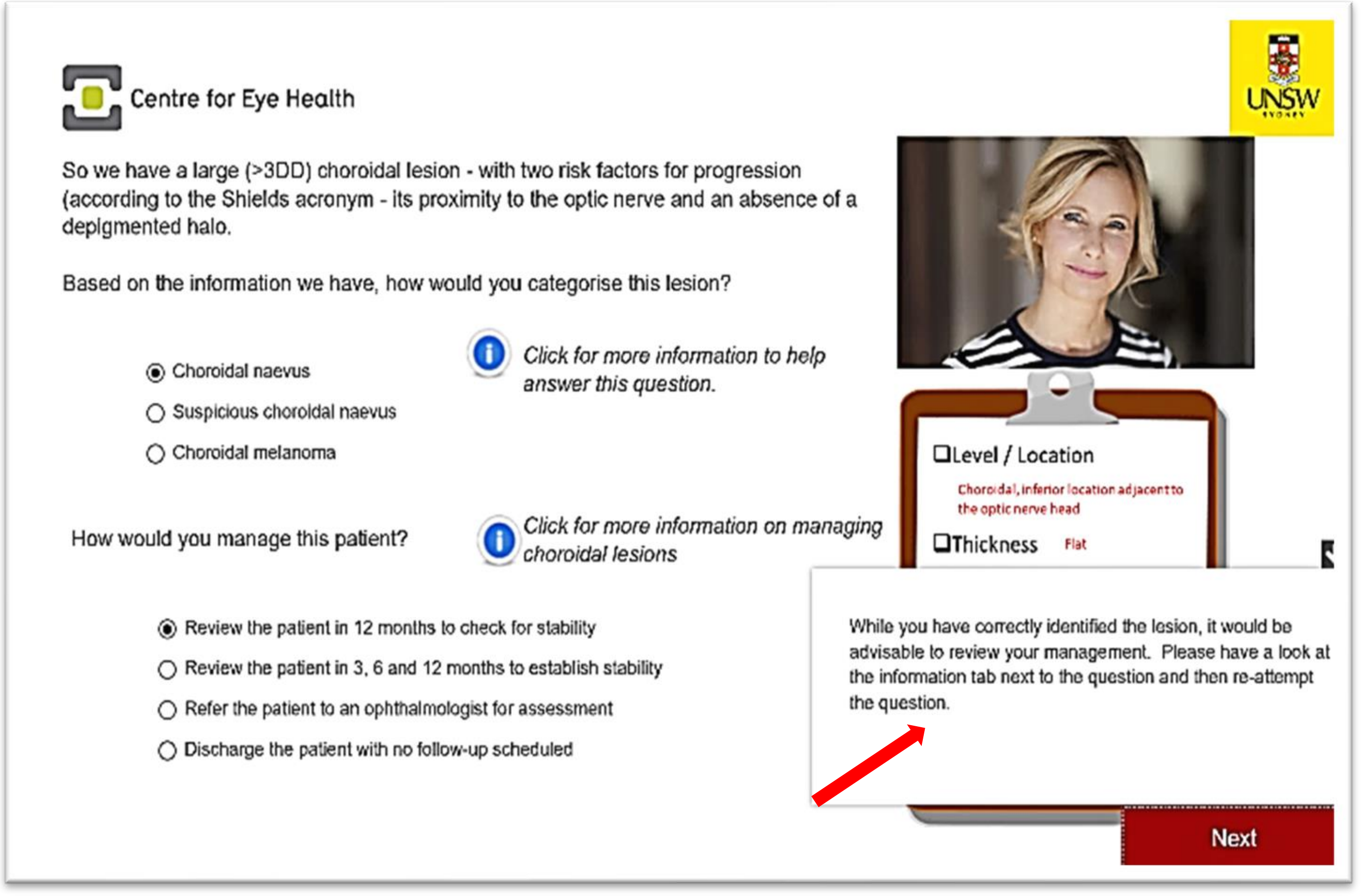

Figure 3.5 Adaptive CPD Intervention Assessment: Case Study Example

Optometrists were directed to relevant literature or case-studies when providing inaccurate responses (see Red arrow).

Smart sparrow Pty Ltd. (www.smartsparrow.com) is an educational and training content online-based system and authoring instrument founded in 2011 by Dr. Dror Ben-Naim. Dr. Ben-Naim led a research group in the field of Intelligent Tutoring Systems and Educational Data Mining at the University of New South Wales in Sydney, Australia, resulting in the development of the Adaptive e-Learning Platform (Smart Sparrow, 2018; Weltman et al., 2017). Smart Sparrow is an award-winning “learn-tech” company promoting the new trend in digital education and assessment. It is utilized by over 700 leading organizations worldwide across primary and secondary education (Rouse, 2005), higher education, and corporate education (Smart Sparrow, 2018). Smart Sparrow can be used to generate effective and adaptive online courses. Adaptation in computer science language and in this context is a very extensive term that describes any software system able to alter some characteristics based on certain operator style, it is also the focus of investigations and developments in the field of online learning (e-Learning) (Ben-Naim. et al., 2008).

3.4.3.2. *Traditional CPD Intervention*

In contrast, the traditional form of the choroidal lesions CPD intervention consisted of an online video of a slideshow narrated PowerPoint lecture with the instructor's voice introducing the educational material on the identical topic of choroidal lesions (Figure 3.6).

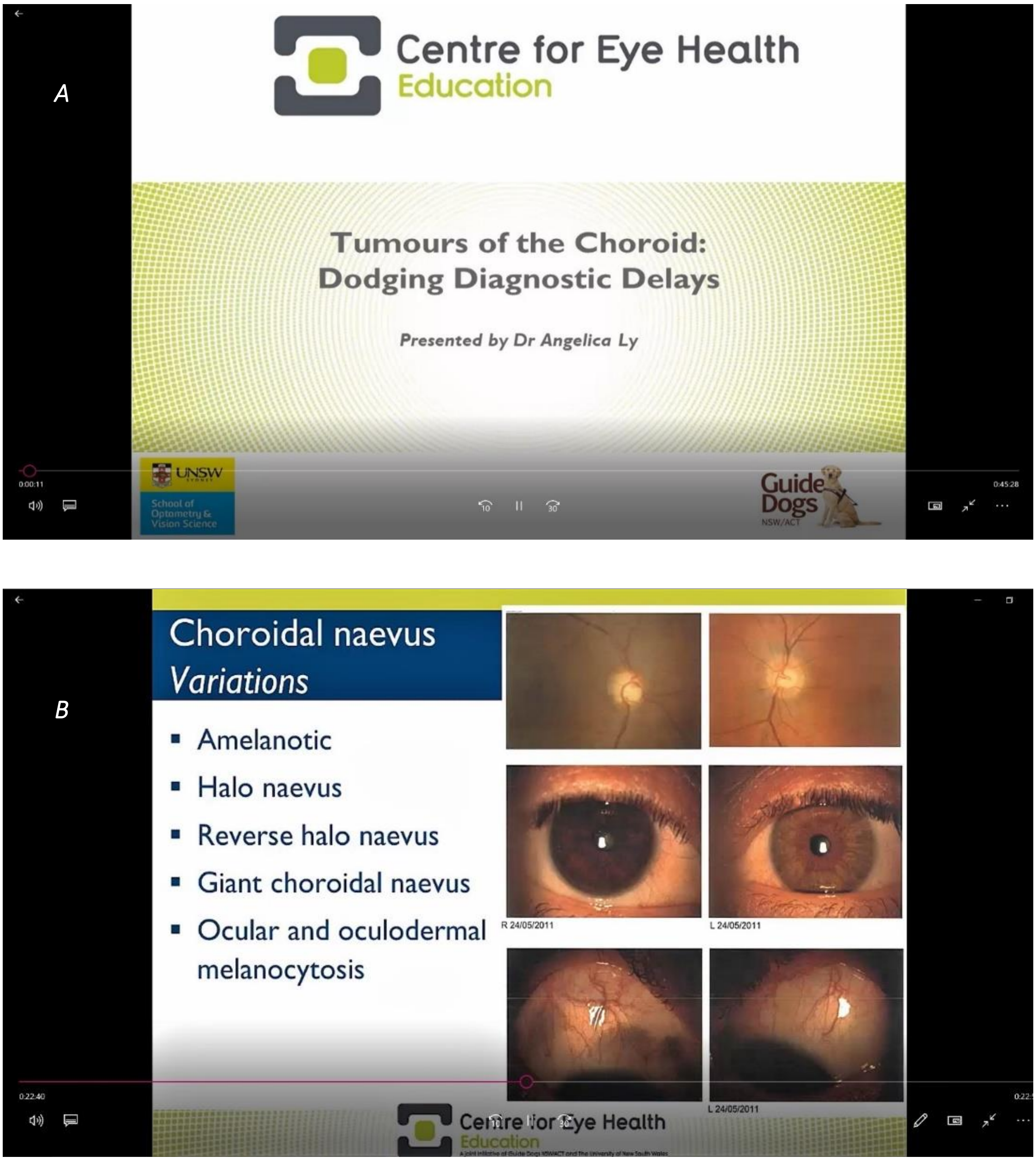

Figure 3.6 Traditional CPD Intervention Title Slide (A) and Example Content Slide (B)
Optometrists were instructed to watch a narrated PowerPoint video lecture.

A copy of the video lecture accessed by optometrists allocated to the traditional CPD arm of the intervention can be viewed by clicking on Figure 3.7 below or by following this link: https://vimeo.com/417838893 .

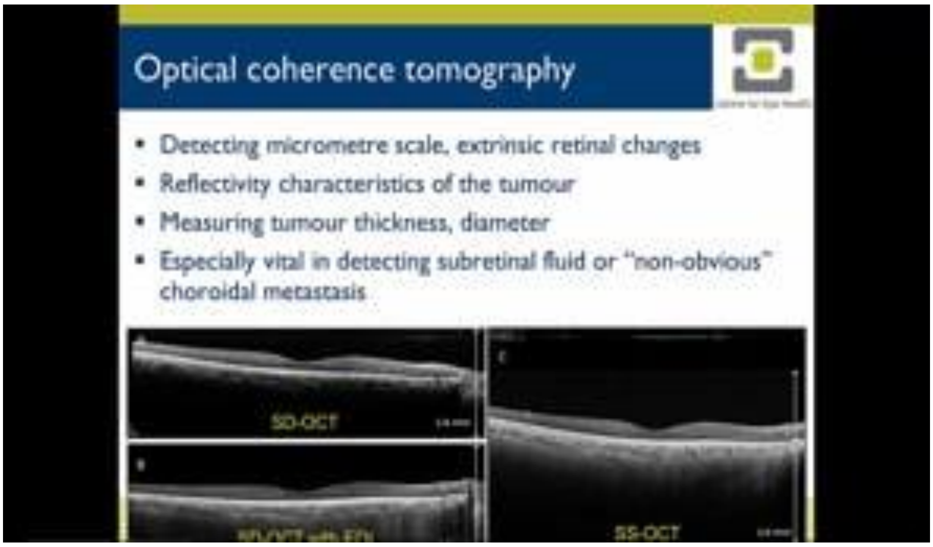

Figure 3.7 A Non-Interactive, Recorded Narrated PowerPoint Presentation Video Lecture Was Provided to Optometrists Allocated to The CPD Traditional Arm of The Intervention
Click on the figure to view the video.

3.5. Dependent Variables

All participants within both groups completed four questionnaires, two of these at baseline (attitude, self-efficacy), and two of these after the CPD intervention was completed (knowledge and skills, user engagement). The knowledge questionnaire was re-administered at a follow-up visit conducted approximately 12-week following the CPD intervention (knowledge retention). All the questioners were administered using the same online platform (Smart Sparrow), except for the 12-week retention of knowledge questioner which was administered using another online platform (Qualtrics) due to a university change in software usage.

3.5.1. Attitude Towards CPD

The attitudes instrument selected for use in this study was modified from an instrument used in a study examining CPD in pharmacists (Saade et al., 2018). This instrument had been developed based on an extensive literature review (Attewell J et al., 2005; Bell et al., 2001; Bollington, 2003; Hull H et al., 2003; Mottram DR et al., 2002; Swallow V et al., 2006) and consisted of seven Likert items. Modifications to the wording of some items were made, to adapt these for use by optometrists. For example, item 3 *"I have sufficient time to achieve my CPD goals that are fixed by OPL"* was changed to *"I have sufficient time to achieve my CPD goals that are fixed by the Optometry Board of Australia's CPD registration standard (or the responsible optometry association that I am registered at)"*, and item 7 *"Live conferences with colleagues motivate me to achieve my CPD goals"* was changed to *"Face-to-face events motivate me to achieve my CPD goals"*. A copy of the modified instrument is provided in Appendix 3-5 (section A), with the modifications highlighted.

For the purpose of total score calculations, the five-level Likert scale was scored from 0 to 4 with Strongly Disagree=0, Disagree=1, Neither Agree nor Disagree=2, Agree=3 and Strongly Agree=4, respectively. Optometrists' attitude score was calculated by summing the scores for each of the seven items. The total possible score therefore ranged from 0 to 28 with higher scores representing a more positive attitude toward CPD. For graphical representation, the five-level Likert scale was scored from -2 to 2 with Strongly Disagree=-2, Disagree=-1, Neither Agree nor Disagree=0, Agree=1, and Strongly Agree=2 to better visually represent the neutral point.

3.5.2. Self-Efficacy

A self-efficacy instrument was designed by the investigators, modelled on existing tools, and adapted to the area of choroidal lesions (Ashman et al., 2016; Sturgiss et al., 2017) The instrument consisted of seven Likert items administered at baseline. A copy of the instrument is provided in Appendix 3-5 (section B).

For the purpose of total score calculations, the five-level Likert scale was scored from 0 to 4 with Strongly Disagree=0, Disagree=1, Neither Agree nor Disagree=2, Agree=3 and Strongly Agree=4, respectively. Optometrists' self-efficacy score was calculated by summing the scores for each of the seven items. The total possible score therefore ranged from 0 to 28 with higher scores representing higher self-efficacy. For graphical representation, the five-level Likert scale was scored from -2 to 2 with Strongly Disagree=-2, Disagree=-1, Neither Agree nor Disagree=0, Agree=1, and Strongly Agree=2 to better visually represent the neutral point.

3.5.3. User-Engagement

The brief nine items five-level Likert user engagement scale developed by Vincent Wong and colleagues (Wong et al., 2015) was administered following completion of the CPD module, to gain an understanding of optometrists' user experience in each arm of the CPD study. A copy of the instrument is provided in Appendix 3-6. For the purpose of total score calculations, the five-level Likert scale was scored from 0 to 4 with Strongly Disagree=0, Disagree=1, Neither Agree nor Disagree=2, Agree=3 and Strongly Agree=4, respectively. As per the original scale, scores for questions 3, 4 and 7 were reverse coded to account for the negative phrasing. User-engagement score was calculated by summing the scores for each of the nine items. The total possible score therefore ranged from 0 to 36 with higher scores representing more effective user engagement. For graphical representation, the five-level Likert scale was scored from -2 to 2 with Strongly Disagree=-2, Disagree=-1, Neither Agree nor Disagree=0, Agree=1, and Strongly Agree=2 to better visually represent the neutral point.

3.5.4. Effectiveness and Retention of Knowledge

To measure and compare the knowledge of choroidal lesions of participants immediately after completion of their CPD, a knowledge questionnaire was administered (Appendix 3-7). The 10-item knowledge questionnaire was developed with the help of educational developers (A.L. and M.C.), to be administered immediately following the educational intervention (Appendix 3-7) and at a follow-up visit approximately 12-week post intervention (Appendix 3-8). The knowledge questionnaire was re-administered 12 weeks after the CPD activity was completed to assess knowledge retention. Multiple-choice questions were developed in accordance with the Optometry Board of Australia (OBA) continuing education guidelines. Appendix 3-7 (Knowledge questionnaire) and Appendix 3-8 (Retention of knowledge questionnaire) shows the 10 multiple-choice questions items used with the correct answers highlighted. Correct answers in the Knowledge questionnaire were scored 1 and incorrect or no response answers were scored 0, for a maximum score of 10 for each questionnaire. Higher scores therefore represented better knowledge and skills and better retention of knowledge on the topic of choroidal lesions.

This 12-week follow-up visit was added to the study design partway through the study and was therefore conducted on a subset of optometrists who had previously consented to receive further invitations from the investigators. Ethics approval was obtained for the ethics modification. The 12-week knowledge retention questionnaire was administrated using the online platform Qualtrics (Qualtrics®, 2020) (see Appendix 3-8).

3.6. Data Analysis Plan

3.6.1. Likert Scale Reliability and Non-Parametric Testing of Individual Scale Items

In order to assess the internal consistency of the Likert questions to see how consistent they are as a scale; Cronbach's alpha was used on each group of time a scale was administered. A Cronbach's alpha score of 0.7 or above was considered robust (George & Mallery, 2003) and the higher the Cronbach alpha, the more inter-correlated the scale items would be (Sullivan & Artino, 2013).

For the Likert scales, as the data are ordinal, the median (Mdn) was chosen as the measure of central tendency (Mdn), representing the number found in the middle of the distribution. The inter-quartile ranges (IQR) were selected as an indication of the spread of the data, showing whether the responses are clustered together or scattered across the range of possible responses (Jamieson, 2004; Sullivan & Artino, 2013). As recommended by Carifio and Perla (2007) and Harpe (2015) when examining a single item and comparing adaptive and traditional groups, non-parametric Mann–Whitney (*U*) tests were employed (Carifio & Perla, 2007; Harpe, 2015).

3.6.2. Likert Scale Scores and Parametric Testing

Once Likert scales are summed, they can be treated parametrically as long as assumptions were met (Harpe, 2015). Assumptions were tested and if acceptable, parametric t-tests and ANOVAs were used for summed Likert data (Carifio & Perla, 2007; Harpe, 2015; Norman, 2010). In the cases where multiple significance tests were carried out, the Bonferroni correction was applied to the alpha level to control for the overall Type I error rate. Each test used an alpha level of 0.05 divided by the total number of tests carried out.

A parametric independent groups t-test was used to compare the mean attitudes of optometrists allocated to each CPD learning group prior to the intervention. This was also done for self-efficacy, to test that there were no significant differences in the quasi-randomly allocated groups prior to commencement of the CPD educational intervention.

To compare the participants' ratings of their CPD educational experience, mean engagement scores between the adaptive group and the traditional group underwent a parametric independent groups t-test analysis.

To look for the effects of the CPD educational intervention (adaptive group versus traditional group) on knowledge total scores, and to assess knowledge retention after 12-week (within group factor), a two-factor mixed-design ANOVA was employed. Data was explored to check for normality, outliers, and homogeneity. No major problems were found. Normality was not violated so we proceeded with a mixed model ANOVA. A two-tailed p-value < 0.05 was considered statistically significant. Effect sizes (r) were calculated. Post hoc testing was done via non-parametric t-testing.

Throughout all analyses of the results, missing data were either excluded listwise or pairwise by SPSS, depending on the analysis being independent or paired. Missing cases are reported throughout the results section, as relevant to each analysis. Statistical analyses were conducted using Microsoft Excel® software (Office 2016) (Microsoft Corporation, 2016) and SPSS software (IBM® SPSS® Statistics 26.0).

3.7. Results

3.7.1. Participant Recruitment

Sixty-eight optometrists expressed interest in participating in the study and were assessed for eligibility (Figure 3.8). Of these, 50 eligible optometrists were randomized to participate in this study (25 optometrists to the traditional CPD arm, and 25 optometrists to the adaptive CPD arm). Of the 50 randomized optometrists, 42 participants completed the choroidal lesions CPD online activity (traditional (n=21), and adaptive (n=21)) and were retained for analysis. As explained above, the 12-week visit was added to the study design partway through the study and was therefore offered to a smaller subset of 41 participants (17 from the traditional arm and 24 from the adaptive arm) who had consented to receive further invitations from the investigators. A detailed study flowchart is provided in Figure 3.8. Demographic information (age, gender, etc.) was not collected from the study participants and can thus not be reported.

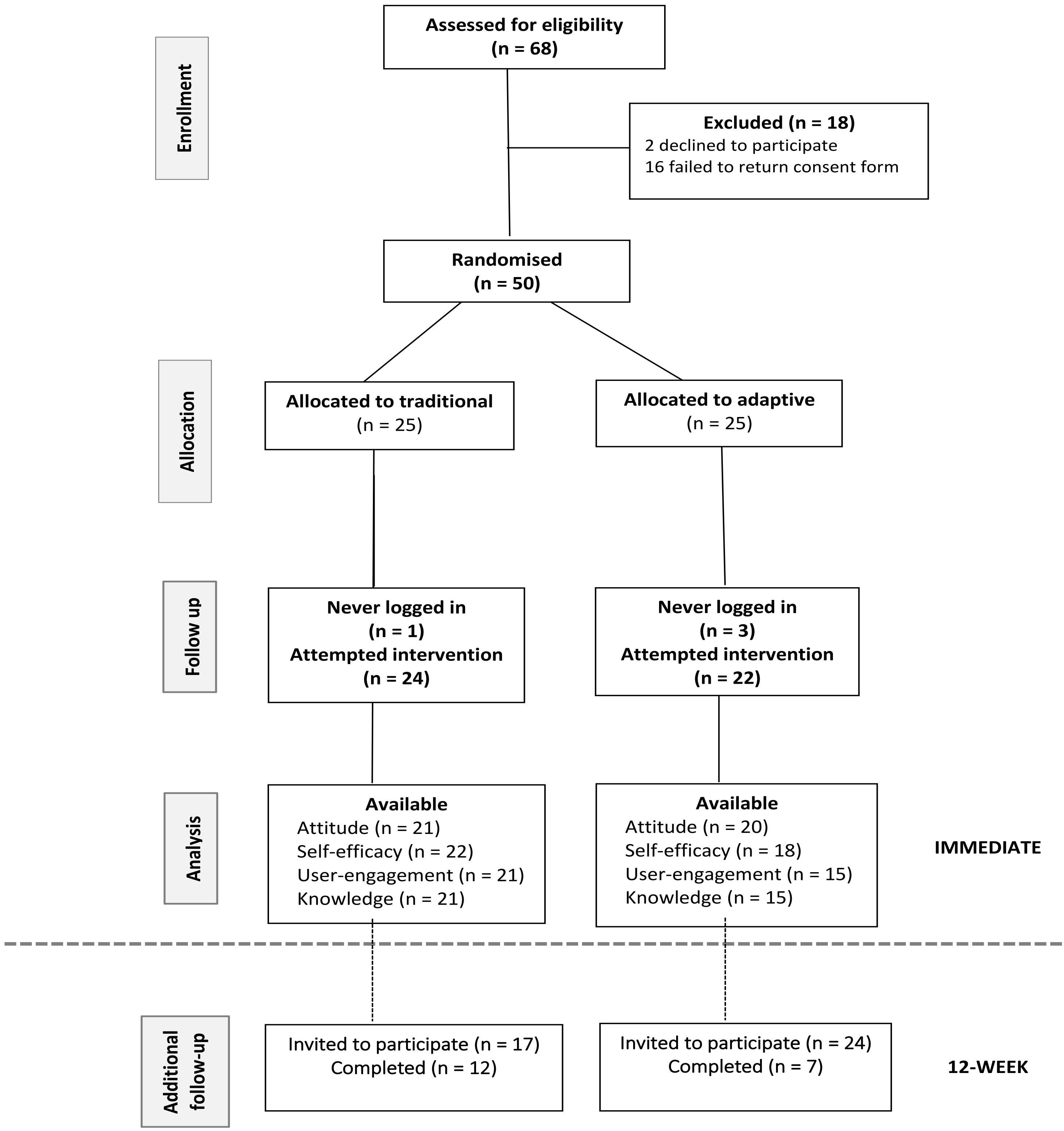

Figure 3.8 Consolidated Standards of Reporting Trials (CONSORT) Flow Diagram
The dotted line in the flow diagram separates the instruments administered immediately versus 12-week post CPD intervention.

3.7.2. Attitude to CPD

The attitude instrument measured optometrists' attitudes to CPD on a five-point Likert scale prior to an educational intervention (Appendix 3-5A).

For the traditional CPD arm, 21 optometrists fully completed the attitude instrument. One optometrist viewed and opened the instrument but did not answer any questions and was thus excluded from the analysis. This participant did, however, complete the subsequent self-efficacy scale and their data was retained for that analysis.

For the adaptive CPD arm, 21 optometrists partially or fully completed the attitude instrument. Two optometrists missed responding to a single item each (Q3 and Q5). One optometrist provided a response to item 1 but did not proceed to answer any other questions on the attitude scale, or to complete the subsequent self-efficacy scale. This optometrist was excluded from all attitude and self-efficacy analyses, resulting in 20 participants being analyzed in the adaptive CPD arm for attitude. All missing data were excluded listwise. Descriptive and statistical data are presented in Table 3.3 and Table 3.4.

The frequencies presented in Table 3.3 are also represented graphically in Figure 3.9 and Figure 3.10. The Cronbach alpha was above 0.7 indicating an internally consistent scale. Frequency responses to each scale item are presented in Table 3.3 and indicate cases where participant missed responding to a question. For all but one instance the midpoint of the item responses was 'Agree' (Table 3.4). The IQR shows that variance of these responses was generally small as it was either 0, 1 category, or 2 categories (Table 3.4). Non-parametric t-tests on each scale item in Table 3.4 compare the medians of adaptive and traditional group responses and do not reveal any significant differences in responding between the randomized groups according to the Bonferroni corrected alpha of 0.05/7=0.007.

An independent groups parametric t-test (Table 3.4) revealed that the summed total attitude scores at baseline were not significantly different between the participants randomized to the adaptive group ($M=19.60$, $SD=4.28$) to those randomized to the traditional group ($M=20.90$, $SD=3.27$), $t(39)=-1.10$, $p=0.21$). The answers from both groups were therefore combined (see Figure 3.11). Overall, the 41 participants displayed an extremely positive attitude score to continuing education ($M=20.27$, $SD=3.81$) out of a maximum possible score of 28. The combined attitude data of the traditional and adaptive CPD interventions are presented in Figure 3.11.

Table 3.3 Optometrists' Attitudes to CPD

Frequency of responses (n) and percentage of participants (%) for the Traditional (n=21) and Adaptive (20) Interventions. CPD: Continuing Professional Development.

Items	*Strongly Disagree*	*Disagree*	*Neither*	*Agree*	*Strongly Agree*
Q1. I feel confident that CPD meets my needs					
Traditional	0	0	3 (14.3)	16 (76.2)	2 (9.5)
Adaptive	0	0	7 (35.0)	12 (60.0)	1 (5.0)
Q2. I feel confident that CPD is preparing me for practice development					
Traditional	0	0	6 (28.6)	13 (61.9)	2 (9.5)
Adaptive	0	0	3 (15.0)	16 (80.0)	1 (5.0)
Q3. I have sufficient time to achieve my CPD goals that are fixed by the Optometry Board of Australia's CPD registration standard (or any the responsible international optometry association that you are registered at if you are not practicing in Australia)					
Traditional	0	0	4 (19.0)	11 (52.4)	6 (28.6)
Adaptive (n=19)	0	4 (21.1)	2 (10.5)	10 (52.6)	3 (15.8)
Q4. I have sufficient resources (computer access, internet access, CPD events) to achieve my CPD goals					
Traditional	0	0	2 (9.5)	8 (38.1)	11 (52.4)
Adaptive	0	1 (5.0)	1 (5.0)	13 (65.0)	5 (25.0)
Q5. I have sufficient enthusiasm to achieve my CPD goals					
Traditional	0	1 (4.8)	5 (23.8)	8 (38.1)	7 (33.3)
Adaptive (n=19)	0	4 (21.1)	1 (5.3)	10 (52.6)	4 (21.1)
Q6. Challenges in my job motivate me to achieve my CPD goals					
Traditional	0	2 (9.5)	5 (23.8)	9 (42.9)	5 (23.8)
Adaptive	0	1 (5.0)	4 (20.0)	9 (45.0)	6 (30.0)
Q7. Face-to-face events motivate me to achieve my CPD goals					
Traditional	0	2 (9.5)	4 (19.0)	11 (52.4)	4 (19.0)
Adaptive	1 (5.0)	2 (10.0)	3 (15.0)	8 (40.0)	6 (30.0)

Table 3.4 Optometrists' Attitudes to CPD

Likert scale descriptive statistics for Traditional (n=21) and Adaptive (n=20) Interventions. CPD: Continuing Professional Development.

Item	*n (missing)*	*Median (Mdn)*	*Interquartile range (IQR)*	*Mann–Whitney (U)*
Q1. I feel confident that CPD meets my needs				
Traditional	21 (0)	'Agree'	0.00	0.13
Adaptive	20 (0)	'Agree'	1.00	
Q2. I feel confident that CPD is preparing me for practice development				
Traditional	21 (0)	'Agree'	1.00	0.53
Adaptive	20 (0)	'Agree'	0.00	
Q3. I have sufficient time to achieve my CPD goals that are fixed by the Optometry Board of Australia's CPD registration standard (or any responsible international optometry association that you are registered at if you're not practicing in Australia)				
Traditional	21 (0)	'Agree'	1.00	0.22
Adaptive	19 (1)	'Agree'	1.00	
Q4. I have sufficient resources (computer access, internet access, CPD events) to achieve my CPD goals				
Traditional	21 (0)	'Strongly Agree'	1.00	0.12
Adaptive	20 (0)	'Agree'	1.00	
Q5. I have sufficient enthusiasm to achieve my CPD goals				
Traditional	21 (0)	'Agree'	2.00	0.52
Adaptive	19 (1)	'Agree'	2.00	
Q6. Challenges in my job motivate me to achieve my CPD goals				
Traditional	21 (0)	'Agree'	2.00	0.52
Adaptive	20 (0)	'Agree'	2.00	
Q7. Face-to-face events motivate me to achieve my CPD goals				
Traditional	21 (0)	'Agree'	1.00	0.78
Adaptive	20 (0)	'Agree'	2.00	

	Overall Mean M (SD)	***Cronbach alpha (α)***	***Overall independent parametric t-test p-value***
Traditional	20.90 (3.27)	0.79	0.21
Adaptive	19.60 (4.28)		
Combined	20.27 (3.81)		

Scores range; 0-28.

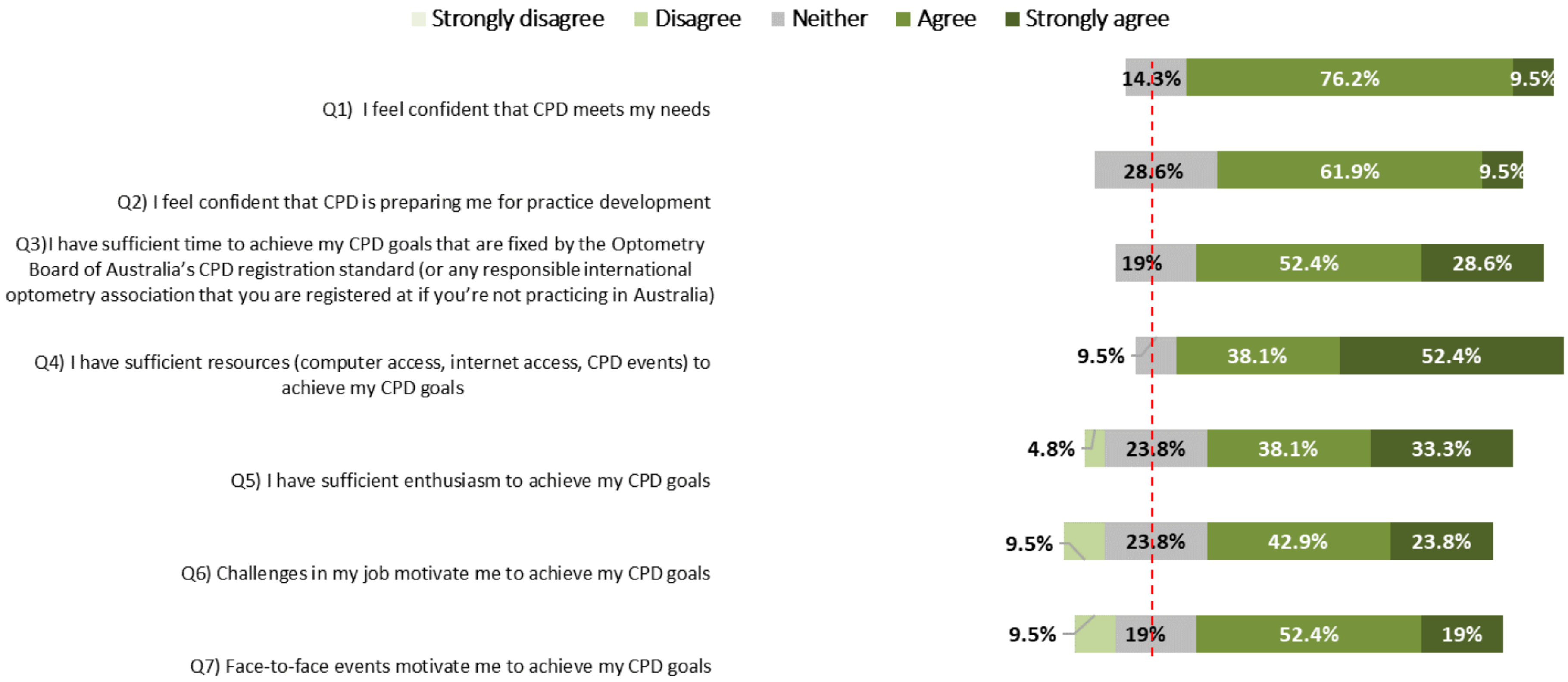

Figure 3.9 Attitude to CPD Prior the Traditional intervention (n=21)

The vertical red dotted line indicates a neutral answer to the Likert question; answers to the right of the vertical line indicate agreement with the proposed statements and answers to the left disagreement with the proposed statements. CPD: continuing professional development.

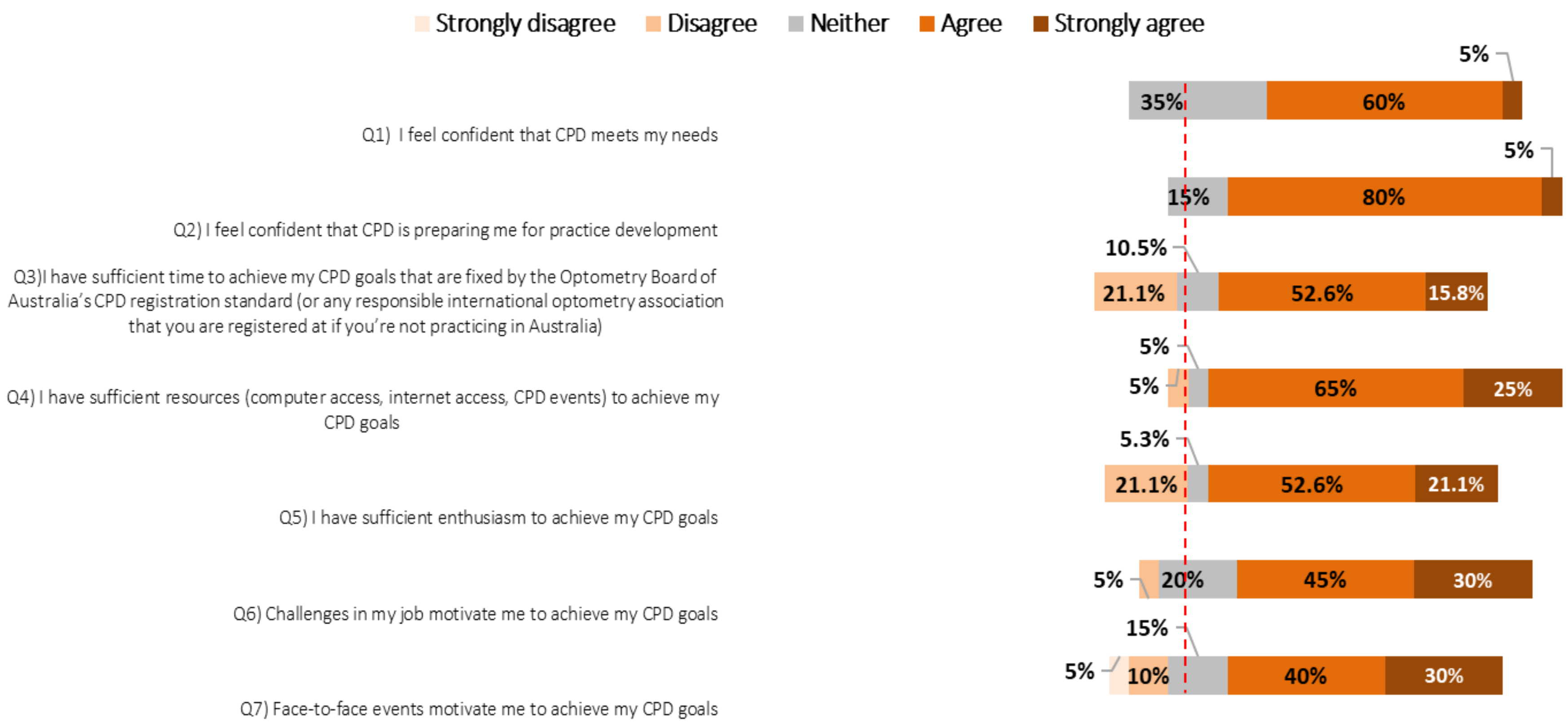

Figure 3.10 Attitude to CPD Prior the Adaptive Intervention (n=20)

The vertical red dotted line indicates a neutral answer to the Likert question; answers to the right of the vertical line indicate agreement with the proposed statements and answers to the left disagreement with the proposed statements. CPD: continuing professional development.

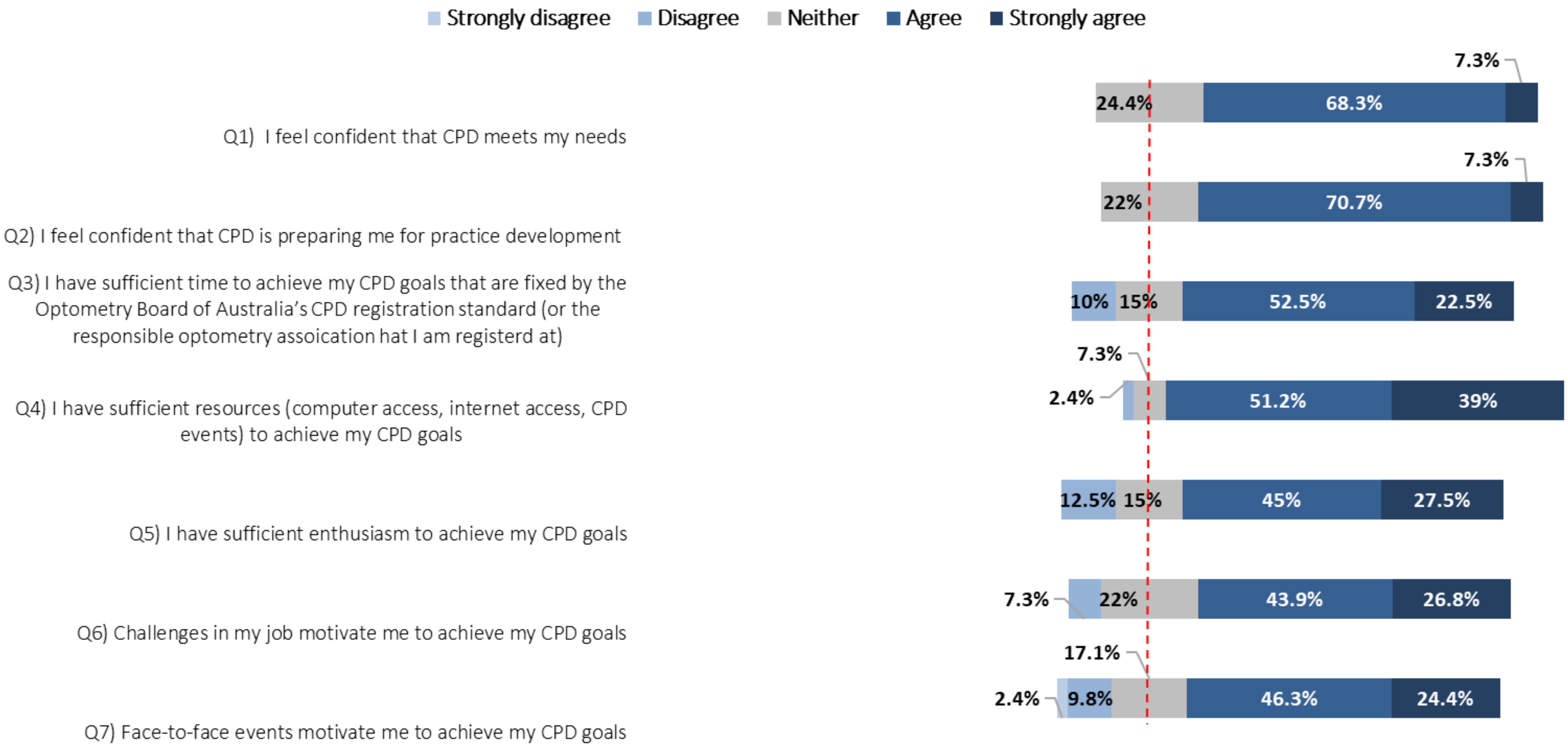

Figure 3.11 Attitude to CPD Prior to Intervention (n=41, Traditional and Adaptive Combined)

The vertical red dotted line indicates a neutral answer to the Likert question; answers to the right of the vertical line indicate agreement with the proposed statements and answers to the left disagreement with the proposed statements. CPD: continuing professional development.

The boxplot chart in Figure 3.12 presents the overall patterns of attitudes for each group of optometrists assigned to the traditional and adaptive CPD interventions, allowing the reader to visualize the range of responses for the whole group of participants (combined) and within each intervention arm. From the sizes of the boxplots and the location of the "X" in the middle of each boxplot (which represent the mean (M) of each group) and the horizontal line inside each boxplot (which represent the median (Mdn) of each group) it was apparent that participants from both groups hold similar positive attitude toward CPD.

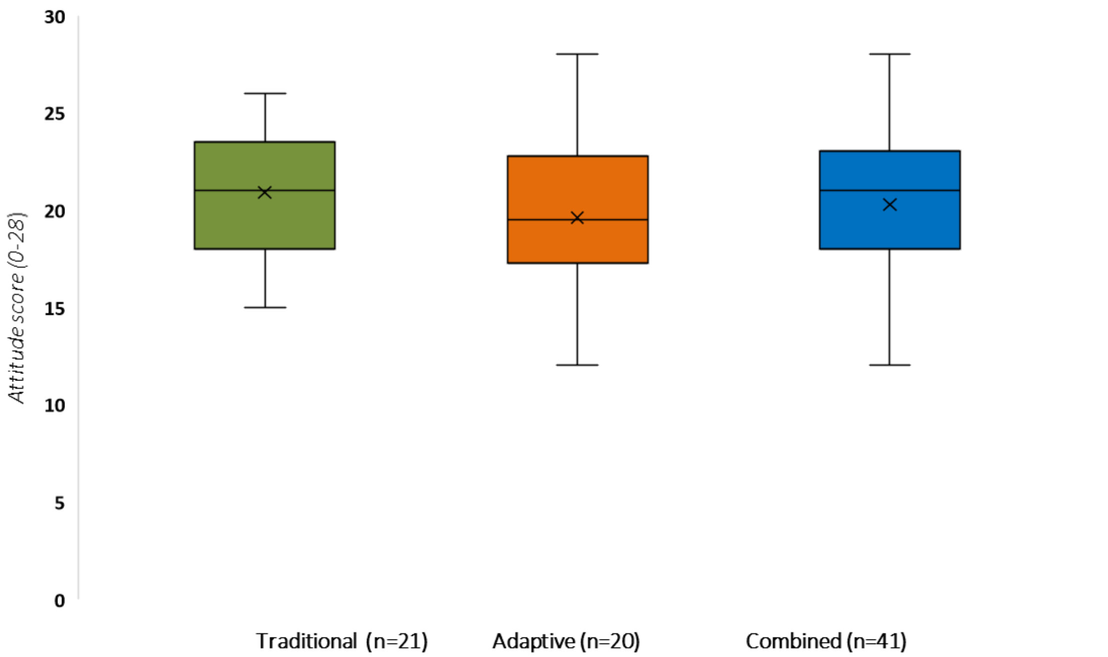

Figure 3.12 Attitude to CPD for the Traditional, Adaptive and for Both Interventions Combined, at Baseline

3.7.3. Self-Efficacy

The self-efficacy questionnaire (Appendix 3-5B) collected subjective evaluations of optometrists' self-efficacy on the topic of choroidal lesions prior the start of the CPD activity. The frequencies presented in Table 3.5 are also represented graphically in Figure 3.13 and Figure 3.14. The Cronbach alpha was above 0.7 indicating an internally consistent scale. Frequency responses to each scale item are presented in Table 3.5 and indicate where participants missed responding to a question. The most common median score was "Agree". The IQR shows that variance of these responses was fairly narrow ranging between 0 and 2.5 (Table 3.6).

Non-parametric t-tests on each scale item in Table 3.6 compare the medians of adaptive and traditional group responses for each item. No significant differences were found for the family wise, conservative Bonferroni alpha, of 0.01.

Overall, the summed self-efficacy score at baseline was not significantly different between the optometrists randomized to the traditional and those randomized to the adaptive groups (t (38) =-1.18, p=0.27), and their answers were therefore combined (Figure 3.15). Optometrists generally assessed their self-efficacy in the diagnosis and management of choroidal lesions as moderate (M=16.53, SD=4.19, out of 28).

Figure 3.15 reveals that only 13% of participants were confident of their ability to interpret ultrasonography findings for Choroidal lesion assessment (Q7). Furthermore, 59% of respondents were not positive that they could confidently use optical coherence tomography (OCT) in diagnosing choroidal lesions (Q3).

Table 3.5 Optometrists' Self-Efficacy

Frequency of responses (n) and percentage of participants (%) for the Traditional (n=22) and Adaptive (n=18) CPD Interventions. CPD: Continuing Professional Development. OCT: Optical Coherence Tomography.

Item	*Strongly Disagree*	*Disagree*	*Neither*	*Agree*	*Strongly Agree*
Q1. I have a good understanding of the ocular anatomy					
Traditional	0	0	2 (9.1)	18 (81.8)	2 (9.1)
Adaptive (n=17)	0	1 (5.9)	4 (32.5)	10 (58.8)	2 (11.8)
Q2. I can confidently detect Choroidal Nevus using an Ophthalmoscopy					
Traditional	0	5 (22.7)	5 (22.7)	10 (45.5)	2 (9.1)
Adaptive	0	4 (22.2)	3 (16.7)	8 (44.4)	3 (16.7)
Q3. I can confidently use OCT in diagnosing Choroidal lesions					
Traditional (n=21)	1 (4.5)	6 (28.6)	6 (28.6)	5 (23.8)	3 (14.3)
Adaptive	0	8 (44.4)	2 (11.1)	4 (22.2)	4 (22.2)
Q4. I am aware of the risk factors for Choroidal Lesion development and progression					
Traditional	0	1 (4.5)	6 (27.3)	14 (63.6)	1 (4.5)
Adaptive	1 (5.6)	4 (22.2)	2 (11.1)	10 (55.6)	1 (5.6)
Q5. I can confidently differentiate Choroidal Nevus from Malignant Melanoma					
Traditional	0	0	9 (40.9)	12 (54.5)	1 (4.5)
Adaptive	0	8 (44.4)	3 (16.7)	6 (33.3)	1 (5.6)
Q6. I can confidently use a Fundus Photography to monitor Choroidal Nevus growth					
Traditional	0	1 (4.5)	4 (18.2)	10 (45.5)	7 (31.8)
Adaptive	0	2 (11.1)	3 (16.7)	10 (55.6)	3 (16.7)
Q7. I can confidently interpret Ultrasonography for Choroidal lesion assessment					
Traditional	5 (22.7)	7 (31.8)	7 (31.8)	2 (9.1)	1 (4.5)
Adaptive	5 (22.2)	9 (50.0)	3 (16.7)	2 (11.1)	0

Table 3.6 Optometrists' Self- Efficacy

Likert scale descriptive statistics for Traditional (n=22) and Adaptive (n=18) CPD Interventions. CPD: Continuing Professional Development. OCT: Optical Coherence Tomography.

Item	*n (missing)*	*Median (Mdn)*	*Interquartile range (IQR)*	*Mann–Whitney (U)*
Q1. I have a good understanding of the ocular anatomy				
Traditional	22 (0)	'Agree'	0.00	0.39
Adaptive	17 (1)	'Agree'	1.00	
Q2. I can confidently detect Choroidal Nevus using an Ophthalmoscopy				
Traditional	22 (0)	'Agree'	1.00	0.64
Adaptive	18 (0)	'Agree'	1.50	
Q3. I can confidently use OCT in diagnosing Choroidal lesions				
Traditional	21 (1)	'Neither Agree nor Disagree'	2.00	0.95
Adaptive	18 (0)	Neither 'Agree nor Disagree'	2.50	
Q4. I am aware of the risk factors for Choroidal Lesion development and progression				
Traditional	22 (0)	'Agree'	1.00	0.48
Adaptive	18 (0)	'Agree'	2.00	
Q5. I can confidently differentiate Choroidal Nevus from Malignant Melanoma				
Traditional	22 (0)	'Agree'	1.00	0.05
Adaptive	18 (0)	'Neither Agree nor Disagree'	2.00	
Q6. I can confidently use a Fundus Photography to monitor Choroidal Nevus growth				
Traditional	22 (0)	'Agree'	1.00	0.38
Adaptive	18 (0)	'Agree'	0.50	
Q7. I can confidently interpret Ultrasonography for Choroidal lesion assessment				
Traditional	22 (0)	'Agree'	1.50	0.51
Adaptive	18 (0)	'Disagree'	1.00	

	Overall Mean M (SD)	***Cronbach alpha (α)***	***Overall independent parametric t-test p-value***
Traditional	17.23 (3.62)	0.77	0.27
Adaptive	15.67 (4.77)		
Combined	16.53 (4.19)		

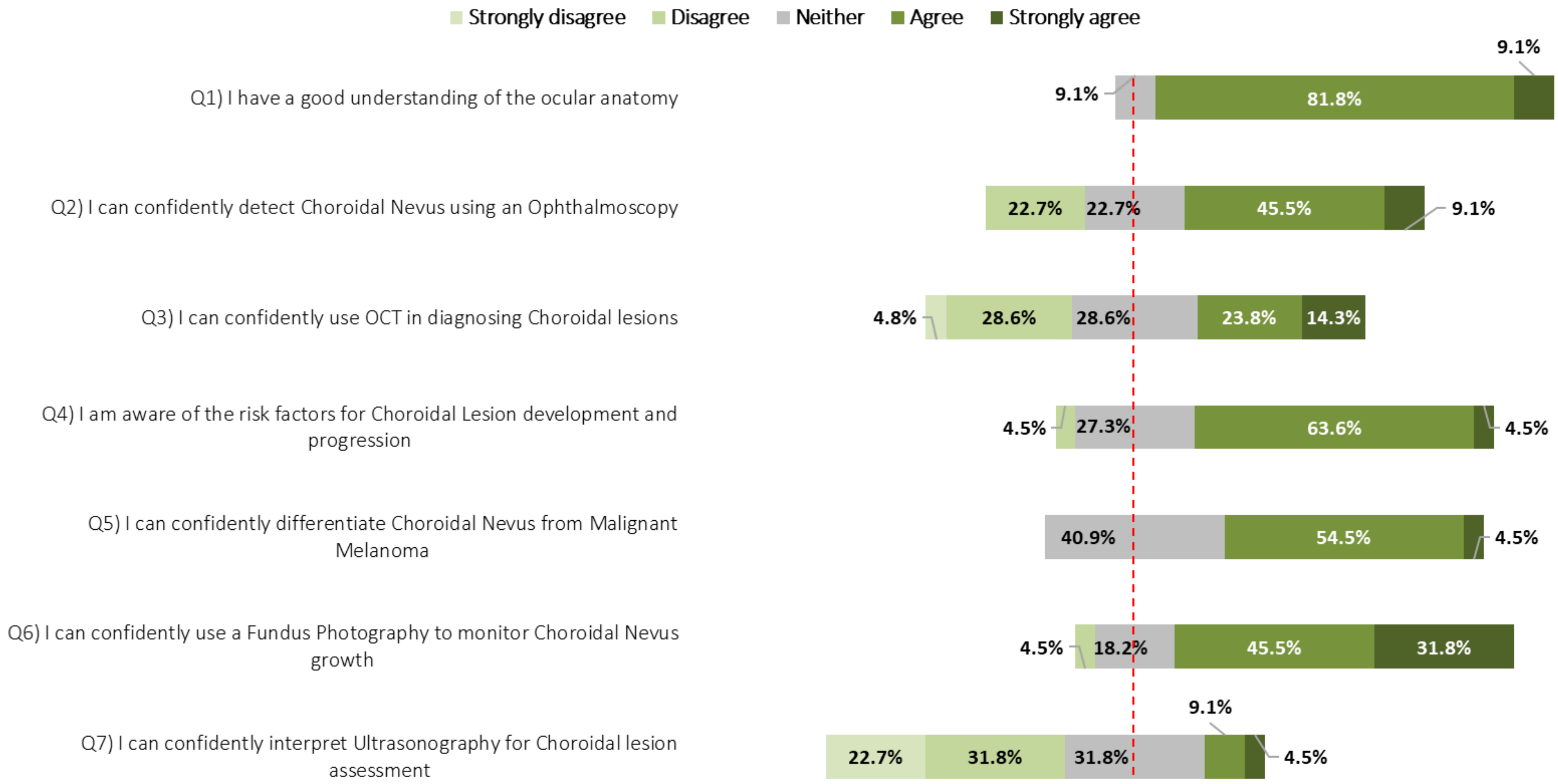

Figure 3.13 Self-Efficacy Prior the Traditional CPD Intervention (n=22)

The vertical red dotted line indicates a neutral answer to the Likert question; answers to the right of the vertical line indicate agreement and answers to the left disagreement with the proposed statements. OCT: Optical Coherence Tomography.

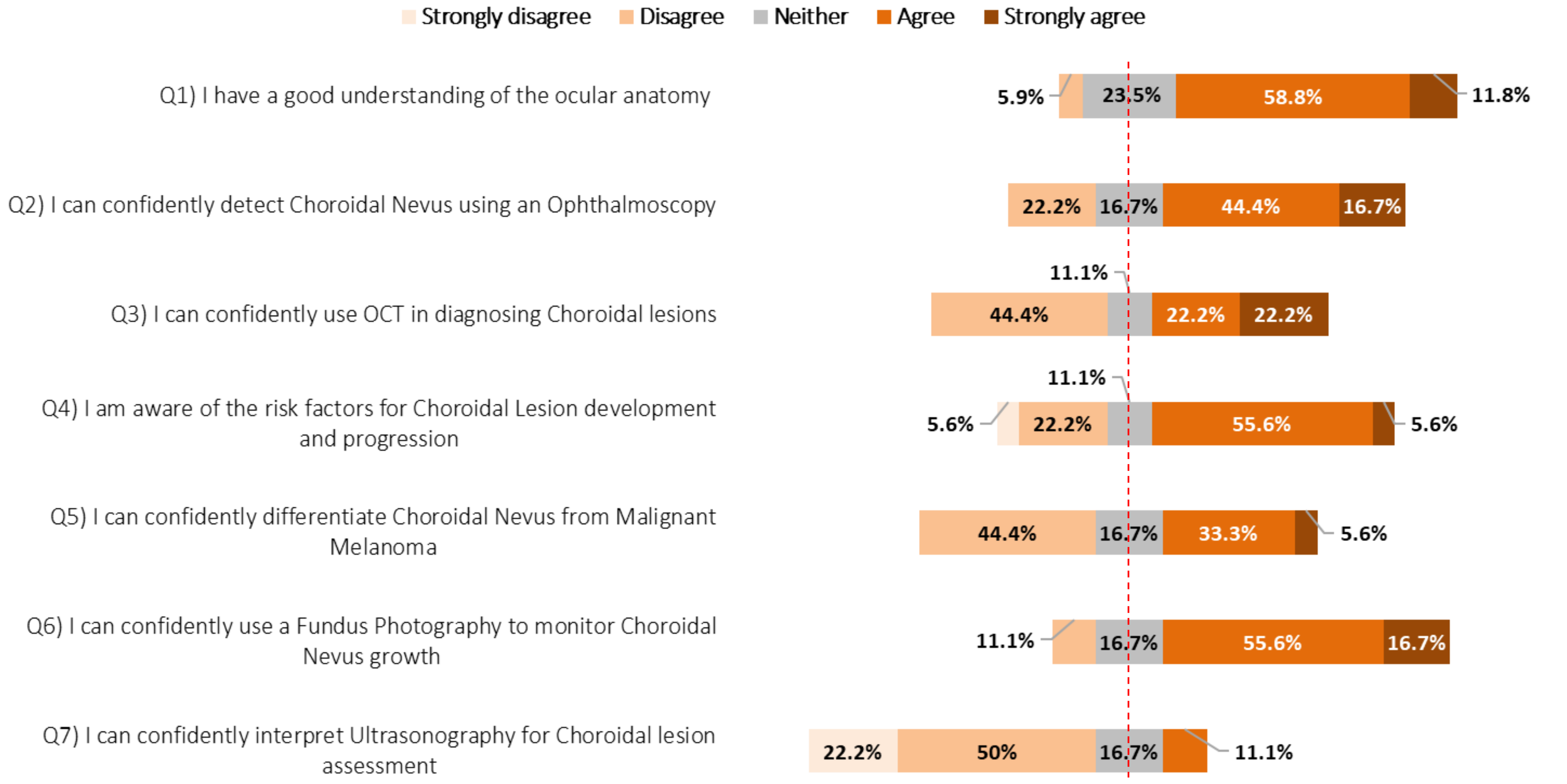

Figure 3.14 Self-Efficacy Prior the Adaptive CPD Intervention (n=18)

The vertical red dotted line indicates a neutral answer to the Likert question; answers to the right of the vertical line indicate agreement and answers to the left disagreement with the proposed statements. OCT: Optical Coherence Tomography.

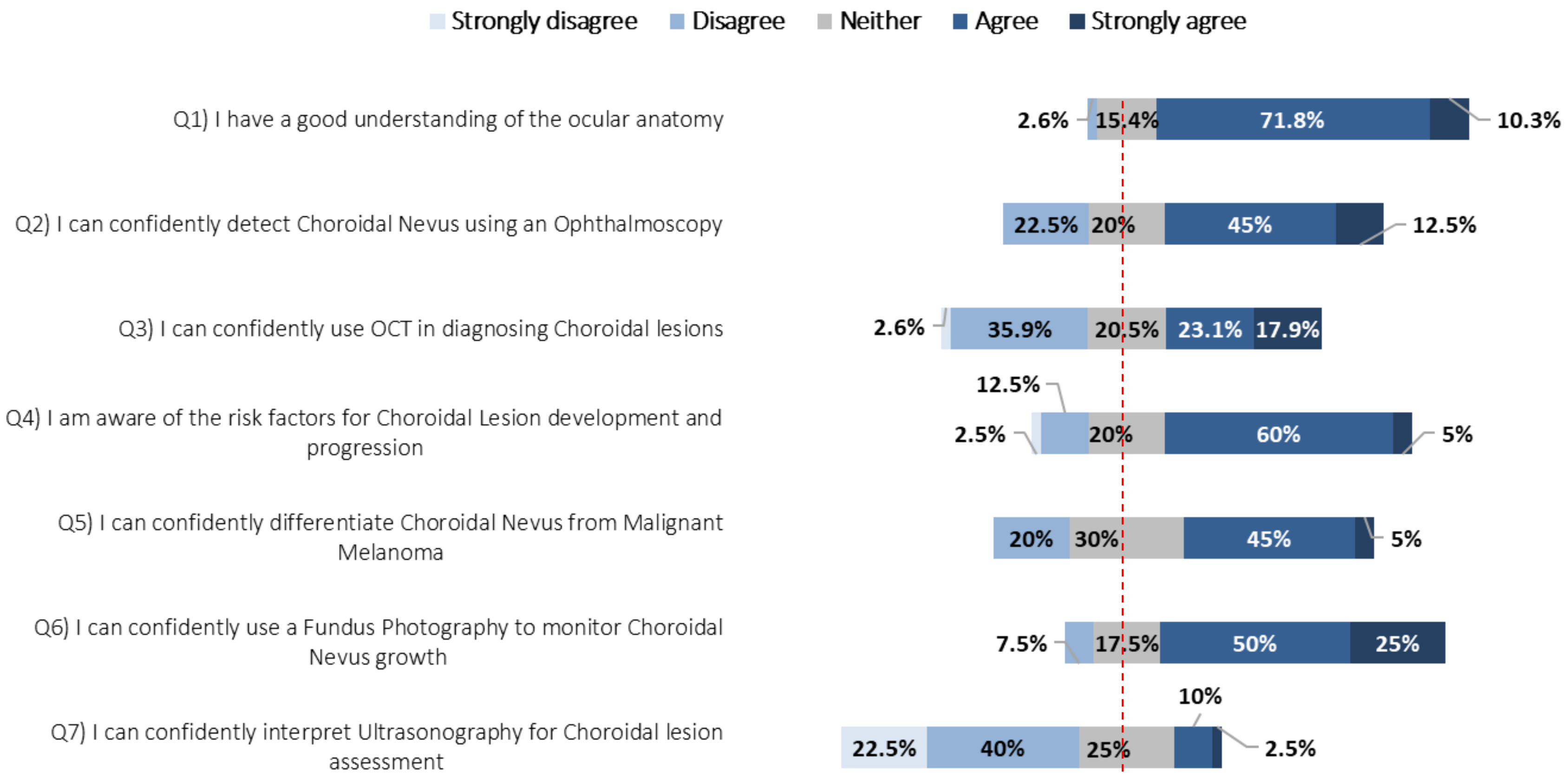

Figure 3.15 Self-Efficacy Prior to CPD Intervention (n=40, Traditional and Adaptive Combined)

The vertical red dotted line indicates a neutral answer to the Likert question; answers to the right of the vertical line indicate agreement and answers to the left disagreement with the proposed statements. OCT: Optical Coherence Tomography.

The boxplot chart in Figure 3.16 presents the overall patterns of self-efficacy for each group and both groups combined, allowing the reader to visualize the range of responses. From the sizes of the boxplots and the relation of the locations of the "X" in the middle of each boxplot (which represent the mean (M) of each group) and the horizontal line inside each boxplot (which represent the median (Mdn) of each group) we can say that the participants from both groups hold similar levels of self-efficacy of knowledge on the topic choroidal lesions.

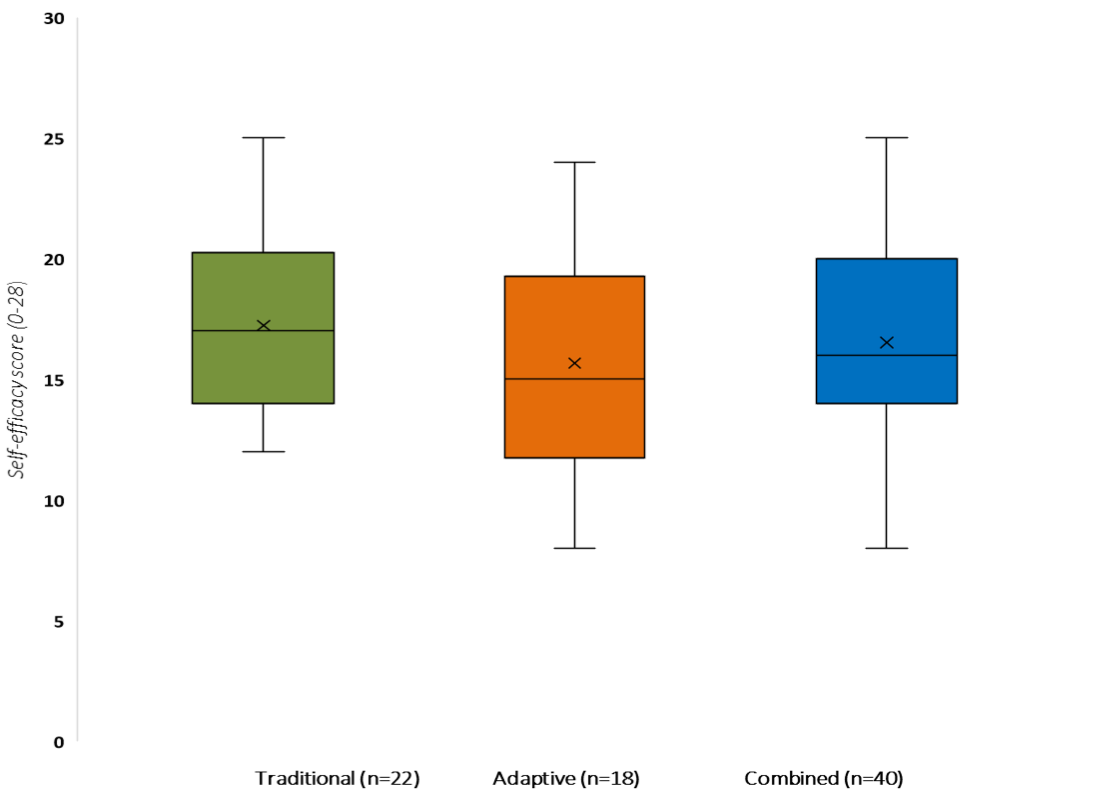

Figure 3.16 Self-Efficacy for the Traditional, Adaptive, and Both CPD Interventions Combined at Baseline

3.7.4. User Engagement

At the conclusion of their participation in this continuing education event, participants were asked to complete a nine-item user engagement questionnaire regarding their CPD experience (Appendix 3-6).

Frequency data is reported in Table 3.7. The frequencies presented are also represented graphically in Figure 3.17 and Figure 3.18 (and combined in Figure 3.19). The Cronbach alpha was strongly above 0.7, indicating an internally consistent scale. Table 3.8 summarizes the results of the comparison of the distribution of medians between the two learning groups. No significant differences were found at a corrected alpha of 0.05/9=0.006. It is noteworthy that the lowest p-value was found for item 5, which was about interest in the CPD activity. Although both groups had identical medians (‘Agree’), the other measure of central tendency, the mean, was numerically higher for the Adaptive learning group (M=3.27, SD=0.59) than for the Traditional group (M=2.48, SD=0.87) indicating slightly more interest in the CPD activity for the Adaptive group.

Although the overall mean engagement score of the Adaptive group (M=26.07, SD=6.43) was higher than that of the traditional group (M=23.67, SD=5.36), there was no significant difference between the traditional and adaptive groups (t (34) =1.22, p=0.72), (Table 3.8). When scores were combined across learning groups the average score (M=24.67, SD=5.87) out of 36 indicated that optometrists mostly enjoyed their CPD experience, no matter what the format.

Table 3.7 Optometrists' User Engagement

Frequency of responses (n) and percentage of optometrists (%) for the Traditional (n=21) and Adaptive (n=15) CPD Interventions. CPD: Continuing Professional Development.

Item	*Strongly Disagree*	*Disagree*	*Neither*	*Agree*	*Strongly Agree*
Q1. The modality of presenting this CPD activity was aesthetically appealing					
Traditional	0	1 (4.8)	3 (14.3)	16 (76.2)	1 (4.8)
Adaptive (n=14)	1 (7.1)	0	2 (14.3)	8 (57.1)	3 (21.4)
Q2. I found the screen layout of this CPD activity to be visually pleasing					
Traditional	0	2 (9.5)	4 (19.0)	12 (57.1)	3 (14.3)
Adaptive	2 (13.3)	2 (13.3)	1 (6.7)	5 (33.3)	5 (33.3)
Q3. I found this form of the CPD activity confusing to use					
Traditional	0	1 (4.8)	4 (19.0)	15 (71.4)	1 (4.8)
Adaptive	1 (6.7)	0	4 (26.7)	8 (53.3)	2 (13.3)
Q4. I felt annoyed while using this form of the CPD activity					
Traditional	1 (4.8)	1 (4.8)	3 (143)	13 (61.9)	3 (14.3)
Adaptive	1 (6.7)	1 (6.7)	2 (13.3)	8 (53.3)	3 (20.0)
Q5. I felt interested in this form of the CPD Activity					
Traditional	0	3 (14.3)	7 (33.3)	9 (42.9)	2 (9.5)
Adaptive	0	0	1 (6.7)	9 (60.0)	5 (33.3)
Q6. The content of this CPD activity incited my curiosity					
Traditional (n=20)	0	2 (10.0)	3 (15.0)	11 (55.0)	4 (20.0)
Adaptive	0	0	0	9 (60.0)	6 (40.0)
Q7. The experience of using this form of the CPD activity did not work out the way I had expected					
Traditional (n=20)	1 (5.0)	3 (15.0)	5 (25.0)	9 (45.0)	2 (10.0)
Adaptive	0	1 (6.7)	5 (33.3)	6 (40.0)	3 (20.0)
Q8. Using this form of the CPD activity was worthwhile					
Traditional	0	0	3 (14.3)	15 (71.4)	3 (14.3)
Adaptive	0	1 (6.7)	0	8 (53.3)	6 (40.0)
Q9. My experience with this CPD activity was fun					
Traditional	1 (4.8)	6 (28.6)	6 (28.6)	6 (28.6)	2 (9.5)
Adaptive	0	3 (20.0)	1 (6.7)	8 (53.3)	3 (20.0)

Table 3.8 Optometrists' User Engagement
Likert scale descriptive statistics for Traditional and Adaptive CPD Interventions.
CPD: Continuing Professional Development.

User Engagement questionnaire questions	*n (missing)*	*Median (Mdn)*	*Interquartile range (IQR)*	*Mann–Whitney (U)*
Q1. The modality of presenting this CPD activity was aesthetically appealing				
Traditional	21 (0)	'Agree'	0.00	0.61
Adaptive (n=14)	14 (1)	'Agree'	1.00	
Q2. I found the screen layout of this CPD activity to be visually pleasing				
Traditional	21 (0)	'Agree'	1.00	0.85
Adaptive	15 (0)	'Agree'	2.00	
Q3. I found this form of the CPD activity confusing to use*				
Traditional	21 (0)	'Agree'	1.00	0.90
Adaptive	15 (0)	'Agree'	1.00	
Q4. I felt annoyed while using this form of the CPD activity*				
Traditional	21 (0)	'Agree'	0.00	0.95
Adaptive	15 (0)	'Agree'	1.00	
Q5. I felt interested in this form of the CPD Activity				
Traditional	21 (0)	'Agree'	1.00	0.01*
Adaptive	15 (0)	'Agree'	1.00	
Q6. The content of this CPD activity incited my curiosity				
Traditional (n=20)	20 (1)	'Agree'	1.00	0.80
Adaptive	15 (0)	'Agree'	1.00	
Q7. The experience of using this form of the CPD activity did not work out the way I had expected*				
Traditional (n=20)	20 (1)	'Agree'	1.00	0.46
Adaptive	15 (0)	'Agree'	1.00	
Q8. Using this form of the CPD activity was worthwhile				
Traditional	21 (0)	'Agree'	0.00	0.17
Adaptive	15 (0)	'Agree'	1.00	
Q9. My experience with this CPD activity was fun				
Traditional	21 (0)	'Neither Agree nor Disagree'	2.00	0.10
Adaptive	15 (0)	'Agree'	1.00	

	Overall Mean M (SD)	*Cronbach alpha (α)*	***Overall independent parametric t-test p-value***
Traditional	23.67 (5.36)	0.84	0.72
Adaptive	26.07 (6.43)		
Combined	24.67 (5.87)		

(*) Scores for questions 3, 4 and 7 were reverse coded.
Scores range; 0-36.

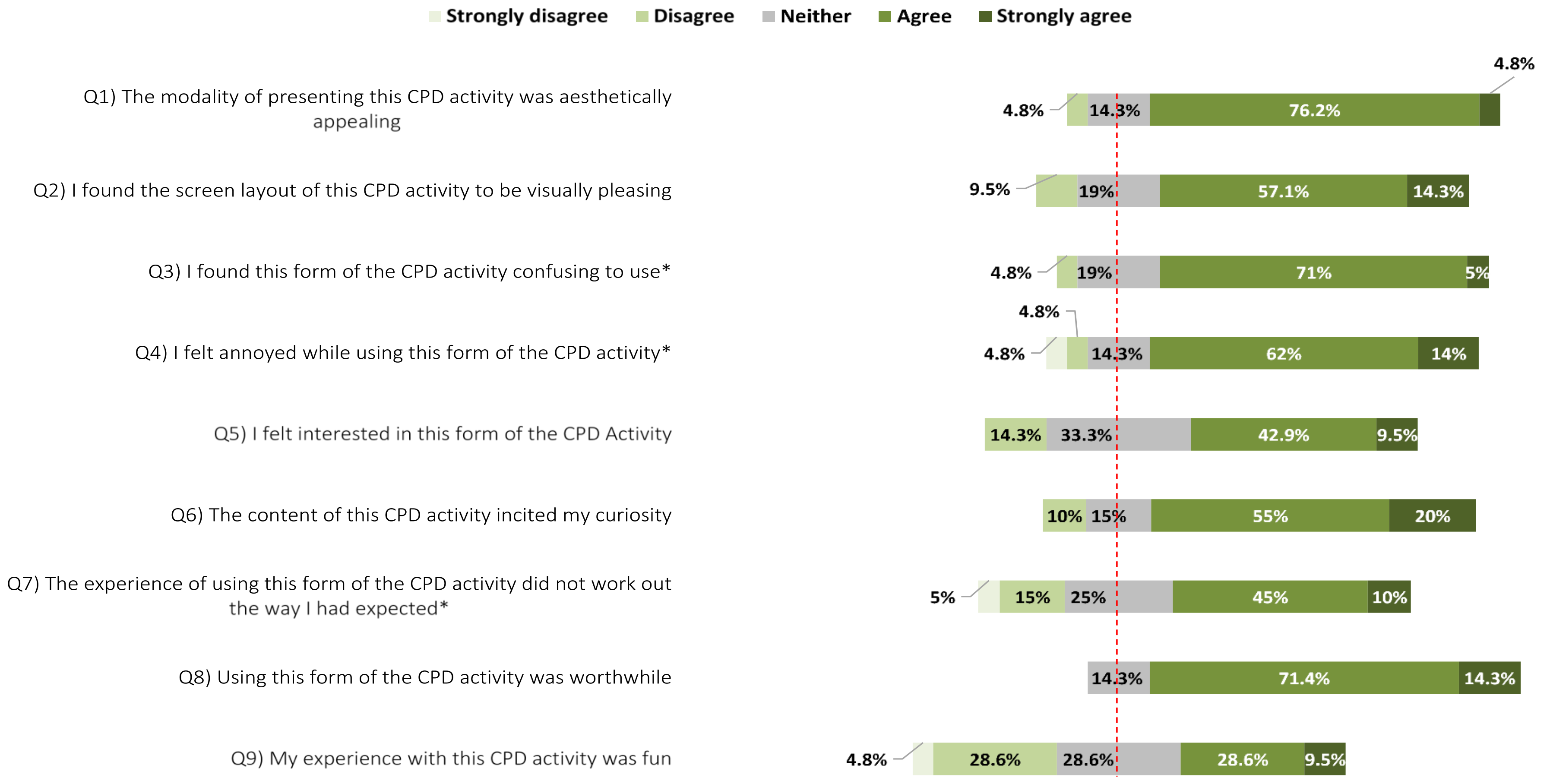

Figure 3.17 User Engagement of the Traditional CPD Intervention (n=21)

The vertical red dotted line indicates a neutral answer to the Likert question; answers to the right of the vertical line indicate agreement and answers to the left disagreement with the proposed statements. (*) Scores for questions 3, 4 and 7 were reverse coded. CPD: Continuing Professional Development.

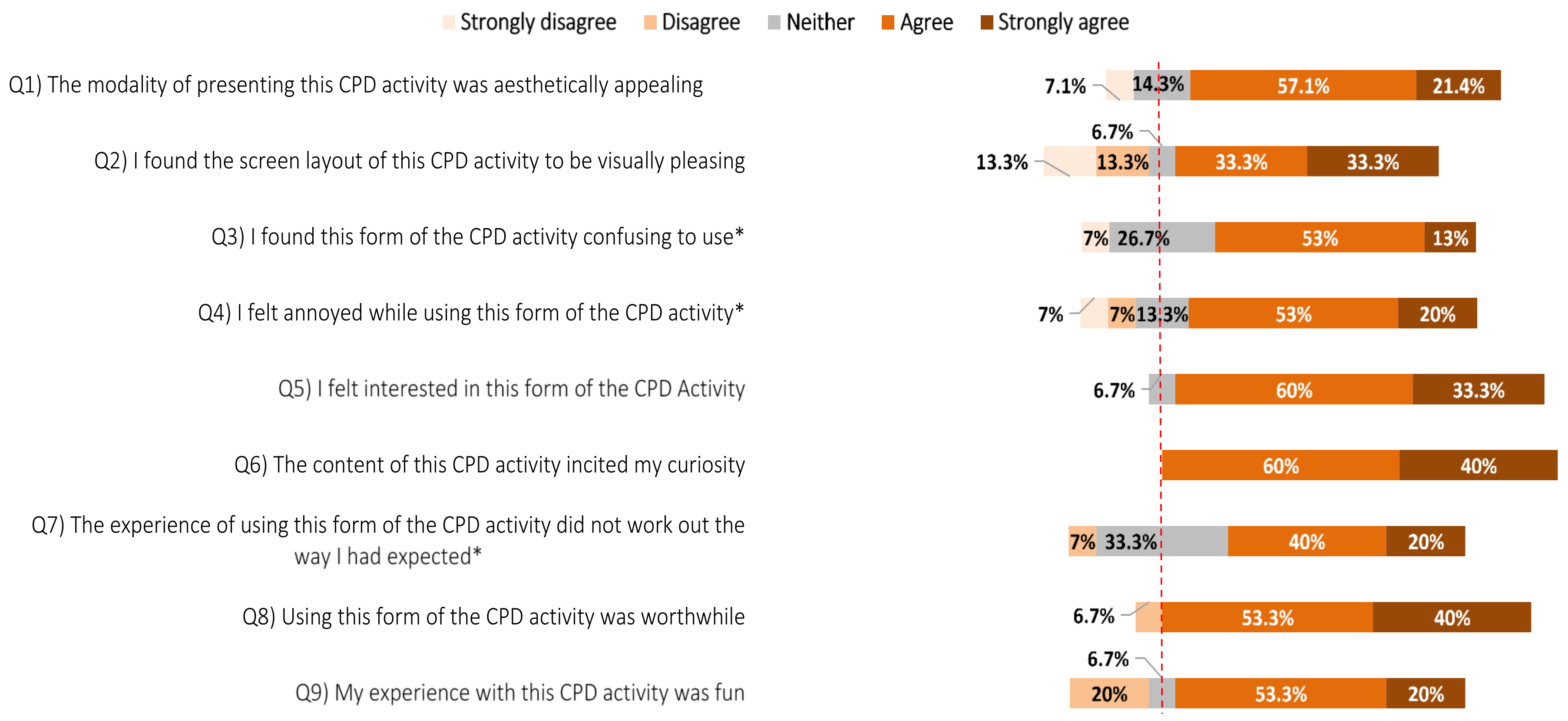

Figure 3.18 User Engagement of the Adaptive CPD Intervention (n=15)

The vertical red dotted line indicates a neutral answer to the Likert question; answers to the right of the vertical line indicate agreement and answers to the left disagreement with the proposed statements. (*) Scores for questions 3, 4 and 7 were reverse coded. CPD: Continuing Professional Development.

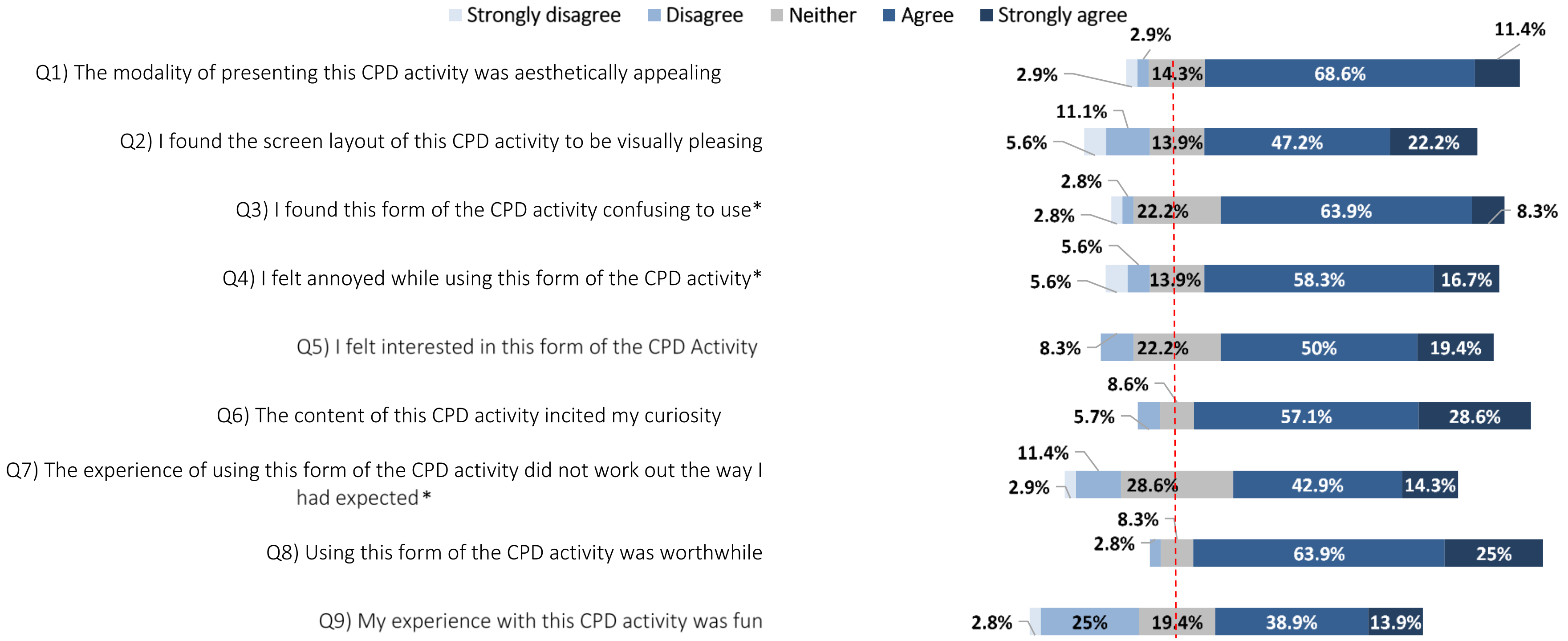

Figure 3.19 User Engagement of the CPD Intervention (n=36, Traditional and Adaptive Combined)
The vertical red dotted line indicates a neutral answer to the Likert question; answers to the right of the vertical line indicate agreement and answers to the left disagreement with the proposed statements. (*) Scores for questions 3, 4 and 7 were reverse coded. CPD: Continuing Professional Development.

The boxplot chart in Figure 3.20 presents the overall patterns of user engagement responses for each of the traditional and adaptive CPD interventions, allowing the reader to visualize the range of responses for the whole group of optometrists in each intervention and for the groups combined. From the sizes of the boxplots and the relation of the locations of the "X" in the middle of each boxplot (which represent the mean (M) of each group) and the horizontal line inside each boxplot (which represent the median (Mdn) of each group) we can say that optometrists from both groups hold similar levels of user engagement to the choroidal lesions CPD intervention.

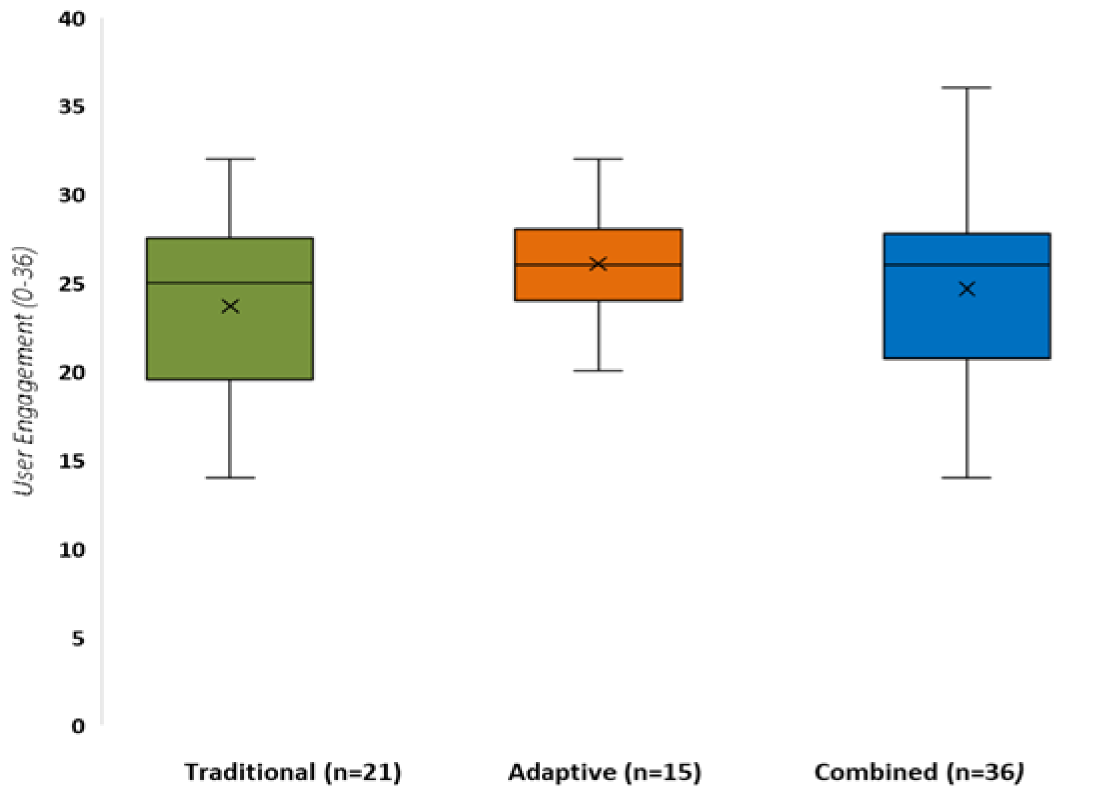

Figure 3.20 User Engagement for the Traditional, Adaptive, and Both CPD Interventions Combined

3.7.5. Knowledge

To investigate the effectiveness of CPD, and the retention of knowledge and compare it between the two interventions, the same knowledge questionnaire was administered immediately following completion and 12 weeks after completion of the CPD intervention. The knowledge questionnaire measured participants' knowledge of diagnosis and management of choroidal lesions and was scored 0-10 (Appendix 3-7).

For the adaptive CPD arm, 15 optometrists attempted the knowledge questionnaire, whereas for the traditional CPD arm 21 optometrists attempted the knowledge questionnaire immediately following completion of the CPD intervention. Forty-one optometrists who had provided consent (Appendix 3-4) to participate in further studies were invited to complete the 12-week knowledge retention questionnaire (Appendix 3-8). Nineteen (46%) optometrists completed the 12-week knowledge questionnaire, 12 from the traditional CPD group and 7 from the adaptive CPD group. Of note, 2 of the 7 adaptive group participants who agreed to complete the 12-week knowledge questionnaire had not completed the knowledge questionnaire administered immediately following completion of the CPD intervention. Their data was included where possible.

Descriptive and statistical data are presented in Table 3.9 and Table 3.10. The frequencies presented in Table 3.9 and Table 3.10 are also represented graphically in Figure 3.22 and Figure 3.23. Cronbach alphas were not above 0.7 for either immediately following completion or at 12 weeks. For the initial sitting (Cronbach Alpha of 0.36), the best alpha possible of 0.43 could be achieved by deleting item 5 about Red Filtered Retinal Photography. For the 12-week test (Alpha 0.31), the best alpha possible of 0.56 could be achieved by deleting the same question.

3.7.5.1. *Mixed Model ANOVA Results: Knowledge*

A two-factor mixed-design ANOVA did not find any main effect of CPD type. Despite the adaptive group means being higher than the traditional group means at both timepoints (Figure 3.22 or Figure 3.23), using an alpha of 0.05, there was no significant difference in knowledge scores of the adaptive CPD group compared to the traditional CPD intervention group ($F(1, 15) = 3.28$, $p = 0.09$. $r = 0.42$).

There was a main effect of time such that knowledge scores were significantly lower at week 12, ($M = 5.23$, $SD = 1.75$) compared to those captured immediately after the CPD intervention ($M = 6.58$, $SD = 1.62$) ($F(1, 15) = 5.39$, $p = 0.035$. $r = 0.51$). The interaction of CPD type by time was not significant ($F(1,15) = 0.583$, $p = 0.457$).

The boxplot chart in Figure 3.21 presents the overall patterns of knowledge immediately following and 12-week after each of the traditional and adaptive CPD interventions, allowing the reader to visualize the range of responses for the whole group of optometrists in each intervention and for both combined.

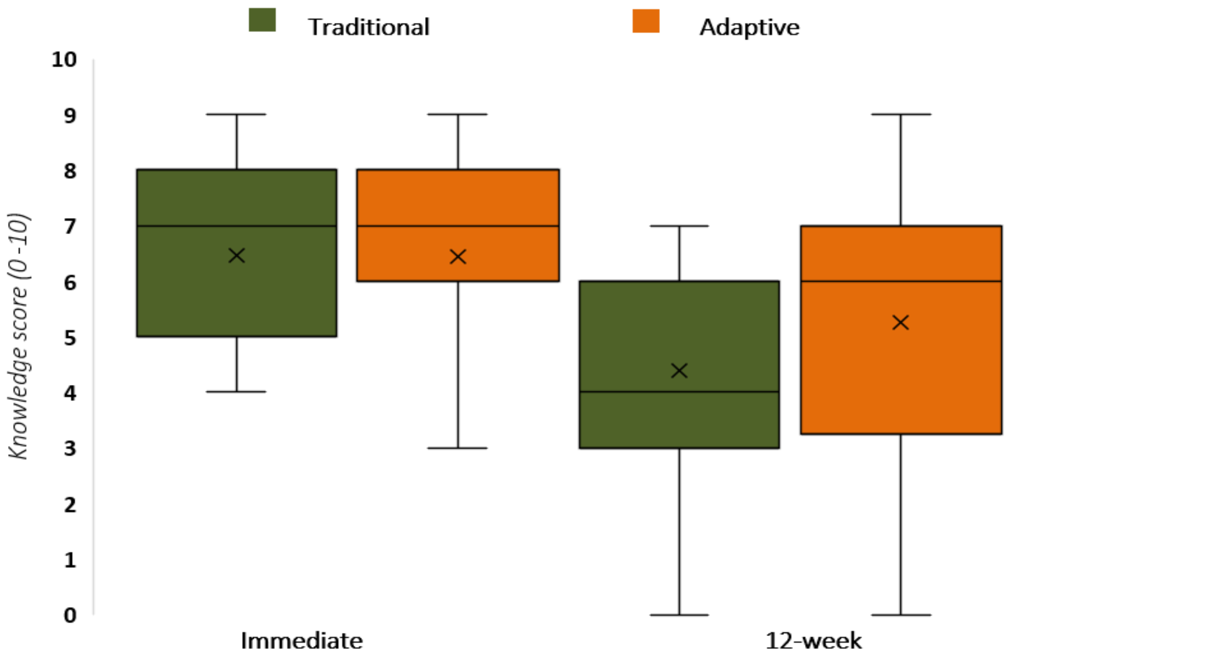

Figure 3.21 Knowledge (Immediate) and Knowledge Retention (12-week) of Choroidal Lesions in the Traditional and Adaptive CPD Intervention Groups

Immediate Traditional (n=21), Adaptive (n=15).

12-week Traditional (n=12), Adaptive (n=7).

3.7.5.2. *Post-hoc Testing of Main Effect*

To further explore the significant main effect of time, paired t-tests were conducted. Due to the sample size of 5 for the adaptive group, non-parametric related-simples Wilcoxon signed rank test were conducted. For those that were in the traditional group, knowledge score dropped significantly after 12 weeks (Mdn=6 immediately and Mdn=4.5 at 12 weeks), (T=3, p=0.01, r=-0.52). As the effect size, r, is above Cohen's 0.5 benchmark, this was considered a large reduction in knowledge score over time. However, those who were assigned to the adaptive CPD intervention had no change to their knowledge score (Mdn =7 and Mdn=7 respectively), (T=3, p=0.450, r=-0.24). Therefore, it appears that the significant effect in the main ANOVA is mostly due to those in the traditional CPD group displaying poorer knowledge retention.

3.7.6. Knowledge at Each Timepoint

Whilst the ANOVA found no overall effect of learning across the two time points, for completeness, each timepoint was considered as a standalone analysis in order to look closely at the individual questions between CPD groups. This was especially important so as to include the two optometrists who only completed the week 12 questionnaire.

For the questionnaire administered immediately following the CPD intervention, frequency responses to each item are presented in Table 3.9 (and Table 3.10 for the 12-week data) and includes means and standard deviations. Parametric t-tests were conducted utilizing a Bonferroni corrected alpha of 0.05/10=0.005. However, as the scale lacked internal consistency (low Cronbach alpha's) one could argue that a p value of 0.01 would be more acceptable in this case as items were not highly correlated.

3.7.6.1. *Immediate Knowledge*

Optometrists in the Adaptive CPD group were significantly more accurate when responding to Question 1 (lifetime risk of Choroidal Nevus undergoing malignant transformation) than those in the traditional group (t (34) =2.95, p<0.01). However, participants in the Traditional CPD group were significantly more accurate when responding to Question 5 (red filtered retinal photography) than those in the adaptive group (t (34) =-4.17, p<0.01).

Despite having a higher mean, optometrists in the Adaptive group performed no differently in the knowledge quiz to those in Traditional group (t (34) =1.83, p=0.71). However, Figure 3.22 helps to visualize those optometrists in the adaptive CPD group on average scored higher than those in the traditional CPD group for 7 out of 10 questions.

Overall, participants from both groups displayed a reasonable amount of knowledge (M=6.81, SD=1.67) out of a maximum score of 10 (Table 3.9).

3.7.6.2. *Knowledge Retention (at 12-week Post Intervention)*

Investigatory comparisons were made between the optometrists of both the traditional (n=12) and adaptive (n=7) groups for the answers (perfect score=10) of the 12-week post choroidal lesions CPD activity knowledge questionnaire.

The only notable result was that the adaptative group performed better than the traditional group on Question 4 *"What is the most typical appearance of Choroidal Melanoma using fundus auto-fluorescence?"* with a p value of 0.01.

Despite the average score being higher for the adaptive group, the 12-week post knowledge survey scores were not significantly different between the traditional and adaptive CPD interventions (M=4.75, SD=1.48 vs M=6.00, SD=2.08 respectively, p=0.24). The adaptive group optometrists produced higher scores than the traditional group optometrists for six out of the 10 knowledge survey questions (see Figure 3.23).

Table 3.9 Optometrists' Knowledge on Diagnosis and Management of Choroidal Lesions Immediately After the CPD Intervention

Likert scale descriptive statistics for Traditional (n=21) and Adaptive (n=15) Interventions.

Knowledge quiz questions	*Frequency (%)*	*Mean (SD)*	*Parametric t-test*
Q1. What is the lifetime risk of choroidal naevi undergoing malignant transformation?			
Traditional	13 (61.9)	0.62 (0.50)	0.00*
Adaptive	15 (100.0)	1.00 (0.00)	
Q2. Which of the following instruments may be used to reveal acoustic hollowness of a choroidal tumor?			
Traditional	19 (90.5)	0.90 (0.30)	0.55
Adaptive	14 (93.3)	0.93 (0.26)	
Q3. Which of the following is NOT associated with choroidal melanoma?			
Traditional	18 (85.7)	0.86 (0.36)	0.15
Adaptive	14 (93.3)	0.93 (0.26)	
Q4. What is the most typical appearance of Choroidal Melanoma using fundus auto-fluorescence?			
Traditional	15 (71.4)	0.71 (0.46)	0.25
Adaptive	12 (80.0)	0.80 (0.41)	
Q5. Which of the following tissues is best visualized using red filtered retinal photography?			
Traditional	21 (100.0)	1.00 (0.00)	0.00*
Adaptive	8 (53.3)	0.53 (0.52)	
Q6. Which of the following features of a choroidal lesion found in a 45-year-old female patient is considered to be a risk factor for malignant transformation?			
Traditional	18 (85.7)	0.86 (0.36)	0.08
Adaptive	11 (73.3)	0.73 (0.46)	
Q7. What would be the appropriate management of a large (5mm diameter) choroidal naevus with 3 risk factors for malignant transformation?			
Traditional	13 (61.9)	0.62 (0.50)	0.83
Adaptive	6 (40.0)	0.40 (0.51)	
Q8. What would be the appropriate management of a small choroidal naevus with associated sub retinal fluid but no other risk factors for malignant transformation?			
Traditional	9 (42.9)	0.43 (0.51)	0.70
Adaptive	8 (53.3)	0.53 (0.52)	
Q9. Which of the following statements about Choroidal Melanoma is INCORRECT?			
Traditional	9 (42.9)	0.43 (0.51)	0.70
Adaptive	7 (46.7)	0.47 (0.52)	
Q10. Using the Shields et al. pneumonic only, how many risk factors for malignancy does this asymptomatic patient have? (Notes: lesion elevation 154µm, yellow areas on the lesion were confirmed as drusen)			
Traditional	7 (33.3)	0.33 (0.48)	0.23
Adaptive	8 (53.3)	0.53 (0.52)	
Overall Mean M (SD)		*Cronbach alpha (α)*	*Overall ANOVA/t-test p-value*
Traditional	6.76 (1.55)	0.36	0.71
Adaptive	6.87 (1.88)		
Combined	6.81 (1.67)		

Scores range from 0 to 10.

**Statistically significant.*

Table 3.10 Optometrists' Knowledge Retention 12 Weeks After the CPD Intervention

Likert scale descriptive statistics for Traditional (n=12) and Adaptive (n=7) Interventions.

Knowledge quiz questions	*Frequency (%)*	*Mean (SD)*	*Parametric t-test*
Q1. What is the lifetime risk of choroidal naevi undergoing malignant transformation?			
Traditional	2 (16.87)	0.17 (0.39)	0.05
Adaptive	4 (57.1)	0.57 (0.53)	
Q2. Which of the following instruments may be used to reveal acoustic hollowness of a choroidal tumor?			
Traditional	11 (91.7)	0.91 (0.29)	0.45
Adaptive	6 (85.7)	0.86 (0.38)	
Q3. Which of the following is NOT associated with choroidal melanoma?			
Traditional	8 (66.7)	0.67 (0.49)	0.06
Adaptive	6 (85.7)	0.86 (0.38)	
Q4. What is the most typical appearance of choroidal melanoma using fundus auto-fluorescence?			
Traditional	5 (41.7)	0.42 (0.51)	0.01*
Adaptive	6 (85.7)	0.86 (0.38)	
Q5. Which of the following tissues is best visualised using red filtered retinal photography?			
Traditional	7 (58.3)	0.58 (0.51)	0.93
Adaptive	4 (57.1)	0.57 (0.53)	
Q6. Which of the following features of a choroidal lesion found in a 45-year-old female patient is considered to be a risk factor for malignant transformation?			
Traditional	4 (33.3)	0.33 (0.49)	0.50
Adaptive	4 (57.1)	0.57 (0.53)	
Q7. What would be the appropriate management of a large (5mm diameter) choroidal naevus with 3 risk factors for malignant transformation?			
Traditional	5 (41.7)	0.42 (0.51)	0.93
Adaptive	3 (42.9)	0.43 (0.53)	
Q8. What would be the appropriate management of a small choroidal naevus with associated sub retinal fluid but no other risk factors for malignant transformation?			
Traditional	5 (41.7)	0.42 (0.51)	0.93
Adaptive	4 (57.1)	0.57 (0.53)	
Q9. Which of the following statements about choroidal melanoma is INCORRECT?			
Traditional	3 (25.0)	0.25 (0.45)	0.76
Adaptive	2 (28.6)	0.28 (0.49)	
Q10. Using the Shields et al. pneumonic only, how many risk factors for malignancy does this asymptomatic patient have? (Notes: lesion elevation 154 µm, yellow areas on the lesion were confirmed as drusen)			
Traditional	7 (58.3)	0.58 (0.51)	0.93
Adaptive	3 (42.9)	0.43 (0.53)	

Overall Mean M (SD)		*Cronbach alpha (α)*	*Overall ANOVA/t-test p-value*
Traditional	4.75 (1.48)	0.31	0.24
Adaptive	6.00 (2.08)		
Combined	5.21 (1.78)		

Scores range from 0 to 10.

**Statistically significant.*

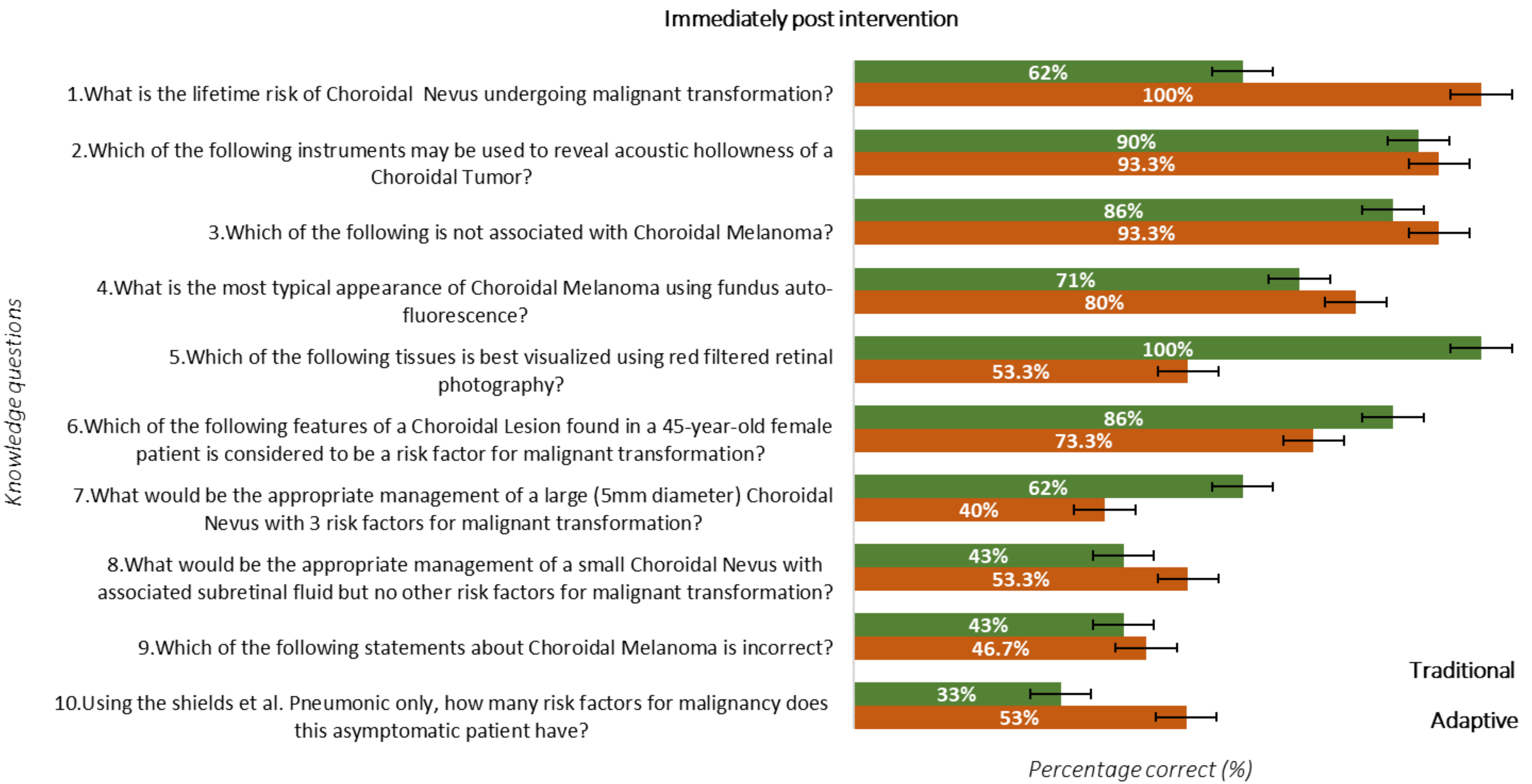

Figure 3.22 Knowledge of Diagnosis and Management of Choroidal Lesions Immediately Post the Traditional (n=21) and Adaptive (n=15) CPD Interventions

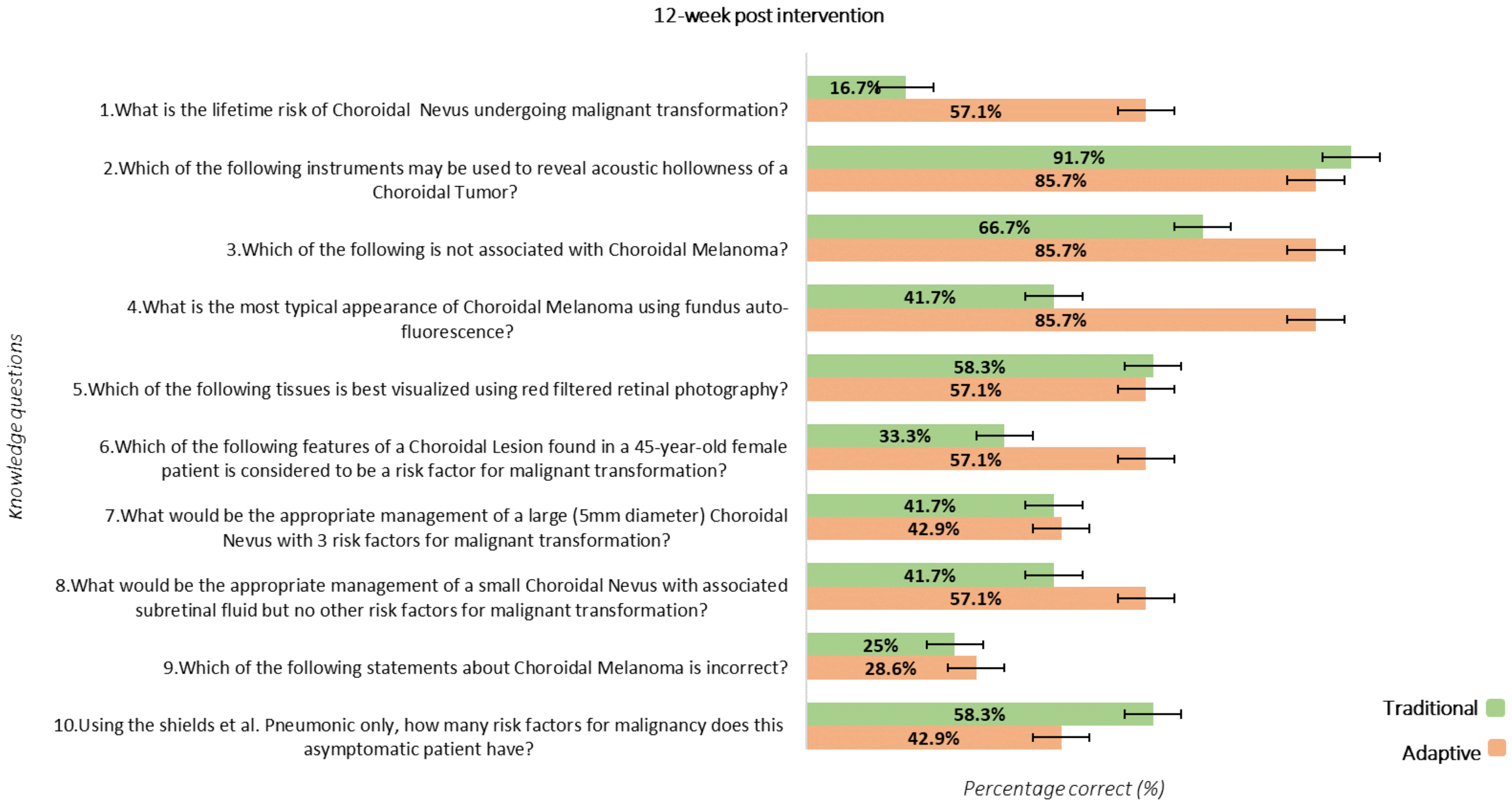

Figure 3.23 Knowledge retention 12 Weeks Post the Traditional (n=12) and Adaptive (n=7) CPD Interventions

3.8. Discussion

This study evaluated the effectiveness, user engagement, and knowledge retention of adaptive learning versus traditional (non-adaptive) CPD for optometrists. A secondary aim was to quantify the attitude and self-efficacy of optometrists towards CPD.

3.8.1. Knowledge

Overall knowledge of diagnosis and management of choroidal lesion averaged 68% immediately after the CPD intervention. The adaptive arm was not more effective than the traditional CPD intervention. Our lack of significant findings immediately post CPD are similar to other studies who found no significant differences between adaptive versus traditional interventions (Flint & Stewart, 2010).

Similar to what has been shown in other fields, knowledge gained dropped significantly after 12 weeks for both intervention types (Courteille et al., 2018). However, in this study we were able to determine that those in the traditional group significantly lost knowledge after 12-week whereas those in the Adaptive group did not. This indicates that adaptive learning may result in stronger knowledge retention than other non-adaptive forms of CPD. The average score for the traditional group significantly dropped to a failure mark of 48%, whereas the adaptive group score moved to 60%. However, statistical testing at the 12-week timepoint did not reveal significant differences between the two intervention arms. Looking at the pattern of responses to the 10 individual knowledge questions at 12 weeks, there were six questions that were answered incorrectly by more than 50% of traditional CPD. Yet only two questions were answered as poorly by those randomized to the adaptive CPD intervention.

Although there were no significant differences between Traditional and Adaptive CPD arms immediately following the intervention, the knowledge retention findings from this study suggest that adaptive CPD may be more effective than traditional CPD. It appears that our study is in the minority as only 42% of the studies that attempted to measure effectiveness of CPD in improving clinical outcomes could previously demonstrate a long-term effect (Marinopoulos, 2007).

An interesting effect of participation occurred in our 12-week follow up test where 71% of traditional group participants partook in the 12-week follow-up, whereas only 29% of adaptive group participants completed the 12-week follow up. We hypothesize that active engagement required from those randomized to the adaptive CPD intervention arm took more work/energy out of optometrists, making them feel more drained by the experience and thus less willing to participate in future follow-up research. Some other reasons might be that some optometrists could also have felt that their knowledge had dropped over the weeks making them less willing to participate. The results could be biased if only participants more confident in their knowledge retention decided to participate in the follow-up research. It has been previously shown that repeated education and assessment can be an important factor that impacts or modulates knowledge retention (Kerfoot et al., 2007; Larsen et al., 2009). We propose that future CPD interventions consider repeat offerings of the training.

3.8.2. User Engagement

Although user engagement was 72% for those randomized to the adaptive intervention, this was not significantly different to the 66% user engagement score for the traditional CPD group. Yet those in the Adaptive group found the activity significantly more interesting than the others. The overall responses to the User engagement questionnaire suggest that optometrists displayed good engagement towards both CPD interventions, however, more optometrists in the Adaptive intervention arm agreed with the statements of the following questions compared to optometrists randomized to the Traditional CPD arm: question 5, that they were *"interested in this form of CPD"* (93% vs 53%), question 6 that they were *"curious about the content"* (100% vs 75%)), question 7 "*The experience of using this form of the CPD activity did not work out the way I had expected"* (scores for this questions reversed, 60% vs 16%), question 8 that participating in the intervention was *"worthwhile"* (93% vs 20%), and question 9, that the intervention they participated in was *"fun"* (73% vs 39%) (Figure 1.17). In summary, those optometrists that were randomized to the Interactive CPD appeared to have found it more interesting, worthwhile, and fun than those that were randomized to Traditional CPD.

Positive experiences with CPD activities that are engaging and fun may have long term effects, encouraging optometrists to return for future CPD training, allowing for repeat exposure effects to be implemented. That is, if the experience was not enjoyable optometrists may not be keen to engage in additional CPD beyond that which was required. As we have seen previously that repeat exposure to CPD was more effective at improving health outcomes (see Table 1.1. in Chapter 1), making CPD sessions enjoyable is likely to be more beneficial. The results of this chapter suggest that those who were randomized to the interactive CPD found it more fun and may be more likely to return for subsequent CPD compared to those in the traditional CPD group.

3.8.3. Attitude and Self-Efficacy

Optometrists' attitudes towards CPD were very positive with all seven CPD statements receiving median scores of "Agree" or "Strongly Agree" and an overall score of 72% on the scale. These findings were well aligned with those of Chapter 2 where qualitative analysis of the perspective of optometrists towards CPD showed that optometrists generally displayed a positive attitude towards CPD and expressed general agreement with CPD. A previous extensive literature review supported the concept that CPD was effective at least to some degree in achieving and maintaining the positive attitudes in health practitioners, with 22 of 26 studies supporting this conclusion (Marinopoulos, 2007). In the same study, eighty-five percent of studies demonstrated that CPD was effective at improving attitudes to learning with the majority (68%) demonstrating long-term sustained improvements (Marinopoulos, 2007). Whilst the evidence was classified as largely heterogenous and unclear (rated as low-quality evidence), it was nevertheless suggested that CPD interventions that favor use of multimedia, multiple techniques, and multiple exposures might yield the most positive impact on attitudes to CPD (Marinopoulos, 2007). Whilst this report is more than 10 years old, there have been little changes to the quality and strength of the evidence in this area.

The topic of Choroidal Lesions is an important topic not only for the health outcomes of patients, but also for the liable risk to health professional surrounding poor diagnosis. Somewhat undesirably, self-efficacy on the topic "Choroidal Lesions" was 59% overall with participants mostly responding "Agree". This demonstrates the importance of continuing to provide CPD on this topic to Australian optometrists. Optometrists were less confident at using OCT (only 41% said they could), differentiating Choroidal Nevus from Malignant Melanoma (50% agreed), and interpreting Ultrasonography (only 12.5% agreed). This last result was to be expected due to ultrasonography sitting squarely within the diagnostic domain of ophthalmology, however it remains important that optometrists be aware of when to refer patients for secondary care, that they know how to interpret ultrasound results that are communicated back to them by the ophthalmologist, and that they can clearly explain the importance of, and the consequences of any referral to their patients.

3.9. Strengths and Limitations

The strengths of the study included the use of a randomized study design, adherence to the CONSORT guidelines, and use of internally consistent scales for the measurement of attitude, self-efficacy, and user engagement.

The limitations of this study included a larger than desired loss to follow up: the number of optometrists that completed the adaptive arm of the study was less than required by the sample size calculation. The chances of finding a significant result were thus reduced. The generalizability of the findings to other Australian optometrists cannot be ascertained as demographic information was not collected from the study participants. Optometrists' engagement, and their ability to gain and retain knowledge may have been modulated by the perceived importance of the CPD topic. Furthermore, the intervention was both adaptive and interactive and therefore, it is not sure if the outcomes are due to the that fact it was adaptive, interactive or both. Knowledge was measured immediately after and 12-week after the CPD intervention but not at baseline. The knowledge scale displayed poor internal consistency. These factors may have limited the study's ability to evaluate the comparative effectiveness of the two CPD interventions. Also, optometrists who struggled at the immediate knowledge test, may have decided to opt-out of the 12-week study. This may have resulted in a biased sample of optometrists at the 12-week mark who were only those who were highly confident in their knowledge. Since the rate of participation differed between the traditional and adaptive arms, this might have significantly impacted the results.

3.10. Conclusion

This is one of the very few studies reporting on the effectiveness of CPD in optometry. Policy makers, educational and CPD providers in optometry will no doubt be encouraged by these findings. This quasi-randomized controlled trial comparing the online experience of an adaptive to traditional CPD demonstrated that optometrists randomized to the traditional CPD arm lost significant more knowledge at 12 weeks compared to those randomized to the adaptive CPD. Adaptive learning was seen as more fun. More and larger studies focused on different areas of care and using a variety of educational methods are needed to confirm the effectiveness of CPD in optometry. Robust instruments developed for this study to measure attitude toward CPD, self-efficacy, and user-engagement can now be used by other investigators in the field of optometry and could similarly be adapted for use by other health professions. The study findings allowed identification of specific gaps in self-efficacy and knowledge that can be targeted by future interventions.

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3.12. Appendices

3.12.1. Appendix 3-1: CONSORT 2010 Checklist of Information to Include when Reporting a Randomized Trial (CONSORT, 2010a)

Section/Topic	*Item No.*	*Checklist item*	*Reported on page No.*
		Title and abstract	
	1a	Identification as a randomized trial in the title	NA- because this study is a quasi-randomized trial.
	1b	Structured summary of trial design, methods, results, and conclusions	In the Abstract.
		Introduction	
Background and objectives	2a	Scientific background and explanation of rationale	6
	2b	Specific objectives or hypotheses	17
		Methods	
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	17
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	NA
Participants	4a	Eligibility criteria for participants	18
	4b	Settings and locations where the data were collected	19
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	19
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	27
	6b	Any changes to trial outcomes after the trial commenced, with reasons	NA
Sample size	7a	How sample size was determined	18
	7b	When applicable, explanation of any interim analyses and stopping guidelines	NA

3.1.1.1. *Appendix 3-1: Continued*

Randomization			
Sequence generation	8a	Method used to generate the random allocation sequence	17
	8b	Type of randomization; details of any restriction (such as blocking and block size)	17
Allocation mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	18
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	19
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	NA
	11b	If relevant, description of the similarity of interventions	NA
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	29
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	25, 26
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analyzed for the primary outcome	31
	13b	For each group, losses and exclusions after randomization, together with reasons	32
Recruitment	14a	Dates defining the periods of recruitment and follow-up	18
	14b	Why the trial ended or was stopped	NA
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	NA
Numbers analyzed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	31
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	35, 42, 49, 57, 59
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	NA

3.1.1.2. *Appendix 3-1: Continued*

Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	NA
Harms	19	All-important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	NA
		Discussion	
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	64
Generalizability	21	Generalizability (external validity, applicability) of the trial findings	53
Interpretation	22	Interpretation consistent with results, balancing benefits, and harms, and considering other relevant evidence	55
		Other information	
Registration	23	Registration number and name of trial registry	NA
Protocol	24	Where the full trial protocol can be accessed, if available	NA
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	NA

3.12.2. Appendix 3-2: The Notification of Ethics Approval

UNSW SYDNEY

09-Nov-2018

Dear Dr Isabelle Jalbert,

Project Title	The Effectiveness and User Acceptability of Adaptive Learning for Continuing Professional Development (CPD) Education in Optometry
HC No	HC180708
Re	HC180708 Notification of Ethics Approval
Approval Period	09-Nov-2018 - 08-Nov-2023

Thank you for submitting the above research project to the **HREAP D: Biomedical** for ethical review. This project was considered by the **HREAP D: Biomedical** at its meeting on **06-Nov-2018**.

I am pleased to advise you that the **HREAP D: Biomedical** has granted ethical approval of this research project. The following condition(s) must be met before data collection commences:

Conditions of Approval:
N/A

Conditions of Approval - All Projects:

- The Chief Investigator will immediately report anything that might warrant review of ethical approval of the project.
- The Chief Investigator will seek approval from the **HREAP D: Biomedical** for any modifications to the protocol or other project documents.
- The Chief Investigator will notify the **HREAP D: Biomedical** immediately of any protocol deviation or adverse events or safety events related to the project.
- The Chief Investigator will report to the **HREAP D: Biomedical** annually in the specified format and notify the **HREAP D: Biomedical** when the project is completed at all sites.
- The Chief Investigator will notify the **HREAP D: Biomedical** if the project is discontinued before the expected completion date, with reasons provided.
- The Chief Investigator will notify the **HREAP D: Biomedical** of his or her inability to continue as Coordinating Chief Investigator including the name of and contact information for a replacement.

The **HREAP D: Biomedical** Terms of Reference, Standard Operating Procedures, membership and standard forms are available from https://research.unsw.edu.au/research-ethics-and-compliance-support-recs.

If you would like any assistance, or further information, please contact the ethics office on:
P: +61 2 9385 6222, + 61 2 9385 7257 or + 61 2 9385 7007
E: humanethics@unsw.edu.au

3.12.3. Appendix 3-3: The Invitation Letter

Centre for Eye Health

UNSW SYDNEY

Invitation to Participate in Research

The Effectiveness and User Acceptability of Adaptive Learning for Continuing Professional Development (CPD) in Optometry

Researchers at UNSW Sydney (The University of New South Wales) and the Centre for Eye Health are seeking volunteer research participants to learn about the effectiveness of interactive versus traditional Continuing Education or Continuing Professional Development (CPD) in Optometry.

Would the research study be a good fit for me?
The study might be a good fit for you if you are:

- An optometrist.
- 18 years old or over.

What would happen if I took part in the research study?
If you decide to take part, you would:

- Complete an online attitude and self-reflection entry survey on CPD and Choroidal Lesions.
- Be randomly allocated into an interactive or traditional form of this CPD event.
- Attend a free online CPD event about Choroidal Lesions.
- Complete online questionnaires about this CPD experience & it's topic immediately after the CPD event.

Will I be paid to take part in the research study?
There are no additional costs associated with participation in this research study, nor will you or the participant be paid. However, you will be eligible to earn free CPD credits after completing the CPD event. All optometrists will be given free access to both the adaptive and the non-adaptive mode of the educational event on Choroidal Lesions for a period of one month and allowed to review the resources of their choice should they wish to do so.

If you would like more information or are interested in being part of the study, please contact:

Name: MS Sally Alkhawajah

Email: s.alkhawajah@student.unsw.edu.au

This research has been reviewed and approved by The University of New South Wales Human Research Ethics Committee. If you have any complaints or concerns about the research study please email humanethics@unsw.edu.au or phone +61 2 9385 6222 quoting the following number HC180708.

Yours sincerely,
A/Prof Isabelle Jalbert
Chief Investigator

3.12.4. Appendix 3-4: The Consent Form

The signture page of the participant information sheet & consent form

Centre for Eye Health

UNSW SYDNEY

ONLINE PARTICIPANT INFORMATION STATEMENT

The Effectiveness and User Acceptability of Adaptive Learning for Continuing Professional Development (CPD) in Optometry

Associate Professor Isabelle Jalbert

Consent Form – Participant providing own consent

Declaration by the participant

- ☐ I understand I am being asked to provide consent to participate in this research study;
- ☐ I have read the Participant Information Sheet or it has been provided to me in a language that I understand;
- ☐ I provide my consent for the information collected about me to be used for the purpose of this research study only.
- ☐ I understand that if necessary I can ask questions and the research team will respond to my questions.
- ☐ I freely agree to participate in this research study as described and understand that I am free to withdraw at any time during the study and withdrawal will not affect my relationship with any of the named organisations and/or research team members;
- ☐ I would like to receive a copy of the study results via email, I have provided my details below and ask that they be used for this purpose only;
- ☐ (optional): I agree to receive invitations to participate in future research studies related to this study via my email provided below;

  Name: ______________________________

  Address: ____________________________

  Email Address: ______________________

- ☐ I understand that I will be given a signed copy of this document to keep;

Participant Details

Name of Participant (please type)	
Participant email address (if applicable)	
Optometry Australia member number (if applicable)	
Date	

I agree, start questionnaire

HC Number: HC180708
Version dated: 13 March 2019

Page 4 of 5

3.12.5. Appendix 3-5: Attitude and Self-Efficacy Questionnaires at Baseline

Red dotted lines (questions 3 and 7) highlight the parts we modified from the original survey designed by Saade and colleagues (Saade et al., 2018).

A. *Attitude towards contiing education survey as presented in the online platform*

Continue

Mode: Anonymous

I feel confident that CPD meets my needs

- Not selected
- a. Strongly Agree
- b. Agree
- c. Neither Agree nor Disagree
- d. Disagree
- e. Strongly Disagree

2. I feel confident that CPD is preparing me for practice development

- Not selected
- a. Strongly Agree
- b. Agree
- c. Neither Agree nor Disagree
- d. Disagree
- e. Strongly Disagree

3. I have sufficient time to achieve my CPD goals that are fixed by the Optometry Board of Australia's CPD registration standard (*or any responsible international optometry association that you are registered at if you're not practicing in Australia)

- Not selected
- a. Strongly Agree
- b. Agree
- c. Neither Agree nor Disagree
- d. Disagree
- e. Strongly Disagree

4. I have sufficient resources (computer access, internet access, CPD events) to achieve my CPD goals

- Not selected
- a. Strongly Agree
- b. Agree
- c. Neither Agree nor Disagree
- d. Disagree
- e. Strongly Disagree

5. I have sufficient enthusiasm to achieve my CPD goals

- Not selected
- a. Strongly Agree
- b. Agree
- c. Neither Agree nor Disagree
- d. Disagree
- e. Strongly Disagree

6. Challenges in my job motivate me to achieve my CPD goals

- Not selected
- a. Strongly Agree
- b. Agree
- c. Neither Agree nor Disagree
- d. Disagree
- e. Strongly Disagree

7. Face-to-face events motivate me to achieve my CPD goals

- Not selected
- a. Strongly Agree
- b. Agree
- c. Neither Agree nor Disagree
- d. Disagree
- e. Strongly Disagree

3.12.5.1. *Appendix 3-5: Continued*

***B.** Self-efficacy of knowledge survey as presented to the particiants in the online platform*

1. I have a good understanding of the ocular anatomy

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

2. I can confidently detect Choroidal Nevus using an Ophthalmoscopy

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

3. I can confidently use OCT in diagnosing Choroidal lesions

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

4. I am aware of the risk factors for Choroidal Lesion development and progression

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

5. I can confidently differentiate Choroidal Nevus from Malignant Melanoma

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

6. I can confidently use a Fundus Photography to monitor Choroidal Nevus growth

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

7. I can confidently interpret Ultrasonography for Choroidal lesion assessment

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

Continue

3.12.6. Appendix 3-6: User-Engagement Questionnaire

User-Engagement Questionnaire

Continue

Mode: Anonymous

Indicate to what extent you agree with each of the following statements about the online form of the presented CPD activity:

1. The modality of presenting this CPD activity was aesthetically appealing:

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

2. I found the screen layout of this CPD activity to be visually pleasing:

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

3. I found this form of the CPD activity confusing to use:

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

4. I felt annoyed while using this form of the CPD activity:

- ◉ Not selected
- ○ a. Strongly Agree
- ○ b. Agree
- ○ c. Neither Agree nor Disagree
- ○ d. Disagree
- ○ e. Strongly Disagree

3.12.6.1. *Appendix 3-6: Continued*

5. I felt interested in this form of the CPD Activity:

- (●) Not selected
- ( ) a. Strongly Agree
- ( ) b. Agree
- ( ) c. Neither Agree nor Disagree
- ( ) d. Disagree
- ( ) e. Strongly Disagree

6. The content of this CPD activity incited my curiosity:

- (●) Not selected
- ( ) a. Strongly Agree
- ( ) b. Agree
- ( ) c. Neither Agree nor Disagree
- ( ) d. Disagree
- ( ) e. Strongly Disagree

7. The experience of using this form of the CPD activity did not work out the way I had expected:

- (●) Not selected
- ( ) a. Strongly Agree
- ( ) b. Agree
- ( ) c. Neither Agree nor Disagree
- ( ) d. Disagree
- ( ) e. Strongly Disagree

8. Using this form of the CPD activity was worthwhile:

- (●) Not selected
- ( ) a. Strongly Agree
- ( ) b. Agree
- ( ) c. Neither Agree nor Disagree
- ( ) d. Disagree
- ( ) e. Strongly Disagree

9. My experience with this CPD activity was fun:

- (●) Not selected
- ( ) a. Strongly Agree
- ( ) b. Agree
- ( ) c. Neither Agree nor Disagree
- ( ) d. Disagree
- ( ) e. Strongly Disagree

Continue

3.12.7. Appendix 3-7: Knowledge Questionnaire (Immediate)

Correct answers are highlighted in Yellow.

Centre for Eye Health

UNSW SYDNEY

The Effectiveness and User Acceptability of Adaptive Learning for Continuing Professional Development (CPD) in Optometry

Knowledge & Skills Questionnaire

Please find below a short questionnaire regarding your gained Knowledge/skills on the completed CPD event about Choroidal Lesions through the online Smart Sparrow Platform. This questionnaire will help us to improve existing and future continuing education/professional development resources in optometry. The questionnaire should take no more than 10 minutes to complete.

This questionnaire is voluntary, and you can discontinue it at any time. Whether or not you take part in this online evaluation questionnaire will have NO effect on your standing with UNSW nor with CFEH.

Choose the most correct answer of the following statements upon the information gained in the presented CPD activity:

1. What is the lifetime risk of choroidal naevi undergoing malignant transformation?
   a. 0.01%
   b. 0.1%
   c. 1%
   d. 10%
   e. Negligible

2. Which of the following instruments may be used to reveal acoustic hollowness of a choroidal tumour?
   a. Optical coherence tomography
   b. Ultra-widefield imaging (Optomap)
   c. Ultrasonography
   d. Fundus photography

3. Which of the following is NOT associated with choroidal melanoma?
   a. Subretinal fluid
   b. Lipofuscin
   c. Shaggy photoreceptors on OCT
   d. Drusen

4. What is the most typical appearance of choroidal melanoma using fundus autofluorescence?
   a. Hypoautofluorescence
   b. Hyperautofluorescence
   c. Isoautofluorescence
   d. Afluorescence

5. Which of the following tissues is best visualised using red filtered retinal photography?
   a. Sclera
   b. Macular pigment
   c. Choroid
   d. Retina

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3.12.7.1. *Appendix 3-7: Continued*

6. Which of the following features of a choroidal lesion found in a 45-year-old female patient is considered to be a risk factor for malignant transformation?
   a. Presence of drusen overlying the lesion
   b. Presence of a depigmented halo
   c. Elevation of lesion measured on OCT to be 145µm
   d. Margins of the lesion 1 DD from the optic nerve
   e. Basal diameter of 2mm

7. What would be the appropriate management of a large (5mm diameter) choroidal naevus with 3 risk factors for malignant transformation?
   a. Review annually to monitor for change
   b. Review patient at 3,6,12 months to monitor for change
   c. Non-urgent referral to ophthalmologist or ocular oncologist for assessment of the lesion
   d. Urgent referral to ocular oncologist
   e. Discharge patient as lesion is not suspicious

8. What would be the appropriate management of a small choroidal naevus with associated sub retinal fluid but no other risk factors for malignant transformation?
   a. Review annually to monitor for change
   b. Review patient at 3,6,12 months to monitor for change
   c. Non-urgent referral to ophthalmologist or ocular oncologist for assessment of the lesion
   d. Urgent referral to ocular oncologist
   e. Discharge patient as lesion is not suspicious

9. Which of the following statements about choroidal melanoma is INCORRECT?
   a. Choroidal melanoma typically arises from existing naevi
   b. A choroidal melanoma diagnosis is associated with a fatality rate of 50% within 10 years of diagnosis
   c. Choroidal melanoma is most often dome-shaped
   d. A more posterior location is associated with a poorer prognosis in cases of choroidal melanoma
   e. Typically show fast growth in a short period of time

10. Using the Shields et al. pneumonic only, how many risk factors for malignancy does this asymptomatic patient have? (Notes: lesion elevation 154µm, yellow areas on the lesion were confirmed as drusen)
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

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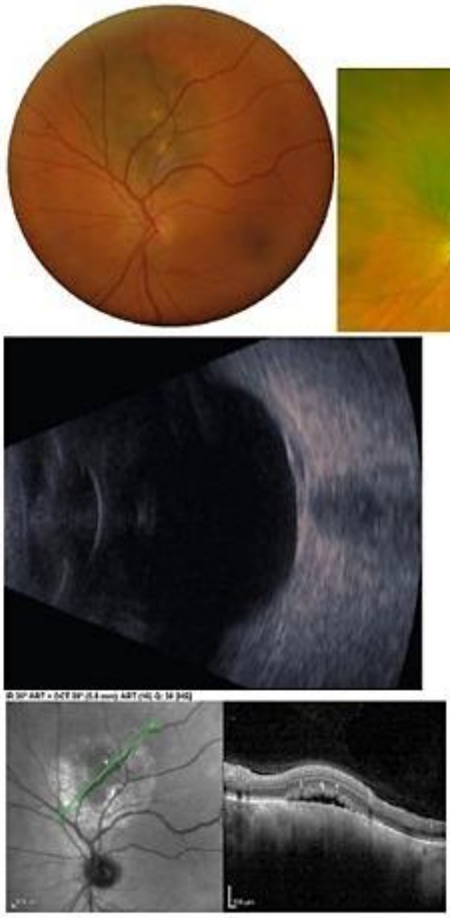
3.12.7.2. *Appendix 3-7: Continued*



Done

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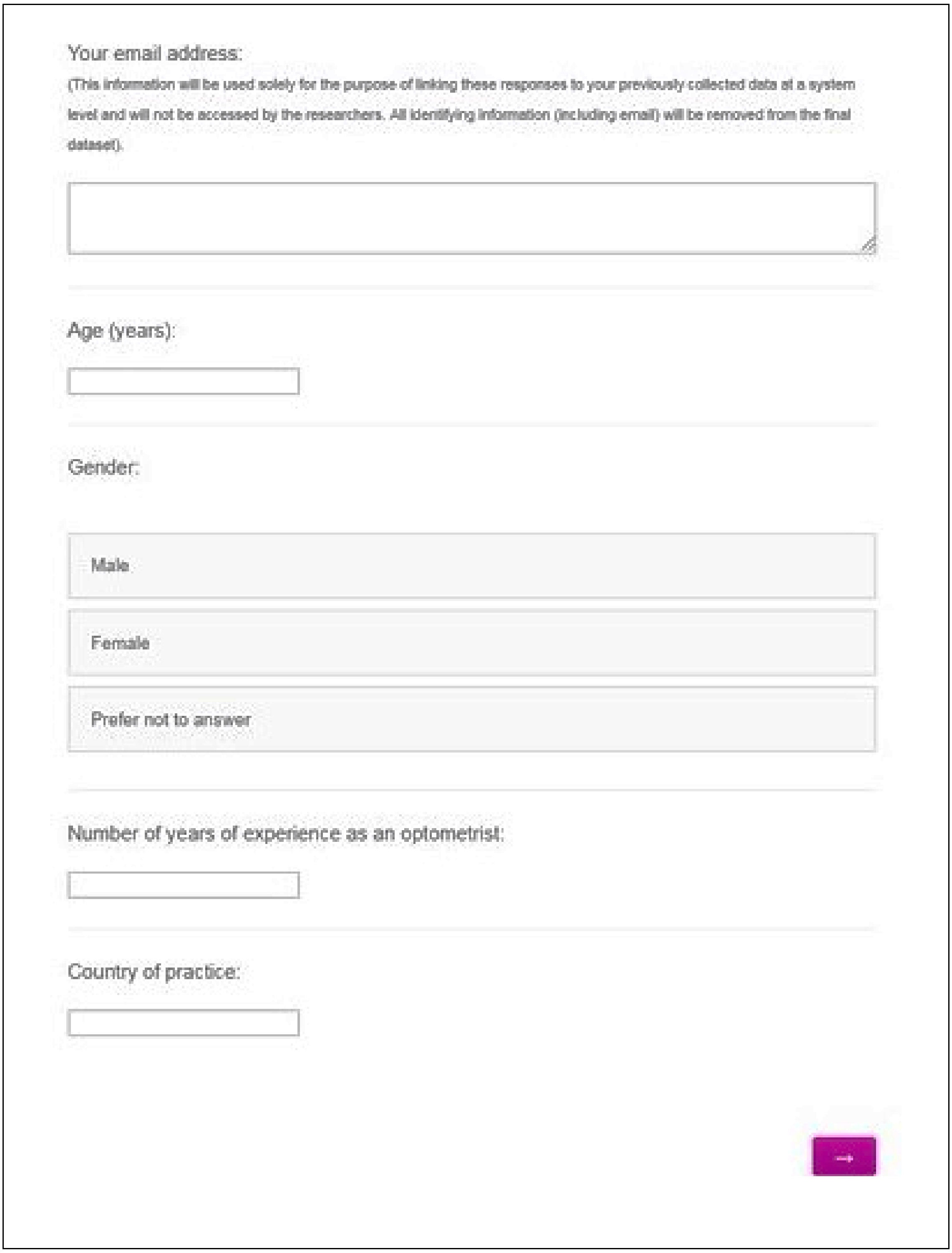
3.12.9. Appendix 3-8: Retention of Knowledge Questionnaire (12-week)

Correct answers are highlighted in Pink.



Your email address:

(This information will be used solely for the purpose of linking these responses to your previously collected data at a system level and will not be accessed by the researchers. All identifying information (including email) will be removed from the final dataset).

Age (years):

Gender:

Male

Female

Prefer not to answer

Number of years of experience as an optometrist:

Country of practice:

3.12.9.1. *Appendix 3-8: Continued*

What is the lifetime risk of choroidal naevi undergoing malignant transformation?

a. 0.01%

b. 0.1%

c. 1%

d. 10%

e. Negligible

Which of the following instruments may be used to reveal acoustic hollowness of a choroidal tumour?

a. Optical coherence tomography

b. Ultra-widefield imaging (Optomap)

c. Ultrasonography

d. Fundus photography

Which of the following is NOT associated with choroidal melanoma?

a. Subretinal fluid

b. Lipofuscin

c. Shaggy photoreceptors on OCT

d. Drusen

3.12.9.2. *Appendix 3-8: Continued*

What is the most typical appearance of choroidal melanoma using fundus autofluorescence?

a. Hypoautofluorescence

b. Hyperautofluorescence

c. Isoautofluorescence

d. Afluorescence

Which of the following tissues is best visualised using red filtered retinal photography?

a. Sclera

b. Macular pigment

c. Choroid

d. Retina

Which of the following features of a choroidal lesion found in a 45-year-old female patient is considered to be a risk factor for malignant transformation?

a. Presence of drusen overlying the lesion

b. Presence of a depigmented halo

c. Elevation of lesion measured on OCT to be 145μm

d. Margins of the lesion 1 DD from the optic nerve

e. Basal diameter of 2 mm

3.12.9.3. *Appendix 3-8: Continued*

What would be the appropriate management of a large (5 mm diameter) choroidal naevus with 3 risk factors for malignant transformation?

a. Review annually to monitor for change

b. Review patient at 3,6,12 months to monitor for change

c. Non-urgent referral to ophthalmologist or ocular oncologist for assessment of the lesion

d. Urgent referral to ocular oncologist

e. Discharge patient as lesion is not suspicious

What would be the appropriate management of a small choroidal naevus with associated sub retinal fluid but no other risk factors for malignant transformation?

a. Review annually to monitor for change

b. Review patient at 3,6,12 months to monitor for change

c. Non-urgent referral to ophthalmologist or ocular oncologist for assessment of the lesion

d. Urgent referral to ocular oncologist

e. Discharge patient as lesion is not suspicious

Which of the following statements about choroidal melanoma is INCORRECT?

a. Choroidal melanoma typically arises from existing naevi

b. A choroidal melanoma diagnosis is associated with a fatality rate of 50% within 10 years of diagnosis

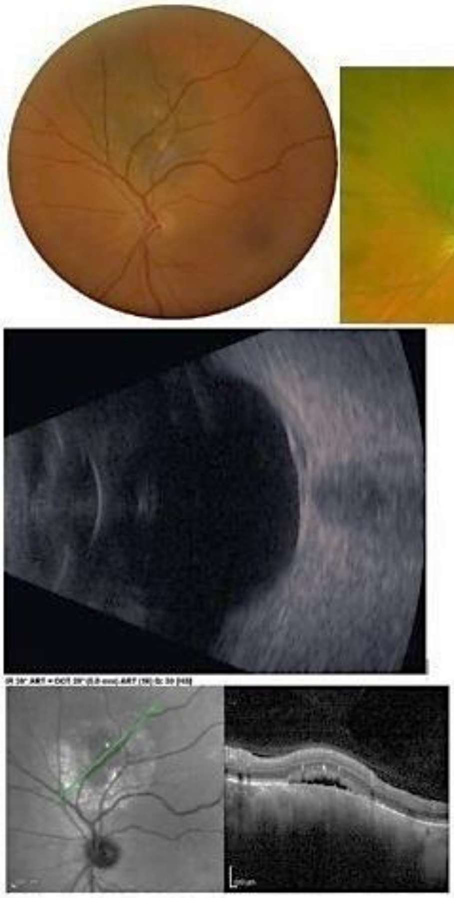
c. Choroidal melanoma is most often dome-shaped

d. A more posterior location is associated with a poorer prognosis in cases of choroidal melanoma

e. Typically show fast growth in a short period of time

3.12.9.4. *Appendix 3-8: Continued*

Using the Shields et al. pneumonic only, how many risk factors for malignancy does this asymptomatic patient have? (Notes: lesion elevation 154 μm, yellow areas on the lesion were confirmed as drusen)



a. 1

b. 2

c. 3

d. 4

e. 5

Chapter 4. Statistics in Optometry

4.1. Background: Significance

Statistical analysis is a fundamental component of understanding science as it assists in translating raw data to clinically applicable evidence. Statistics allow health practitioners to understand risk factors, treatment effects, and other aspects of disease. Albert (1981) stated: *"One of the most important skills a physician should have is the ability to critically analyze original contributions to the medical literature" (Albert, 1981)*. Statistical techniques permeate the ophthalmic literature. Use of statistics allow researchers and health practitioners to interpret the results of an experiment and to decide whether actual differences exist. Statistics are one of the most important ways or method to describe and present new research information to health practitioners (Shen et al., 2018) (Lisboa et al., 2014), (Albert, 1981). Statistics is defined by the American Statistical Association (ASA) as *"the science of learning from data, and of measuring, controlling and communicating uncertainty"* (Davidian & Louis, 2012). Statistics is also the description and analysis of results found in the literature. As primary healthcare practitioners of the eye and visual system, optometrists are required to apply evidence-based practice (EBP) to guide their clinical decision making. EBP encourages the systematic adoption of the most current evidence in the clinical decision-making process (Majid et al., 2011). A key component of the EBP process is the critical appraisal of the literature for its validity, reliability, and clinical relevance of the evidence, which involves a detailed interpretation of statistical analyses (Tilson et al., 2011). Therefore, an adequate understanding of statistics is needed in order to judge the appropriateness of the statistical methods chosen and identify any confounding factors or shortfalls in the research (Ali et al., 2014). Arguably, a healthcare practitioner or an optometrist is not required to completely comprehend all statistical techniques presented in a research paper to understand its main message or findings, however a basic knowledge of statistics remains essential for health practitioners to critically evaluate the reviewed data. An understanding of statistics also allows a reader to draw holistic and reasonable conclusions from the results of a scientific publication, laying the basis for informed clinical decision making. Understanding basic statistical concepts therefore allows optometrists to become more critical consumers of the eye care literature, and as a result enables them to make better clinical decisions.

The use of statistical analyses in the healthcare sector is evolving, where more advanced methods are increasingly used by many subspecialties. For example, articles related to glaucoma and retina tend to apply complex statistical analyses, such as Bayesian regression model and logistic longitudinal linear mixed-effect models, compared to those related to cornea and external eye diseases (Lisboa et al., 2014), (Friberg et al., 2012; Medeiros et al., 2012). Basic statistical methods such as t-tests and non-parametric tests have been frequently used in medical investigations, however, more advanced methods may be required for specific research questions or research designs, for instance, multiple potentially confounding variables, repeated measures, and inter-eye correlation in paired eye designs ((Zhang & Ying, 2018), (Armstrong, 2013),(Kleinbaum, 2008; Vittinghoff et al., 2011; Zhou et al., 2011). By using more advanced statistical methods, researchers can focus on such factors and solve previously unanswered questions. The frequent use of these more advanced methods may make it even more challenging for health practitioners to appraise the published literature (Lisboa et al., 2014). Hence, it is important to identify which statistical methods are commonly used in the ophthalmic and optometric literature. This in turn can guide the optometry profession to increase their knowledge of certain methods, to allow better comprehension of the literature in the eyecare field.

4.2. Overall Aim

This explorative chapter used a multi-pronged approach of discrete studies to investigate a number of indirect pieces of information, aiming to build a picture of the alignment between the level of statistical knowledge required to successfully appraise the optometric literature and what is actually reported by optometrists with regards to their knowledge, attitude, and practice (KAP) of statistics. A first study examined the most commonly used statistical methods in the ophthalmic literature while a second study determined the knowledge, attitudes, and practices of Australian optometrists towards statistics.

4.3. Study 1- Statistics in the Optometric Literature

Scientific journals rely largely on the peer review process to judge the adequacy and correctness of the statistical methods used in the manuscripts submitted for publication. Readers may be tempted to rely on the robustness of this peer review process, however, the imperfections and challenges inherent with peer review have been repeatedly highlighted (Bohannon, 2013) (Smith, 2006, 2010). Contemporary research often requires more advanced analysis to be conducted to handle large volumes of data and factor in multiple potentially confounding variables, repeated measures, and inclusion of both eyes of study subjects (Kleinbaum, 2008; Vittinghoff et al., 2011) (Zhou et al., 2011) (Lisboa et al., 2014). As a result, many peer reviewers may lack the statistical knowledge required to perform such sophisticated critical appraisals. This in turn implies that readers of the scientific literature (including optometrists) cannot entirely or safely rely on the peer review process, highlighting the importance of readers being able to evaluate the published literature themselves.

In recent years, a number of attempts have been made in diverse health fields to characterize the frequency of use of various statistical methods, in order to provide guidance as to the level of knowledge needed by readers of the published literature (Lisboa et al., 2014) (Juzych et al., 1992) (Akhtar et al., 2016) (Tilson et al., 2016) (Roush et al., 2015) (Al-Benna et al., 2010) (Meyr, 2010; Windish et al., 2007) (Kurichi & Sonnad, 2006) (Lee et al., 2004) (Bandy, 2003; Rigby et al., 2004) (Reed et al., 2003). Two studies have specifically investigated the ophthalmology literature (Juzych et al., 1992; Lisboa et al., 2014), but no investigations of the published optometry literature have been undertaken to date (see Table 4.1).

Table 4.1 Summary Results of the Top Statistical Methods (%) Found in a Number of Eyecare and Other Health Area Publications Organized by Area of Study

Study (author, year, journal)	*Purpose*	*Health area*	*Sampling method including journals sampled Articles' characteristics Number of articles, inclusion / exclusion criteria*	*Data Collection Method Data Analysis*	*Major Findings*
Eyecare Studies					
(Lisboa et al., 2014) Ophthalmol	To review the ophthalmic literature to ascertain the most frequently used statistical methods	Ophthalmology	All articles published in 2012 Three peer-reviewed journals: Arch Ophthalmol (now JAMA Ophthalmol), Am J Ophthalmol, Ophthalmol n=780 articles	Two independent reviewers Categorized into scheme with 34 statistical tests based on Emerson, 1983 scheme Categorized by subspecialty	No statistics or descriptive statistics only (20.8%) *Statistical methods:* t-tests (31.5%) Contingency tables (34.1%) Nonparametric tests (21.8%) ANOVA (12.7%) Multiple logistic regression (11.4%) Survival methods (10.9%) *Statistical accessibility:* t-tests + contingency tables + nonparametric tests (3/34 categories) (34.1%) 15/34 categories (51.4%) 21/34 categories (70.9%) 29/34 categories (90%) *Subspecialty:* 133/780 cornea and external diseases (17%)

					111/780 glaucoma (14%) 288/780 retina (36.9%) 40/780 cataract (5.1%) 44/780 strabismus and pediatrics (5.6%) 14/780 orbit and oculoplastic (1.8%) 12/780 refractive surgery (1.5%) 46/780 ocular oncology (5.9%) 35/780 uveitis (4.5%) 117/780 comprehensive ophthalmology (15%) Retina and glaucoma more complex statistics than cornea (observation with no statistics)
(Juzych et al., 1992) Arch Ophthalmol	To assess the frequency of statistical methods used in the ophthalmic literature	Ophthalmology	All articles published in 1990 (all 3 journals) All articles published in 1970, 1980, and 1990 (1 journal only) Three peer-reviewed journals: Arch Ophthalmol, Am J Ophthalmol, Ophthalmol n=974 articles (n=592 from 1990)	Two independent reviewers 98 of 974 articles (10%) random sample reviewed twice Categorized into central tendency (e.g., mean, mode, median) versus dispersion (e.g., SEMs, SDs,	*Statistical methods:* Central tendency (65%) Dispersion (50.3%) t-test (20.3%) Contingency tables (16.6%) Nonparametric tests (8.3%) Unspecified test (3.7%) Repeatability 96/98 (98% repeatable) *Statistical accessibility:* Central tendency only (43.1%) Add dispersion (58.6%) Add t-test and contingency tables (69.3%) 10 statistical techniques (add

Study (author, year, journal)	Purpose	Health area	Sampling method including journals sampled Articles' characteristics Number of articles, inclusion / exclusion criteria	Data Collection Method Data Analysis	Major Findings
			Included: clinical sciences, laboratory sciences, expedited publications, original articles Excluded: letters to the editor, case reports, book reviews, meeting notices, editorials, supplements, symposiums	range)	nonparametric tests, ANOVA, simple linear regression, Pearson's correlation coefficient, survival analysis, multiple comparisons) (88.9%) *Differences in statistical content of journals:* Arch Ophthalmol (75.3%) > Ophthalmol (66.8%) > Am J Ophthalmol (55.2%) (p=0.0003) Increased statistics over time (53.6% in 1970, 57.5% in 1980, 75.3% in 1990, *p*=0.0001) and greater sophistication
Other Health Area Studies					
(Akhtar et al., 2016) Pak J Med Sci	To compare the study design and statistical methods used in 2005, 2010, and 2015 of PJMS	Medicine	All articles published in 2005, 2010, and 2015 (January to August) Included: original research Excluded: case reports,	Number of reviewers not specified. Variables recorded: Statistics type Study design	Descriptive statistics (67.6%, 75.4%, 74.0%) *Complex statistics (e.g., factor analysis, component analysis, Poisson regression) rarely used.* *Trends over time:* Increased use of t-test (27.0% in 2005, 48.9% in 2015, p = 0.005)

			reviews, conference proceedings, meta-analysis, publication audit n=429 articles (17.2% from 2005, 41.7% from 2010, 41.0% from 2015)		Increased use of logistic regression (5.4% in 2005, 9.7% in 2015, *p*=0.03) Increased use of contingency tables (20.3% in 2005, 51.1% in 2015, $p < 0.001$) Increased use of epidemiological statistics (4.1% in 2005, 17.6% in 2015, *p*=0.001) Increased use of nonparametric statistics (5.4% in 2005, 24.4% in 2015, $p < 0.001$) *Study design:* Cross-sectional (40%) Prospective (27%) Retrospective (18%) Randomized clinical trial (8%) Not specified (7%)
(Tilson et al., 2016) BMC Med Educ	To enumerate the frequency of use of statistical terms and study designs in physical therapy literature	Physiotherapy	All articles published between October 2011 and September 2012 (1 year) Fourteen peer-reviewed Journals: Cardiopulm Phys Ther J, Int J Sports Phys Ther, J Acute Care Phys Ther, J Geriatr Phys Ther, J	Two trained raters Variables recorded: Statistical term Study design	ICC >0.97 *Use of statistical terms:* 532 terms Combined into 321 representative terms. 81 terms represent 90% of occurrences. 13.1 (SD=8.0) terms per article (range, 0 to 39) 44% terms used in single article. *Study design:*

	Neurol Phys Ther, J Orthop Sport Phys, J Phys Ther Educ, J Womens Health Phys Ther, Orthop Phys Ther Prac, Pediatr Phys Ther, Phys Ther J, PTJ-PAL, Rehabil Oncol, Sports Health Included: systematic reviews, primary research reports, case series, case reports Excluded: perspective papers, clinical commentaries, narrative/literature reviews, clinical imaging reports, editorials, lectures, conferences abstracts, organizational announcements/news, letters, book reviews n=391 articles	Prospective cohort (32.5%) Case reports (16.9%) Randomized controlled trials (7.9%)

(Roush et al., 2015) J Phys Ther Educ	Explore the frequencies and percentage of occurrence for statistical methods used by authors in core journals of physical therapy and physiotherapy	Physiotherapy	All articles published in 2009 and 2010. 16 journals related to physiotherapy (Arch Phys Med Rehabil, Aust J Physiother, BMJ, Clin Orthop Relat Res, Clin Rehabil, J Orthop Sports Phys Ther, J Am Ger Soc, J Bone Joint Surg, Med Sci Sports Exerc, Phys Ther, Physiotherap, Physiotherap Can, Spine, Stroke, Clin J Pain) Included: research reports, scientific articles, original contributions, clinical investigations, brief reports Excluded: announcements, case reports, case studies,	Three reviewers randomly assigned 5 or more journals each to review. Categorized by statistical content based on statistics textbooks. Pilot study of Phys Ther J articles published between Jan and Apr 2009 by 4 reviewers.	*Statistical methods:* Descriptive statistics (19.9%) Confidence intervals (9.3%) t tests (8.4%) Epidemiology (8.2%) Regression (7.8%) *Reliability:* Kappa coefficient ranged from 0.90 to 0.94. *Statistical accessibility:* Descriptive statistics (19.9%) Add confidence intervals (29.2%) Add t tests (37.6%) Add epidemiology (45.8%) Add regression (53.6%) Add nonparametric tests, ANOVA, chi-square, survival, multiple comparison tests (82.6%)

			clinical trials, commentaries, conference series, corrections, editorials, instructional course lectures, indexes, letters, notices, opinions, education/training, erratum, ethics, ethnogeriatrics/special populations, fellowships, forums, grants, medical economics, public policy, reviews, scholarships, special articles, miscellaneous n=5,546 articles		
(Al-Benna et al., 2010) Burns	To determine the descriptive methods and survey the inferential statistics used in articles in	Burn	All articles published in 2007. Included: original articles defined as studies that included primary data collection	Number of reviewers not specified. Variables recorded: Number and types of statistical	Descriptive statistics (100%): Standard deviation (59%) SEM (37%) *Inferential statistics (96%):* Student t-test (53%) ANOVA / ANCOVA (33%) Chi-square (27%) Wilcoxon / Mann-Whitney tests (22%)

	the journal Burn		Excluded: letters to the editor, brief reports, reviews, case reports, burn care in practice, literature review, editorials, personal reports, analyses of secondary data, theoretical articles without data n=51 articles	methods Study design Statistical software	Fisher's exact (12%) *Study design:* Randomised controlled trials (22%) Cohort studies (35%) Case control studies (22%) Case series (22%) *Statistical accessibility:* Student's t-test only (26%) Add contingency tables (39%) Add Fisher's exact test (45%) Add ANOVA/ANCOVA (61%) Add nonparametric tests (Mann-Whitney, Willcox, Kruskal-Wallis) (74%) 10 statistical techniques (add confidence intervals, Bonferroni, and Turkey-Kramer multiple comparisons (90%) Statistical software named (65%) Significance level defined (88%) Exact significance reported (57%)
(Meyr, 2010) J Foot Ankle Surg	To report the prevalence with which various statistical methods were used to	Surgery	All articles published in 5-year period between January 2004 to December 2008 Included: original research, case report, "tips, quips, and pearls"		Descriptive statistics (84%) *Inferential statistics (68%):* Student t-test (30%) ANOVA (14%) Mann Whitney / Wilcoxon tests (13%) Chi-square (11%) Fisher's exact (10%)

	report foot and ankle surgical results		n=215 articles		
(Windish et al., 2007) JAMA	Not stated (sub-aim of larger study)	Medicine	All original articles published from January to March 2005 Six peer-reviewed medical journals: Am J Med, Ann Intern Med, BMJ, JAMA, Lancet, N Engl J Med n=239 articles	Frequency of statistical methods	No statistics (2.1%) Descriptive statistics (91.6%) *Simple statistics (50.2%):* Chi-square (29.3%) t-test (20.1%) Kaplan-Meier (20.1%) Wilcoxon rank sum (15.95%) Fisher exact (13.8%) ANOVA (8.8%) Correlation (6.7%) *Multivariate statistics (68.6%):* Cox proportional hazards (26.8%) Multiple logistic regression (22.6%) Multiple linear regression (2.9%) Other regression analyses (15.9%) *Other methods (17.6%):* Intention-to-treat analysis (17.6%) Incidence/prevalence (16.3%) Relative risk/risk ratio (12.2%) Sensitivity analyses (8.8%) Sensitivity/specificity (6.3%)

(Kurichi & Sonnad, 2006) J Am Coll Surg	To identify the frequency of use of statistical methods in major surgical journals, to ascertain the trends in the use of statistics, and to assess the misuse and incorrect reporting of statistical methods and techniques over the past 18 years	Surgery	Randomly selected issues (3 per year) from odd-numbered years All articles published in 2003 (all 5 journals) Randomly selected issues from odd-numbered years between 1985 and 2003 (2 journals only) Five peer-reviewed journals: Ann Surg, Arch Surg, J Am Coll Surg, J Surg Res, Surg n=830 (Ann Surg 404 + Arch Surg 426) Included: original research Excluded: case reports, editorials, letters, anatomic studies, policy analyses, small case series	Procedures used recorded. Categorized into descriptive (e.g., mean, standard deviations, modes, medians, central tendency, variation, range, variance), t-tests (one-sample, independent samples, paired samples), contingency table analyses (chi-square, Fisher's exact test, Pearson's goodness-of-fit test, likelihood ratio), ANOVA	No statistics (<15%) Exact p-value reported (80% to 90%) Descriptive statistics (~50%) *Inferential statistics:* t-test (30% to 40%) nonparametric statistics (~30%) contingency tables (20% to 60%) ANOVA (20% to 45%) advanced statistics (20% to 60%) *Trends over time:* Increased statistics (65% in 1985, >90% in 2003, $p < 0.0001$) Increased use of nonparametric tests (0% and 12% in 1985, 33% and 49% in 2003, $p < 0.0001$) Increased reporting of exact *p*-value (~40% and 50% in 1985, >95% and ~70% in 2001 and 2003, $p < 0.0001$) More sophistication (e.g., regression analysis, survival analysis) in 2001, 2003 (~30%) *Incorrect selection or reporting of statistics (27%):* mistake related to type of variable (continuous vs categorical) (77%) mistake related to data distribution (normal vs nonnormal) (23%)

				(simple and multivariate analysis and post-hoc tests), reporting p-values, nonparametric tests (Wilcoxon rank-sum test, Mann-Whitney test, Wilcoxon's signed-rank test, sign test, runs test, Kolmogorov-Smirnov test, Kruskal-Wallis test) Advanced statistical techniques (regression analyses, general linear model, survival analysis) (for 2001, 2003	Power calculation present in <1% of studies

				only) Correctness of methods examined (e.g., power calculation present, test appropriate for type of data collected (e.g., continuous vs. categorial, parametric vs nonparametric), correction factors for multiple comparisons, general appropriate use) for 2003 only. Trends over time	

(Lee et al., 2004) Ann Pharmacother	To update previous reports of the types and frequencies of statistical terms and procedures in research studies of selected professional pharmacy journals	Pharmacy Health services and health systems research (51%) Physiochemical/pharmacological properties of drug (19%) Pharmacoeconomic studies (8%) Clinical trials (9%) Drug utilization studies (10%)	All articles published in 2001. Six peer-reviewed journals: Am J Health-Syst Pharm, Ann Pharmacother, Can J Hosp Pharm, Formulary, Hosp Pharm, J Am Pharm Assoc n=144 articles Included: meta-analyses Excluded: editorials, advertisements, letters to the editor, administrative reports, descriptive summaries, literature reviews	Two independent reviewers Procedures and terms used recorded. Number of reviewers not specified. Categorized into descriptive (e.g., mean, median, mode, standard deviation, range) versus inferential (e.g., chi-square, t-test, ANOVA) statistics. Study design	Descriptive statistics (98%) including descriptive statistics only (28%) *Inferential statistics (69%):* Chi-square (33%) Student t-test (26%) Person's correlation coefficient (18%) ANOVA (14%) Logistic regression (11%) More than 1 inferential test (49%) Terms: percentage (90%), mean (74%), standard deviation (58%), range (46%) Agreement between independent reviewers 92% *Study design:* Paper surveys and telephone and personal interviews (25%) Interventional trials (24%) Observational studies (22%) Drug assay studies (12%) Formal drug utilization evaluation/adverse events monitoring programs (10%) Miscellaneous (7%)
(Rigby et al., 2004) BMC Med Res Methodol	To review leading journals in general	General practice	All articles published in 2000. Three UK journals of general practice: BMJ	Three reviewers (statisticians) each reviewed one of 3	No statistics or simple summaries (33.8%) *Statistical methods:* Chi-square (23.6%)

	practice to see what statistical methods are being used.		(general practice section), Br J Gen Pract, Fam Pract n=305 articles Excluded: letters	journals each. Pilot phase on random sample of 10 papers used as concordance training – reliability not measured. Categorized by statistical content based on Emerson, 1983 scheme. Study design based on Wang 1998 scheme	t-test (15.1%) logistic regression (14.4%) nonparametric (12.8%) odds ratios/relative risks (12.5%) *Study design:* Cross-sectional survey (35.1%) Qualitative study (11.8%) Cohort study (10.8%) Diagnostic study (3.6%) rarely used. BMJ wider range and greater diversity of statistical methods than other 2 journals
(Bandy, 2003) J Phys Ther Educ	To identify the types of statistical techniques used in Physical Therapy	Physiotherapy	All articles published between July 2000 and July 2002 in Phys Ther n=138 articles Included: research reports Excluded: special series, case reports, technical reports, literature review, perspective,	Single reviewer with assistance from statistics professor Categorized by statistical content into 25 categories based on list modified from	*Statistical methods:* Descriptive statistics (28.7%) ANOVA (7.8%) t-test (7.5%) Factorial ANOVA (6.8%) ICC (6.5%) Post hoc tests (6.5%) *Statistical accessibility:* Descriptive statistics (28.7%) Add ANOVA (36.5%)

			update	previous publications	Add t-test (44%) Add factorial ANOVA (50.8%) Add ICC, post hoc testing, Perason correlation, regression, chi square, nonparametric tests (82.4%)
(Reed et al., 2003) J Med Syst	To catalog the statistical methods used in journals from 3 different fields	General practice Emergency medicine Obstetrics and gynecology	All articles published between in 2000 (all journals) All articles in 1998 and 1999 (J Fam Pract, J Fam Med, Ann Emerg Med, Acad Emerg Med) Six peer-reviewed journals from Family Practice (J Fam Pract, J Fam Med), Emergency medicine (Ann Emerg Med, Acad Emerg Med) and Obstetrics and Gynecology (Am J Obstet Gynecol, Obstet Gynecol) n=1828 articles Excluded: case reports, editorials	Number of reviewers not specified. Categorized by statistical content based on checklist developed for the study. Study design	*Statistical methods:* Pearson's chi-square/Fisher's Exact test (47.5%) Student's t-test (33.1%) ANOVA (23.3%) Nonparametric methods (8.1%) Linear regression (17.6%) Odds ratios/logistic regression (17.4%)

4.3.1. Aims

The primary aim of this study was to identify and enumerate the most frequently used statistical methods in the ophthalmic literature with a primary focus on the optometry literature, to determine the level of statistical knowledge required by optometrists to adequately comprehend the ophthalmic literature. A secondary aim was to characterise statistical accessibility, by determining the possible gain in the level of understanding the ophthalmic literature that optometrists could expect if they were to add knowledge of more advanced techniques sequentially to their statistical selection.

The scope of this study was to characterise used methods. It was outside the current scope to determine the appropriateness or validity of the use of statistical methods in the ophthalmic literature or the conclusions reached in the articles being analysed.

4.3.2. Methods

4.3.2.1. Study Design

A cross-sectional study was designed where the ophthalmic literature from three optometry journals and one ophthalmology journal was reviewed to identify the most used statistical methods. These four scientific journals were selected based on their quality (peer-reviewed, high citation ranking) and reputation amongst other optometric and ophthalmic journals. The scientific journal *Ophthalmic & Physiological Optics (OPO)* is the official journal of the professional organization The College of Optometrists in the United Kingdom. Likewise, the scientific journal *Clinical and Experimental Optometry (CEO)* is the official journal of the professional organization Optometry Australia in Australia. In the United States of America, *Optometry and Vision Science (OVS)* is the official journal of the professional organization American Academy of Optometry. Together, OPO, CEO and OVS are the three most frequently cited optometry journals in the ISI Journal Citation Reports Ophthalmology Ranking for 2019, ranked 18, 34, and 40 out of 60 ophthalmology journals, respectively. *Ophthalmology* is the journal of the professional organization American Academy of Ophthalmology. *Ophthalmology* is the most cited ranked generalist, clinically oriented ophthalmology journal that publishes original research, ranked third out of 60 ophthalmology journals. An ophthalmology journal was included in the sample because optometrists need to comprehend both optometric and ophthalmic literature to address primary care and the ocular pathology aspects of their profession (Krishnakumar et al., 2016).

4.3.2.2. Selection of Articles

A random sample of articles published during the 12-month period from January through December 2018 in the four journals listed above was reviewed. The issues list and table of contents of all published 2018 issues of each journal were hand searched. Eligible articles included original articles, research papers and systematic reviews and meta-analyses. Other forms of published materials that did not include statistical analyses such as editorials, non-systematic reviews, communications, letters to the editor, and clinical cases or case reports were excluded (Table 4.2). The aim was to proportionately sample more than 80% of articles published by the four journals throughout 2018. All published articles from the calendar year 2018 in each sampled journal were assigned a random number, using a free online random number generator; RANDOM.ORG (https://www.random.org/sequences/). This generated a randomized sequence of integers used to determine the publications to be analyzed until the required proportionate sample had been reached. When a non-eligible article was encountered, it was skipped, and the next random integer was checked for eligibility. Two independent reviewers compared potentially eligible articles and settled any discrepancies through consensus discussion. The two reviewers independently examined each eligible article, identified, and extracted statistical analyses used, and assigned them to pre-defined categories (Table 4.3). Study design was not extracted. All sections of the eligible articles including the discussion section were examined. The reviewers were two final year Master of Clinical Optometry students at UNSW Sydney who had received statistics foundations and applied training throughout the previous four years of their combined 5-year degree (Bachelor of Vision Science / Master of Clinical Optometry) and were supervised by PhD candidate Alkhawajah. The reviewers used a categorization scheme adapted from one that was initially designed by Emerson and Colditz and further modified by Lisboa and colleagues to incorporate more recently introduced statistical methods (Emerson & Colditz, 1983; Lisboa et al., 2014). To facilitate and ensure appropriate application of the categorization scheme, it was enhanced with the addition of some brief explanatory notes that enabled the reviewers to match the description of statistics in the journal articles to the categories listed by the scheme (Table 4.3). These definitions were gathered from a variety of sources including previous schemes' descriptions (Emerson & Colditz, 1983; Juzych et al., 1992) (Brownlee, 2019; Frost, 2018; Kang, 2013; Kruschke, 2014; Neuhaus & McCulloch, 2011; UCLA, 2016), statistics textbooks (Yount, 2006), and Wikipedia (https://www.widipedia.org).

Table 4.2 Article Eligibility Prior to Random Sampling of the Ophthalmic Literature

Scientific Journal	*Eligible*	*Ineligible*
Ophthalmic & Physiological Optics	Original articles Technical Reports Review articles & meta-analyses	· Editorial · Invited review articles · Letters to the editor
Clinical and Experimental Optometry	Original research papers Systematic reviews	· Review articles, scoping reviews · Clinical guidelines, clinical standards · Editorials, viewpoints · Profiles, obituaries & historical overviews · Clinical communications, clinical pictures · Letters to the editor
Optometry and Vision Science	Original investigations Clinical trials Evidence-based reviews (systematic review and meta-analyses)	· Editorials · Case reports/case series · Topical reviews · Letters to the editor
Ophthalmology	Original articles AAO meeting papers Systematic reviews and meta-analyses	· Editorials · Reports · Correspondence · Pictures & perspectives · Reports-invited · Translational science reviews

Thirty-seven categories were pre-defined (Table 4.3). If more than one statistical technique in each category was present in an article, the category would only be counted once, regardless of the number of techniques within that category that appeared in the article. For example, if an article used the Chi-square test and Fisher's exact test, the Contingency tables category would only be counted once. Only statistical procedures performed by the authors or investigators themselves were classified and not those cited by published articles. Cumulative percentages were calculated starting with the statistical technique with the highest number of total occurrences. Statistical accessibility was defined as the percentage of articles a practitioner would be able to understand by knowing the next most frequently used statistical technique. No judgments or inferences were made regarding the appropriateness of the statistical techniques used.

Ethics approval was not necessary, since this study did not involve humans, animals, gene technology, or radiation safety. Each article was assessed independently by both reviewers and, as during article selection, discrepancies between the two independent reviewers were discussed and resolved by consensus. Data was also recorded on whether the research described in the article involved humans, animals, or cells. Where available, the keywords associated with each article were extracted to characterize the research field, topics, or areas of most relevance for each journal. This exploratory analysis was conducted as it was convenient to do so as part of the data extraction process already under way (see Figure 4.5).

4.3.3. Statistical Analysis

Descriptive statistics were used to characterise the results. Chi-square tests were used to test the associations between statistical methods and the four journals. The likelihood ratio revealed if the frequency of the statistical method was significantly greater or less than the expected frequency of that method in consideration of the total frequencies observed across all journals. An alpha of 0.05 was used to test significance. Cramer's V effect sizes were measured. If frequency of counts was less than five for two journals or more, the chi-square test was not executed. When the chi-square test involved only two comparisons, Odds Ratios and their respective 95% confidence intervals were reported.

Table 4.3 Classification of Statistical Methods

	Statistical category	Description
0	No statistical methods	No statistical content
1	Analysis of covariance	ANCOVA (Using F ratio to fit linear model controlling for covariate effects on outcomes)
2	Analysis of variance	ANOVA, F-tests; Tests whether average scores of three or more groups means differ
3	Bayesian analysis	The mathematics of re-allocating credibility by finding the credibility of parameter values in a descriptive model of data. An exact mathematical design for the posterior distribution on the parameter values
4	Bland-Altman, ICC, CCC	Cohen's Kappa, Intraclass correlation coefficient (ICC), Concordance correlation coefficient (CCC); Measures agreement between two different methods or reliability of measurements or ratings (including inter-rater reliability)
5	Contingency tables	Chi-squared test, Fisher's exact test, McNemar test, Cochran's Q, Test of Independence; Chi-square test of association between two nominal variables
6	Correlation unspecified	Correlation analysis measuring the relationship between two items. The resulting value (called the "correlation coefficient") shows if changes in one item will result in changes in the other item
7	Cost-benefit analysis	The process of combining estimates of cost and health outcomes to compare policy alternatives
8	Descriptive statistics	Descriptive statistics (e.g., percentages, means, medians, modes, standard deviations, standard errors, histograms); Measures population or sample variables
9	Diagnostic Proportions	Odds ratio, relative risk, log odds, sensitivity, specificity
10	Generalized estimating equations	An estimate of the parameters of a generalized linear model with a possible unknown correlation between outcomes
11	Generalized linear models	Are extensions of the classical linear regression model for continuous, normal responses that allow the regression analysis of a variety of non-normal responses such as binary indicators, counts, and positively valued random variables
12	Inferential statistics	It takes data from a sample and makes inferences about the larger population from which the sample was drawn. The most popular methods in inferential statistics are hypothesis tests, confidence intervals, and regression analysis.
13	Linear mixed models	A model containing both fixed effects and random effects used where repeated measurements are made (e.g., longitudinal study) or where measurements are made on clusters of related statistical units (e.g., two eyes)
14	Meta-analysis	Statistical technique for combining the findings from multiple independent studies; Used to assess the effectiveness of clinical interventions by combining data from 2 or more randomized clinical trials

15	Missing data methods	The data value that is not stored for a variable in the observation of interest
16	Multiple comparisons	Bonferroni correction, Dunnett's test, Tukey's test, Newmann-Keuls test, Holm correction, Scheffe's test, Duncan's multiple procedures; Procedures for handling multiple inferences on same data sets
17	Multiple linear regression	Includes polynomial regression and stepwise regression; Establishes the relationship between one variable and multiple predictor variables
18	Multiple logistic regression	Used to model the impact of multiple predictors on a categorial variable
19	Multivariate analysis of variance	MANOVA (An ANOVA that has more than one outcome variable)
20	Multivariate regression analysis	A technique that estimates a single regression model with more than one outcome variable. When there is more than one predictor variable in a multivariate regression model, the model is a multivariate multiple regression
21	Multi-way tables	Mantel-Haenszel procedure, log-linear models
22	Non-parametric correlation	Spearman's correlation, Kendall's correlation; Correlation between two sets of ranks (Spearman's rho)
23	Non-parametric tests	Mann-Whitney U test, Wilcoxon signed-rank test, Friedman, Kolmogorov– Smirnov; Methods where data is not required to fit normal distribution (e.g., ordinal)
24	Pearson's correlation	Classical bivariate product-moment correlation; Looks at the associated between two interval/ratio variables
25	Post hoc analysis	Consists of looking at the data after the experiment has concluded to look for patterns that were not specified at the outset (or a priori)
26	Prevalence / incidence	Pertains to epidemiologic statistics such as incidence rates and prevalence rates, Includes adjustment and standardization
27	Power analysis	Loosely defined, includes use of the size of detectable (or useful) difference in determining sample size
28	Rasch analysis	Item response theory: Mathematical modeling based upon a latent trait which accomplishes probabilistic conjoint additivity (where conjoint means measurement of people and items on a single scale and additivity means the equal-interval property of the scale)
29	Receiver-operating characteristics (ROC)	Assess the accuracy of model predictions by plotting sensitivity versus (1-specificity)
30	Repeated measures	Uses the same subjects for every condition including the control, in contrast to non-repeated measures studies who

	analysis	compare the same measure under two different conditions
31	Resampling	Selecting observations from the domain with the objective of estimating a population parameter. Whereas data resampling refers to methods for economically using a collected dataset to improve the estimate of the population parameter and help to quantify the uncertainty of the estimate
32	Simple linear regression	Least-squares regression with one predictor and one response variable, assuming that the relationship is linear
33	Simple logistic regression	Represented by an odds ratio (OR); Used to model the impact of single predictor on a categorical (usually dichotomous) variable
34	Survival analysis/Life table	Kaplan-Meier plots, Breslow's Kruskal-Wallis, log rank, Cox proportional hazards regression model; Used to estimate the survival function from lifetime data
35	t-tests	One-sample, two-sample, matched-pair; Tests whether the average scores of two groups are statistically different
36	Transformation	Use of data transformation (e.g., logs), often in regression
37	Other	Any statistical method not fitting above headings; including cluster analysis, discriminant analysis and some mathematical modeling

4.4. Results

4.4.1. Frequency of Statistical Method in Literature

In total, 400 articles were randomly sampled and 375 were found to be eligible and thus were reviewed. The stated aim of sampling approximately 80% of published articles was achieved and more than met for all journals (see Table 4.4). Of the total 375 articles sampled, 17 were systematic review (2 from OPO, 4 from CEO, 1 from OVS and 10 from *Ophthalmology*) and these are reported on separately. The remaining 358 original articles analyzed included 36 from OPO, 72 from CEO, 84 from OVS and 166 from *Ophthalmology*.

Table 4.4 Number (%) of Articles Published, Ineligible and Sampled in Our Study of Each Journal In 2018

	OPO	CEO	OVS	Ophthalmology	The total
N of articles published in 2018	51	126	122	358	657
N of ineligible articles	13	50	37	182	282
N of eligible articles	38	76	85	176	375
N of article sampled	2 systematic reviews	4 systematic reviews	1 systematic review	10 systematic reviews	17 systematic reviews
	36	72	84	166	358

Table 4.5 shows the frequency of each statistical method found in the 358 original articles from our audit of the ophthalmic literature. The most frequently used statistical method was descriptive statistics, which was used in 322 articles (89.9%), however, only 31 articles (8.7%) used descriptive statistics as their only statistical method. The most commonly used inferential statistical methods were t-tests, found in 120 articles (33.5%), followed by contingency tables in 114 articles (31.8%), non-parametric tests in 74 articles (20.7%), other statistical methods in 70 articles (19.6%) and ANOVA in 62 articles (17.3%). Only 15 articles (4.2%) did not use any statistical method. Multiway tables and cost-benefit analysis were not used in any articles, whilst methods which were present in less than 1% of original articles included resampling,

Bayesian analysis, Rasch analysis, item response theory, and repeated measures analysis. Seventy articles (19.6%) used statistical methods that were not listed in the categories and were classified as “other”. This included statistical methods such as Levene’s test and Shapiro-Wilk’s test. Systematic reviews were analyzed separately. Five of 17 (29.4%) systematic reviews contained meta-analysis and the remaining 12 systematic reviews (70.6%) did not contain any meta-analysis. The most frequently used statistical methods are presented in Figure 4.1.

In Table 4.5, we estimated the accumulated number and percentage of publications that a reader could be expected to understand based on his or her knowledge of statistics. To achieve this, it was assumed that a reader had no knowledge of statistics. We then calculated that percentage of articles a reader would understand by knowing each of the most frequently used statistical techniques, in turn. For the order in the analysis, we chose the somewhat arbitrary descending frequency of statistical methods used in the combined sample of articles. For example, if a reader hypothetically understood t-tests he would understand 33.5% of the articles. However, if a reader understood t-tests and contingency tables they would understand 47.8% of the articles and so on. Also, that 67.9%, 77.4%, 82.4%, or 84.4% of the ophthalmic literature could be understood if a reader hypothetically understands the top 5 (t-tests, Contingency tables, Non-parametric tests, Analysis of variance, and Diagnostic Proportions), top 10 (top 5 methods and: Survival analysis, Multivariate regression analysis, Multiple linear regression, Pearson's correlation, Post hoc analysis), top 15 (top 10 methods and: Multiple comparisons, Multiple logistic regression, Non-parametric correlation, Power analyses, Bland-Altman), or top 20 (top 15 methods and: Linear mixed models, Receiver operating characteristics, Analysis of covariance, Simple logistic regression, Correlation Analysis) respectively statistical methods. Figure 4.1 show this information in graphical form.

Table 4.5 Statistical Methods Present in Articles (n=358) Published in the Optometry and Ophthalmology Journals OPO, CEO, OVS, and Ophthalmology in 2018

OPO: Ophthalmic & Physiological Optics; CEO: Clinical and Experimental Optometry; OVS: Optometry and Vision Science.

Rank	*Statistical method*	*Article containing method n (%)*	*Accumulation by article n (%) **
1.	Descriptive statistics / Normal distribution	322 (89.9)	-
2.	t-tests: One-sample / Two-sample / Matched-pair	120 (33.5)	120 (33.5)
3.	Contingency tables / crosstab analyses: Chi squared test / Fisher's exact test / Mc-Nemar test / Cochran's Q	114 (31.8)	171 (47.8)
4.	Non-parametric tests: Mann-Whitney U test / Wilcoxon signed-rank test / Freidman / Kolmogorov–Smirnov	74 (20.7)	196 (54.7)
5.	Analysis of variance (ANOVA) / F-tests	62 (17.3)	218 (60.9)
6.	Diagnostic Proportions: Odds ratio / Sensitivity / Specificity	54 (15.1)	243 (67.9)
7.	Survival analysis / Life table: Kaplan-Meier plots / Breslow's Kruskal-Wallis / log rank / Cox proportional hazards regression model	49 (13.7)	257 (71.8)
8.	Multivariate regression analysis	48 (13.4)	265 (74.0)
9.	Multiple linear regression	46 (12.8)	273 (76.3)
10.	Pearson's correlation	43 (12.0)	275 (76.8)
11.	Post hoc analysis	39 (10.9)	277 (77.4)
12.	Multiple comparisons	38 (10.6)	278 (77.7)
13.	Multiple logistic regression	37 (10.3)	287 (80.2)
14.	Non-parametric correlation	30 (8.4)	288 (80.4)
15.	Power analyses/Sample size calculations	29 (8.1)	289 (80.7)
16.	Bland-Altman/Cohen's Kappa	29 (8.1)	295 (82.4)
17.	Linear mixed models	27 (7.5)	296 (82.7)
18.	Receiver operating characteristics (ROC)	18 (5.0)	296 (83.5)
19.	Analysis of covariance (ANCOVA)	17 (4.7)	299 (83.5)
20.	Simple logistic regression	14 (3.9)	299 (83.5)
21.	Correlation Analysis	13 (3.6)	302 (84.4)

22.	Generalized estimating equations	9 (2.5)	303 (84.6)
23.	Simple linear regression	8 (2.2)	303 (84.6)
24.	Transformation	7 (2.0)	303 (84.6)
25.	Missing data methods2	7 (2.0)	304 (84.9)
26.	Prevalence/Incidence	6 (1.7)	304 (84.9)
27.	Generalized linear models (excluding linear and logistic regression)	6 (1.7)	304 (84.9)
28.	Multivariate analysis of variance (MANOVA)	4 (1.1)	305 (85.2)
29.	Resampling	3 (0.8)	305 (85.2)
30.	Bayesian analysis	3 (0.8)	305 (85.2)
31.	Rasch analysis and item response theory	3 (0.8)	306 (85.5)
32.	Meta-analysis	2 (0.6)	306 (85.5)
33.	Repeated measures analysis	1 (0.3)	306 (85.5)

**14.5% of the articles contained either no statistics or descriptive statistics only.*

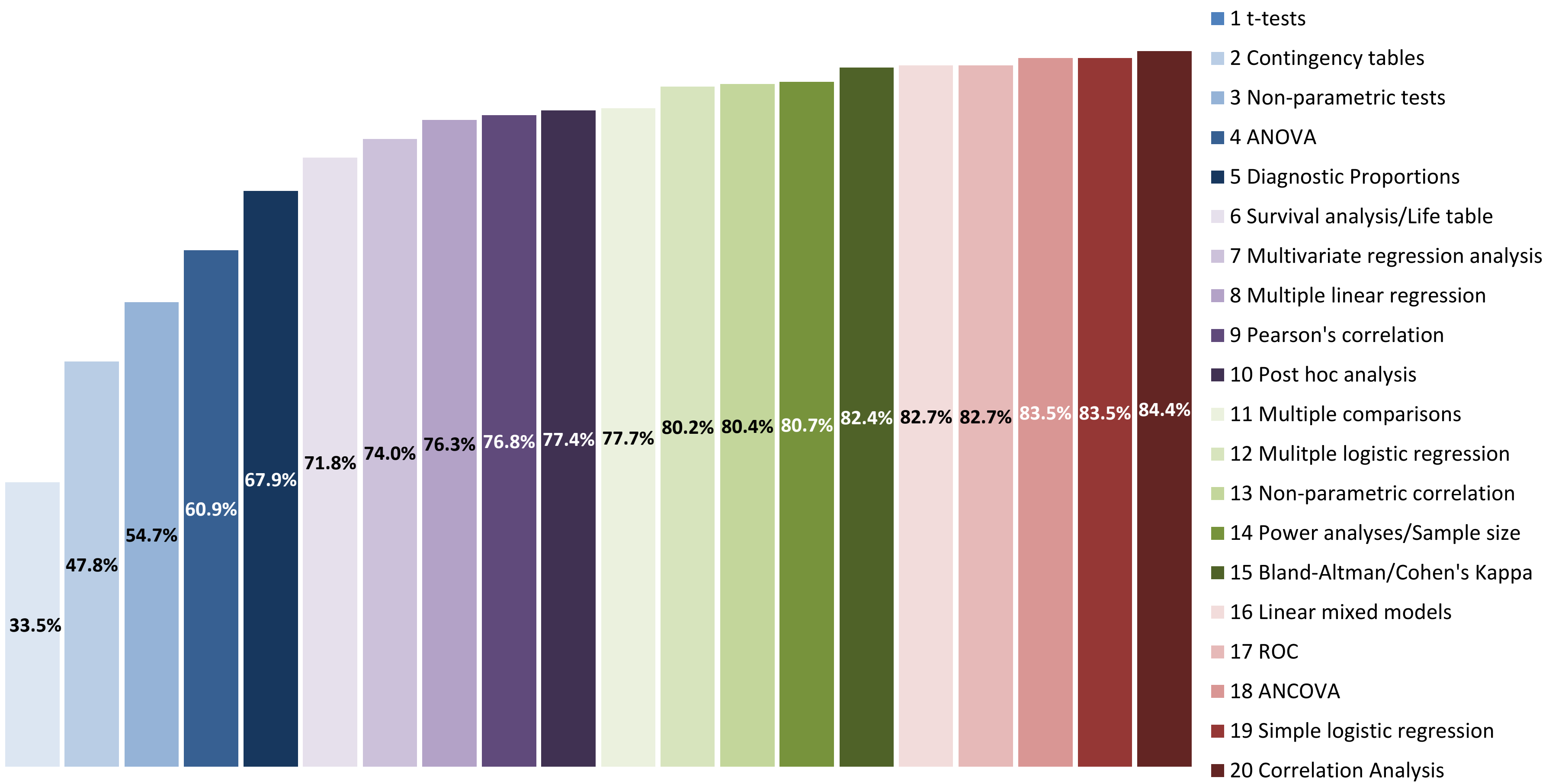


Figure 4.1 Cumulative Percentage of the Top 20 Frequently Used Statistical Methods in Articles (n=358) Published in the Optometry and Ophthalmology Journals: OPO, CEO, OVS and Ophthalmology in 2018

OPO: Ophthalmic & Physiological Optics; CEO: Clinical and Experimental Optometry; OVS: Optometry and Vision Science.

4.4.2. Frequency and Odds of Statistical Methods in Optometric and Ophthalmology Journals

Chi-square tests were conducted to determine if there was a difference between the expected presence of each statistical method between the four journals. As the frequency counts were not large, the likelihood ratio was chosen as the preferred test over the Pearson chi-square (Özdemir & Eyduran, 2005). All Cramer V effect sizes for significant results were below 0.25, thus considered small. Table 4.6 shows the results for both sets of chi-square tests. The first set of tests reveals associations between statistical methods and each of the four journals. As also indicated by stars in Figure 4.2, the likelihood ratios for each of the four journals revealed:

- OPO had less than expected articles using contingency tables, more than expected number of papers with Bland Altman/Cohen's Kappa;
- CEO had all methods as expected with no significant differences;
- OVS had fewer contingency tables than expected, however there were more non-parametric tests present, a greater than expected use of ANOVAs and multiple comparisons, and fewer diagnostic proportions;
- Ophthalmology had more than expected articles using contingency tables and diagnostic proportions. The following methods were also used significantly less than expected: Descriptive statistics/Normal distributions, ANOVAs, Multiple linear regressions, Non-parametric correlations, Bland-Altman/Cohen's Kappas.

The second set of chi-square tests are presented in the right side of Table 4.6 and in Figure 4.3. Here the frequencies of each statistical test were combined for the three Optometric journals and labelled 'combined optometric'. These frequencies were tested alongside the ophthalmology journal. According to the chi-square tests and the odds ratios, the following statistical methods are significantly more probable to be found in the combined optometry journals compared to the Ophthalmology journal: ANOVAs, Multiple linear regressions, non-parametric correlations, and bland-Altman/Cohen's Kappas. However, the Ophthalmology journal has significantly higher odds of using the following statical methods compared to Combined optometry journals: Contingency tables, Diagnostic Proportions, Survival analysis/Life tables, Multivariate regression analyses, Multiple logistic regressions, Linear mixed models, and ROCs.

Table 4.6 shows that Descriptive statistics, t-tests, Non- parametric tests, Analysis of variance (ANOVA), and Contingency tables were the most five common statistical methods reported (respectively) in the three investigated optometric journals (OPO, CEO, and OVS), however, Descriptive statistics, Contingency tables, t-tests, Survival analysis, and Multivariate regression analysis were the top five common statistical methods reported (respectively) in the ophthalmology journal in 2018.

Table 4.6 Statistical Techniques in Selected Optometry (Ophthalmic & Physiological Optics (OPO), Clinical and Experimental Optometry (CEO), Optometry and Vision Science (OVS)), and Ophthalmology Journals. Chi-Square Results

The first set of chi-square tests were conducted to determine if there was a difference between the presence the statistical method between the four journals. A significant likelihood ratio is indicated by a (*) or (ns) for non-significant. Significance is determined at alpha level .05. Green text indicates situations where the journal had significantly more than expected articles including the specified statistical method compared to the other journals. Red text indicates cases where the journal had significantly more than expected articles without the statistical method compared to the other journals. A second set of chi-square tests compared the three optometry journals combined to the Ophthalmology journal. The results follow the same green/red text convention. Odds ratios (OR) and their respective confidence intervals for this second test are presented in the final column. If the OR is above 1, the statistical method is more likely found in the combined optometry journals than it is the Ophthalmology journal. E.g., for the method, ANOVAs, the OR of 2.7 indicates that the odds of ANOVAs being present in the Combined Optometry journals are 2.7 higher than those of being present on Ophthalmology journals. When the frequency of counts is less than 5 for 2 journals, the chi-square test cannot be executed. In these cases, text is grey.

			Chi squared set 1. Four **journals**				Chi-Square set 2. Combined Optometric vs Ophthalmology		
Rank	*Statistical Method*	*All journals (n=358)* n (%)	*OPO (n=36) n (%)*	*CEO (n=72) n (%)*	*OVS (n=84) n (%)*	*Ophthalmology (n=166)* n (%)	*Combined Optometric (n=192) n (%)*	*Ophthalmology (n=166) n (%)*	*Odds Ratio [95% Confidence interval] Combined optometric vs Ophthalmology*
0.	No statistical methods	15 (4.2)	0	5 (6.9)	3 (3.6)	7 (4.2)	8 (4.2)	7 (4.2)	ns
1.	Descriptive statistics/ Normal distribution	322 (89.9)	35 (97.2)	64 (88.9)	80 (95.2)	143* (86.1)	179 (93.2)	143* (86.1)	2.22 [1.08, 4.53]
2.	t-tests	120 (33.5)	9 (25.0)	24 (33.3)	33 (39.3)	54 (32.5)	66 (34.4)	54 (32.5)	ns
3.	Contingency tables	114 (31.8)	6* (16.7)	21 (29.2)	15* (17.9)	72* (43.4)	42* (21.9)	72* (43.4)	0.37 [0.23, 0.58]
4.	Non-parametric tests	74 (20.7)	9 (25.0)	12 (16.7)	26* (31.0)	27 (16.3)	47 (24.5)	27 (16.3)	ns
5.	Other statistical methods	70 (19.6)	8 (22.2)	14 (19.4)	21 (25.0)	27 (16.3)	43 (22.4)	27 (16.3)	ns

Rank	*Statistical Method*	*All journals (n=358)* n (%)	Chi squared set 1. Four **journals**				Chi-Square set 2. Combined Optometric vs Ophthalmology		
			OPO (n=36) n (%)	*CEO (n=72) n (%)*	*OVS (n=84) n (%)*	*Ophthalmology (n=166)* n (%)	*Combined Optometric (n=192) n (%)*	*Ophthalmology (n=166) n (%)*	*Odds Ratio [95% Confidence interval] Combined optometric vs Ophthalmology*
6.	ANOVA	62 (17.3)	6 (16.7)	15 (20.8)	24* (28.6)	17* (10.2)	45* (23.4)	17* (10.2)	2.68 [1.47, 4.90]
7.	Diagnostic Proportions	54 (15.1)	5 (13.9)	11 (15.3)	3* (3.6)	35* (21.1)	19* (9.9)	35* (21.1)	0.41 [0.23, 0.75]
8.	Survival analysis/Life table	49 (13.7)	4 (11.1)	3 (4.2)	5 (6.0)	37 (22.3)	12* (6.3)	37* (22.3)	0.23 [0.12, 046]
9.	Multivariate regression analysis	48 (313.4)	3 (8.3)	6 (8.3)	3 (3.6)	36 (21.7)	12* (6.3)	36* (21.7)	0.24 [0.12, 0.48]
10.	Multiple linear regression	46 (12.8)	8 (22.2)	11 (15.3)	16 (19.0)	11* (6.6)	35* (18.2)	11* (6.6)	3.14 [1.54, 6.41]
11.	Pearson's correlation	43 (12.0)	6 (16.7)	8 (11.1)	15 (17.9)	14 (8.4)	29 (15.1)	14 (8.4)	ns
12.	Post hoc analysis	39 (10.9)	4 (11.1)	8 (11.1)	12 (14.3)	15 (9.0)	24 (12.5)	15 (9.0)	ns
13.	Multiple comparisons	38 (10.6)	6 (16.7)	4 (5.6)	15* (17.9)	13 (7.8)	25 (13.0)	13 (7.8)	ns
14.	Multiple logistic regression	37 (10.3)	6 (16.7)	0	7 (8.3)	24 (14.5)	13* (6.8)	24* (14.5)	0.43 [0.21, 0.87]
15.	Non-parametric correlation	30 (8.4)	6 (16.7)	5 (6.9)	13* (15.5)	6* (3.6)	24* (12.5)	6* (3.6)	3.81 [1.52, 9.56]
16.	Power analyses/ Sample size	29 (8.1)	1 (2.8)	8 (11.1)	4 (4.8)	16 (9.6)	13 (6.8)	16 (9.6)	ns

			Chi squared set 1. Four **journals**				Chi-Square set 2. Combined Optometric vs Ophthalmology		
Rank	*Statistical Method*	*All journals (n=358)* n (%)	*OPO (n=36) n (%)*	*CEO (n=72) n (%)*	*OVS (n=84) n (%)*	*Ophthalmology (n=166)* n (%)	*Combined Optometric (n=192) n (%)*	*Ophthalmology (n=166) n (%)*	*Odds Ratio [95% Confidence interval] Combined optometric vs Ophthalmology*
17.	Bland-Altman/ Cohen's Kappa	29 (8.1)	8* (22.2)	8 (11.1)	9 (10.7)	4* (2.4)	25* (13.0)	4* (2.4)	6.06 [2.06, 17.81]
18.	Linear mixed models	27 (7.5)	1 (2.8)	3 (4.2)	4 (4.8)	19 (11.4)	8* (4.2)	19* (11.4)	0.34 [0.14, 0.79]
19.	ROC	18 (5.0)	1 (2.8)	3 (4.2)	3 (3.6)	11 (6.6)	7* (3.6)	11* (6.6)	0.53 [0.20, 1.41]
20.	ANCOVA	17 (4.7)	3 (8.3)	2 (2.8)	5 (6.0)	7 (4.2)	10 (5.2)	7 (4.2)	ns
21.	Simple logistic regression	14 (3.9)	0	6 (8.3)	1 (1.2)	7 (4.2)	7 (3.6)	7 (4.2)	ns
22.	Correlation analysis	13 (3.6)	0	7 (9.7)	3 (3.6)	3 (1.8)	10 (5.2)	3 (1.8)	ns
23.	Generalized estimating equations	9 (2.5)	1 (2.8)	0	2 (2.4)	6 (3.6)	3 (1.6)	6 (3.6)	ns
24.	Simple linear regression	8 (2.2)	2 (5.6)	0	4 (4.8)	2 (1.2)	6 (3.1)	2 (1.2)	ns
25.	Transformation	7 (2.0)	1 (2.8)	0	4 (4.8)	2 (1.2)	5 (2.6)	2 (1.2)	ns
26.	Missing data methods	7 (2.0)	0	0	2 (2.4)	5 (3.0)	2 (1.0)	5 (3.0)	Count too small to test
27.	Prevalence / Incidence	6 (1.7)	0	1 (1.4)	0	5 (3.0)	1 (0.5)	5 (3.0)	Count too small to test
28.	Generalized linear models[1]	6 (1.7)	1 (2.8)	0	2 (2.4)	3 (1.8)	3 (1.6)	3 (1.8)	Count too small to test
29.	MANOVA	4 (1.1)	0	1 (1.4)	1 (1.2)	2 (1.2)	2 (1.0)	2 (1.2)	Count too small to test
30.	Resampling	3 (0.8)	0	0	1 (1.2)	2 (1.2)	1 (0.5)	2 (1.2)	Count too small to test

Rank	Statistical Method	All journals (n=358) n (%)	Chi squared set 1. Four **journals**				Chi-Square set 2. Combined Optometric vs Ophthalmology		
			OPO (n=36) n (%)	*CEO (n=72) n (%)*	*OVS (n=84) n (%)*	*Ophthalmology (n=166)* n (%)	*Combined Optometric (n=192) n (%)*	*Ophthalmology (n=166) n (%)*	*Odds Ratio [95% Confidence interval] Combined optometric vs Ophthalmology*
31.	Bayesian analysis	3 (0.8)	0	0	1 (1.2)	2 (1.2)	1 (0.5)	2 (1.2)	Count too small to test
32.	Rasch analysis and item response theory	3 (0.8)	0	0	1 (1.2)	2 (1.2)	1 (0.5)	2 (1.2)	Count too small to test
33.	Meta-analysis	2 (0.6)	0	0	0	2 (1.2)	0	2 (1.2)	Count too small to test
34.	Repeated measures analysis	1 (0.3)	0	0	1 (1.2)	0	1 (0.5)	0	Count too small to test
35.	Cost-benefit analysis	0	0	0	0	0	0	0	Count too small to test
36.	Multi-way tables	0	0	0	0	0	0	0	Count too small to test

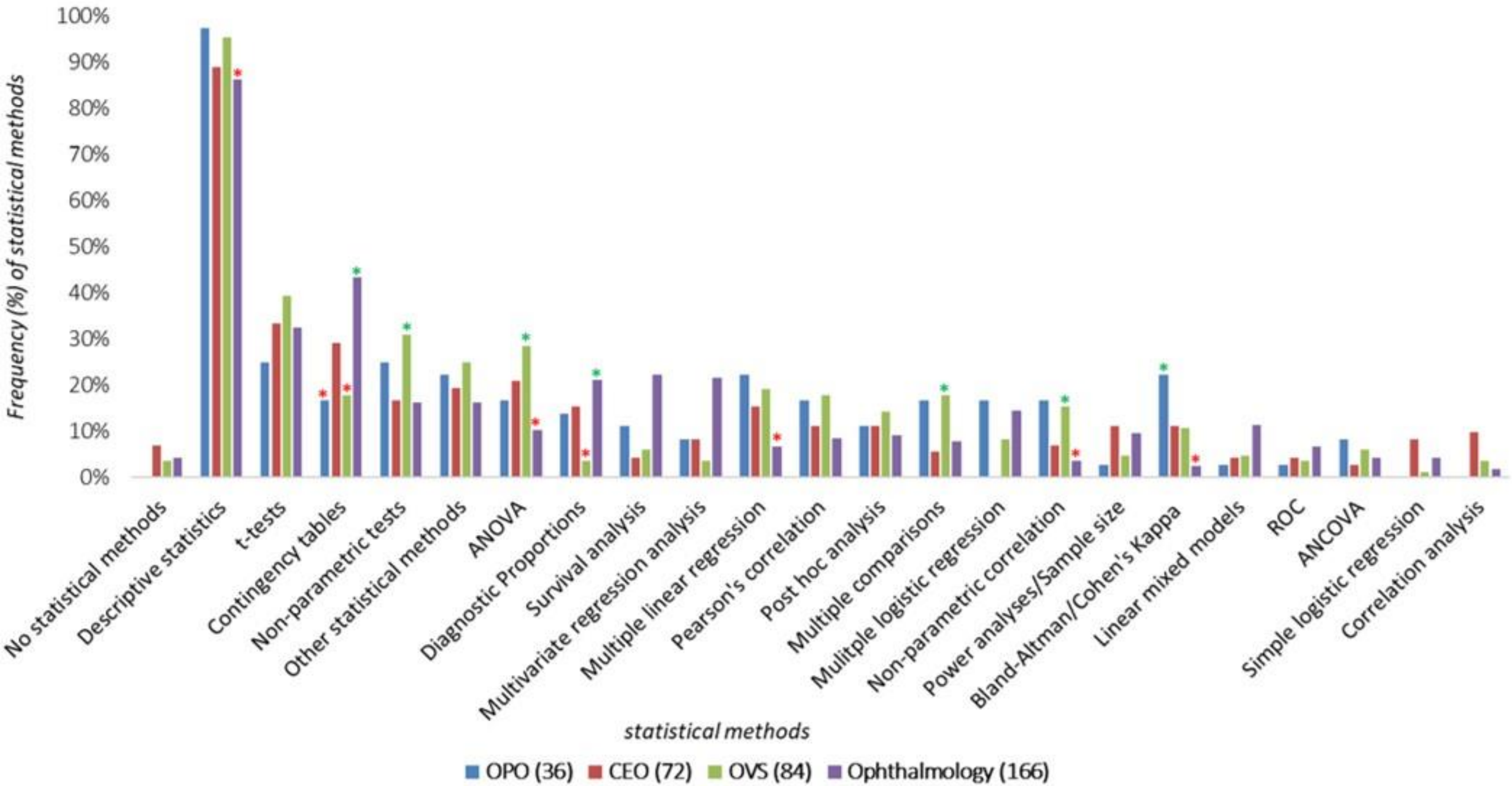


Figure 4.2 The Frequency (%) of the Most Commonly Used Statistical Techniques in 358 Articles Published in the Optometry and Ophthalmology Journals OPO, CEO, OVS, and Ophthalmology in 2018

OPO: Ophthalmic & Physiological Optics; CEO: Clinical and Experimental Optometry; OVS: Optometry and Vision Science. A significant likelihood ratio is indicated by a green (*) when the journal had significantly more than expected articles including the specified statistical method compared to the other journals, and a red (*) for cases where the journal had significantly more than expected articles without the statistical method compared to the other journals.

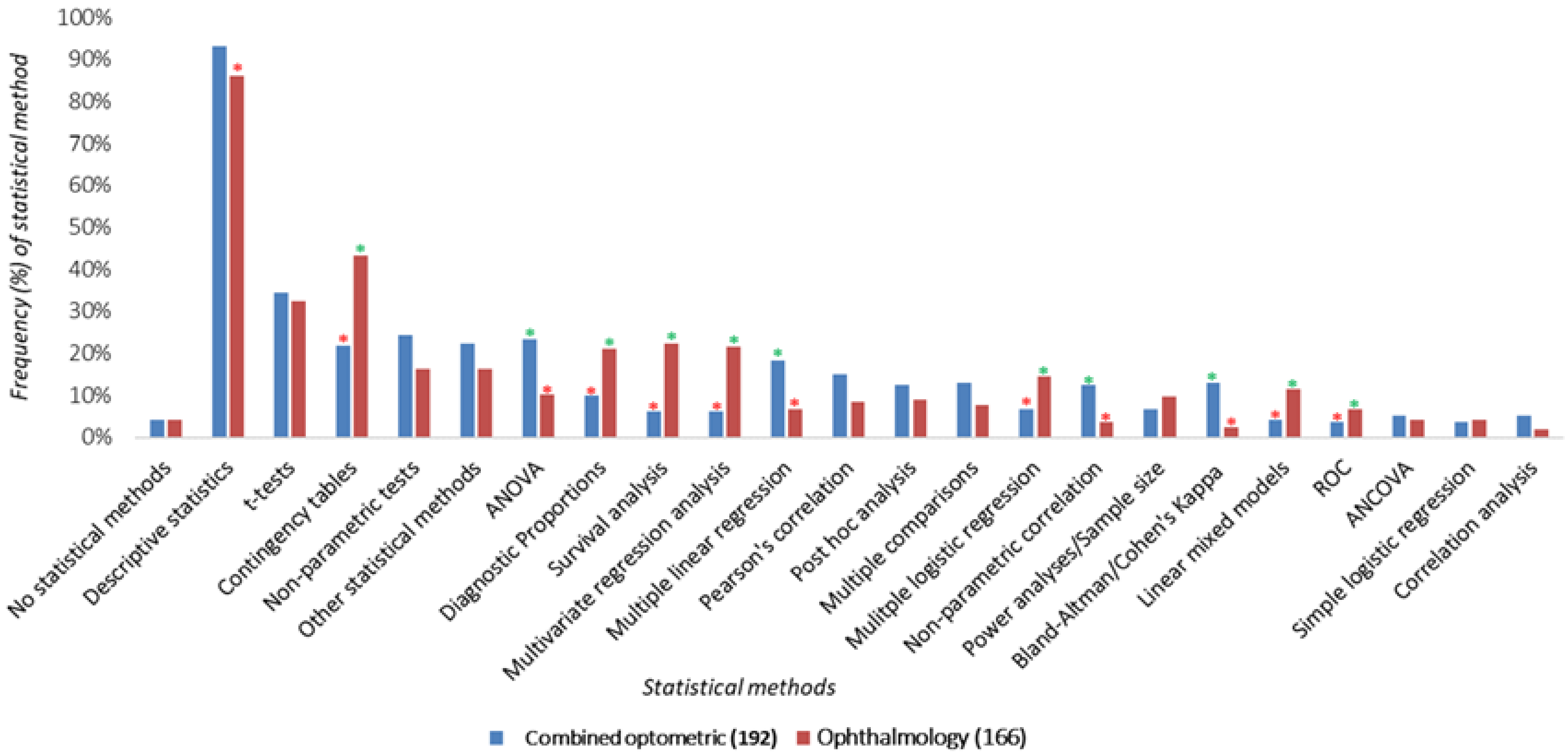


Figure 4.3 Frequency (%) of the Most Commonly (Top 20) Used Statistical Techniques in 358 Articles Published in the Combined 3 Optometry Journals (OPO, CEO, OVS) and the Single Ophthalmology Journal in 2018

OPO: Ophthalmic & Physiological Optics; CEO: Clinical and Experimental Optometry; OVS: Optometry and Vision Science.

A significant likelihood ratio is indicated by a green (*) when the journal had significantly more than expected articles including the specified statistical method compared to the other journals, and a red (*) for cases where the journal had significantly more than expected articles without the statistical method compared to the other journals.

To allow for a brief comparative overview of frequency by journal, the rank order of statistical techniques for each journal and for optometry journals combined is displayed in Table 4.7. Statistical techniques that were equally employed were assigned joint half ranks. For example, t-test and non-parametric tests were equally used in journal articles published in OPO, accounting for the 2nd and 3d most frequently used statistical techniques and were thus awarded a rank of 2.5 each. This snapshot overview highlights key differences in the rank order of statistical methods between optometry and ophthalmology journals and amongst optometry journals.

Table 4.7 Ranking of Statistical Techniques Used in the 358 Articles Published in the Combined 3 Optometry Journals (OPO, CEO, OVS) and the Single Ophthalmology Journal in 2018
OPO: Ophthalmic & Physiological Optics; CEO: Clinical and Experimental Optometry; OVS: Optometry and Vision Science.

Statistical method	*Rank*				
	OPO	*CEO*	*OVS*	*Optometry journals combined*	*Ophthalmology*
Descriptive statistics/Normal distribution	1	1	1	1	1
t-tests	2.5	2	2	2	3
Contingency tables	8.5	3	7	5	2
Non-parametric tests	2.5	5	3	3	7
Analysis of variance (ANOVA)	8.5	4	4	4	10
Diagnostic Proportions	12	6.5	20.5	12	6
Survival analysis/Life table	13.5	18	13.5	15.5	4
Multivariate regression analysis	15.5	13.5	20.5	15.5	5
Multiple linear regression	4.5	6.5	5	6	15.5
Pearson's correlation	8.5	9.5	7	7	13
Post hoc analysis	13.5	9.5	10	10.5	12
Multiple comparisons	8.5	16	7	8.5	14
Multiple logistic regression	8.5	29	12	13.5	8
Non-parametric correlation	8.5	15	9	10.5	19.5
Power analyses/Sample size calculations	20.5	9.5	16.5	13.5	11
Bland-Altman/Cohen's Kappa	4.5	9.5	11	8.5	23
Linear mixed models	20.5	18	16.5	19	9
Receiver operating characteristics (ROC)	20.5	18	20.5	20.5	15.5
Analysis of covariance (ANCOVA)	15.5	20	13.5	17.5	17.5
Simple logistic regression	29.5	13.5	28.5	20.5	17.5
Correlation analysis	29.5	12	20.5	17.5	24.5
Generalized estimating equations	20.5	29	24	24.5	19.5
Simple linear regression	17	29	16.5	22	29
Transformation	20.5	29	16.5	23	29
Missing data methods	29.5	29	24	26.5	21.5
Prevalence / Incidence	29.5	21.5	33.5	30	21.5

Generalized linear models (excluding linear and logistic regression)	20.5	29	24	24.5	24.5
Multivariate analysis of variance (MANOVA)	29.5	21.5	28.5	26.5	29
Resampling	29.5	29	28.5	30	29
Bayesian analysis	29.5	29	28.5	30	29
Rasch analysis and item response theory	29.5	29	28.5	30	29
Meta-analysis	29.5	29	33.5	34	29
Repeated measures analysis	29.5	29	28.5	30	34
Cost-benefit analysis	29.5	29	33.5	34	34
Multi-way tables	29.5	29	33.5	34	34

4.5. Journals Focus and Keywords

Of the 375 published articles including systematic reviews, 341 (90.9%), 8 (2.1%), and 17 (4.5%) publications involved humans, animals, and cells, respectively. Also, 9 (2.4%) of the total included papers (n=375) targeted their investigations towards issues "other" than the three previously mentioned categories, as these papers focused on ophthalmic solutions, contact lens or spectacle materials, low vision optical aids, or cost evaluations Figure 4.4.

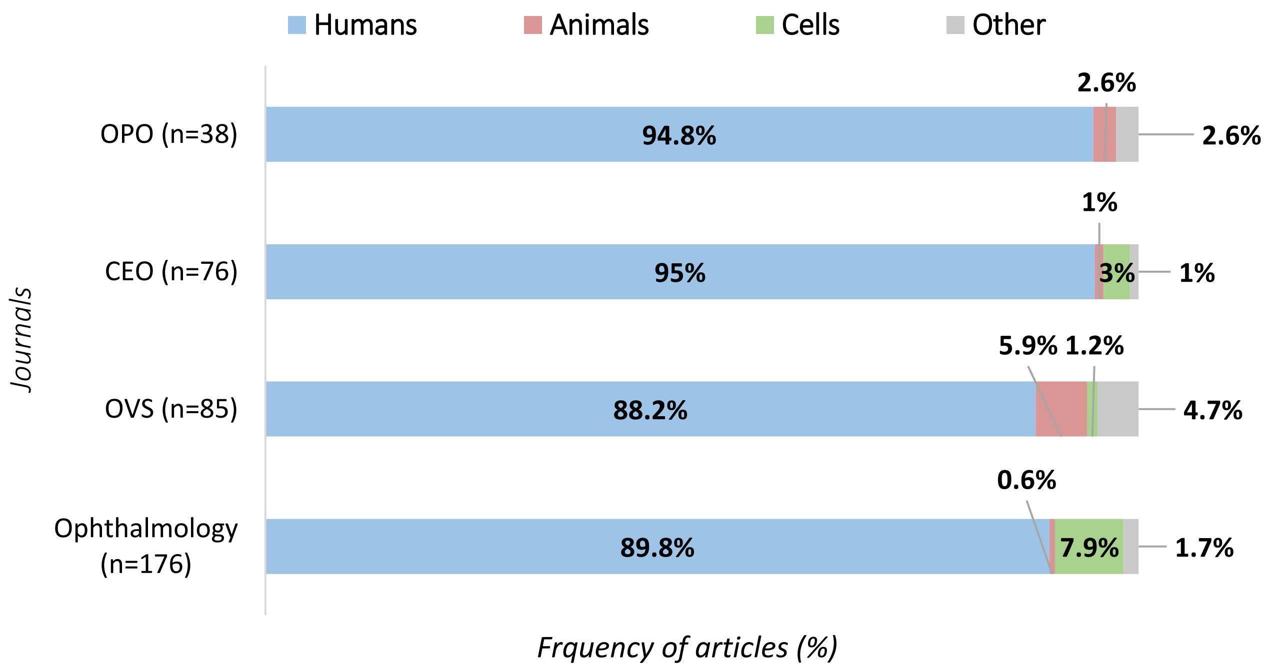


Figure 4.4 The Frequency of Published Articles Investigating Humans, Animals, and Cells in the 3 Optometry Journals (OPO, CEO, OVS) and the Single Ophthalmology Journal (n=375) Published in 2018
OPO: Ophthalmic & Physiological Optics; CEO: Clinical and Experimental Optometry; OVS: Optometry and Vision Science. "Other" means other than human, animals, and cells, for example, ophthalmic solutions, contact lens or spectacle materials, low vision optical aids, or cost evaluations.

The keywords listed for each article were also extracted, as indicators of research areas. Only two of the four selected journals published keywords, and these were OPO and CEO. Note that OPO allowed at least 4 and up to 6 keywords, and CEO required 3 to 4 keywords on submission of a manuscript. This difference in the number keywords required to be listed likely modulated the frequency results presented below. The frequency of keywords is summarized in Table 4.8. The top four keywords extracted from the 114 articles in OPO (n=38) and CEO (n=76) were myopia, children's vision, refractive error and Optical Coherence Tomography or OCT.

Table 4.8 The Most Frequent Keywords Found in the OPO (n=38) and CEO (n=76) Journals in 2018

Keywords	*Frequency (n)*	*Percentage (%)*
Myopia	15	13.2
Children's Vision	12	10.5
Refractive Error	11	9.6
Optical Coherence Tomography	10	8.8
Spectacles	9	7.9
Glaucoma	9	7.9
Visual Impairment	9	7.9
Age-Related Macular Degeneration	9	7.9
Low Vision	8	7.0
Contact Lenses	7	6.1

OPO: Ophthalmic & Physiological Optics; CEO: Clinical and Experimental Optometry.

Keywords extracted from this subset of 114 articles from OPO and CEO are displayed using a Word Cloud (Figure 4.5). The "word cloud" analysis technique allows for graphical representation and quantitative viewing of qualitative data. This was used to display the most frequently researched areas in the two optometry journals sampled. The word cloud was created using the Word Art Creator (https://wordart.com/), where the size of the word represents the frequency of occurrence of it being listed as a keyword Figure 4.5.

Figure 4.5 Word Cloud of the Keywords from the Articles (n=114) Published in OPO and CEO in 2018

OPO: Ophthalmic & and Physiological Optics. CEO: Clinical Experimental Optometry.

4.6. Discussion: Optometrists Must Understand Statistics

The different categories of statistical methods and their frequency of use in articles from three high impact optometric journals and one high impact ophthalmic journal throughout 2018 were investigated. Out of 358 original articles, 313 (87%) used at least one statistical method that was not descriptive statistics. The most frequently used statistical methods were t-tests (33.5%), contingency tables (31.8%), non-parametric tests (20.7%), other statistical methods (19.6%) and ANOVA (17.3%). The top three most commonly used statistical methods found in our audit of optometry and ophthalmology literature is very similar to that identified in the literature of general medicine , ophthalmology, and physiotherapy, most likely due to their relatively lower complexity of use (Emerson & Colditz, 1983; Juzych et al., 1992; Lisboa et al., 2014; Roush et al., 2015). Other methods that were present in over 10% of articles include diagnostic proportions, survival analysis, regression analyses, Pearson's correlation and post hoc analysis.

Almost 96% of original articles investigated used at least one statistical method. This was notably higher than a similar analysis conducted by Lisboa et al. in 2014 on articles from three ophthalmology journals (80%) as well as Emerson and Colditz in 1983 (42%) on articles from the New England Journal of Medicine (Emerson & Colditz, 1983; Lisboa et al., 2014). This discrepancy may be partially due to differences in the eligibility in the types of articles analyzed between studies, as the inclusion criteria was not clearly mentioned in these past studies. Lisboa et al. also suggested that increasing use of statistics over time could account for these type discrepancies and this may also be true for our audit (Emerson & Colditz, 1983; Lisboa et al., 2014). Whilst almost 90% of articles used descriptive statistics, only 9% of articles used this as the sole statistical method, an indication that understanding of statistics beyond descriptive statistics is necessary for comprehension of most of the ophthalmic literature.

T-tests, contingency tables and non-parametric tests were the only methods present in more than 20% of articles. An understanding of these methods, along with descriptive statistics, will allow comprehension of 92.5% of articles, whilst knowledge of an additional twelve different methods would be needed for comprehension of 95% of articles. No single statistical method would allow for understanding of a majority of articles, given that multiple statistical techniques are often used in most articles; rather, a repertoire of numerous statistical methods is necessary in order to grasp the ophthalmic literature.

The increasing availability of computers and statistical software over time has allowed for greater accessibility and quicker data analysis. Furthermore, with such changes in technology as well as the development of the Internet, the number of articles published and access to the scientific literature has increased and improved, enabling an increased awareness towards the importance of statistics in research. Consistent with prior research we found there was a continued trend toward increased use of newer and more sophisticated statistical methods by journal authors. Readers with knowledge of only the topics typically included in introductory statistics courses may not fully comprehend a large fraction of the statistical content of original articles. We thus concur with the conclusion of Emerson and Colditz that "*an acquaintance with a few basic statistical techniques cannot give full statistical access to research appearing in the journal*"(Emerson & Colditz, 1983; Switzer & Horton, 2013).

Considering the frequency of statistical methods presented in different journals, the observed pattern of results is consistent with content presented in each journal. ANOVAs, Multiple linear regressions, non-parametric correlations, and bland-Altman/Cohen's Kappas were found more frequently in combined optometry journals than the Ophthalmology journal. However, the Ophthalmology journal has significantly higher odds of using the following statical methods compared to Combined optometry journals: Contingency tables, Diagnostic Proportions, Survival analysis/Life tables, Multivariate regression analyses, Multiple logistic regressions, Linear mixed models, and ROCs. Whereas, Ophthalmology has more overlap with medicine and had higher rates of using contingency tables and diagnostic proportions as one might expect. Another noteworthy finding was that the use of survival analysis was significantly greater in Ophthalmology (22%) compared to an average between the three optometric journals (6%). This is likely due to a greater focus on pathology in ophthalmic literature, therefore needing to determine duration before events such as death or certain visual consequences. Diagnostic proportions were significantly more prominent in ophthalmology which is a secondary/ specialty care area. The rate of Diagnostic Proportions is disappointing small for optometry in Journals which are focus on primary care (Optometry) Rigby (2004) (Rigby et al., 2004) . It would be desirable that those journals targeted at primary practice should contain info on screening and disease versus no disease rather than other methods.

For OVS fewer contingency tables than expected were used, however there were more non-parametric tests present, a greater than expected use of ANOVAs and multiple comparisons, and fewer diagnostic proportions. OVS has a vison science focus, which has interdisciplinary overlap with the field of Psychology. Tests such as ANOVAs and non-parametric testing are suited to perceptual experiments and were more prominent in OVS. OPO had less than expected articles using contingency tables, more than expected articles with Bland Altman and Cohen's Kappa, indicating a possible focus on the evaluation or validation of new instrumentations and/or new methods. CEO's proportion of articles was as expected. It was possible that the "instructions for authors" specifically set by each journal modulated which and how statistical methods were reported. Table 4.9 summarizes the "statistics" instructions for authors provided by each journal (OPO, OVS, CEO, Ophthalmology). From that, it is clear that the instruction for authors for OPO may partially explain the higher proportions of articles using Bland Altman type statistical methods.

A limitation of this study was that statistical terms beyond those used to describe a statistical method were not analyzed, such as for example terms associated with the description of study or statistical design or with the interpretation of the results. Yet, study design and statistical methods are intimately linked and therefore concurrent collection of data and analysis on both types of information may have proved extremely valuable and provide more insights to the training needs for optometrists.

The categorization of statistical tests was not standardized in the articles analyzed and as a result different approaches have been used by each group of investigators, making comparisons across fields difficult. Tilson and colleagues used an approach where statistical terms rather than statistical techniques were extracted from journal articles: (1) between group comparison, (2) clinically meaningful statistics, (3) describing variables, (4) diagnostic statistics, (5) measures of association, (6) measures of central tendency, (7) results terms, and (8) sundry statistical terms (Tilson et al., 2016). Their proposed eight categories may prove useful in future analysis of the ophthalmic literature.

Better knowledge of the frequency of use of the different statistical methods in the ophthalmic literature could enhance the development of educational programs designed to increase the statistical knowledge of optometry students, practitioners, and researchers (Lisboa et al., 2014). The results of this study demonstrate the importance of knowledge of contemporary statistical methods for optometrists to comprehend the ophthalmic literature.

Table 4.9 Authors' Guidelines for the OPO, OVS, Ophthalmology Journals and the ICMJE Uniform Requirements

CEO did not provide specific guidelines for statistics.

Journal	*OPO*	*OVS*	*Ophthalmology*	*ICMJE* *"The Uniform Requirements"*
Statistical guidelines for the authors	The statistical approach recommended by OPO is presented in Armstrong and colleagues (OPO, 2011). Studies that assess agreement between tests or the repeatability of test results should consult McAlinden et al. (OPO, 2011). For issues regarding the use of data from one or both eyes of patients, consult Armstrong (OPO, 2013) and for issues regarding the use of multiple statistical tests and/or the Bonferroni correction, consult Armstrong (OPO, 2014). Other useful guidelines, including the assessment of data that are not normally distributed, are available at: http://statisticsgroup.nihr.ac.uk/ research/ophthalmology/. Altman and colleagues' (BMJ, 1983) statistical guidelines for the	**Tests of Statistical Significance:** Tests of statistical significance generally provide little useful information beyond what can be learned by looking at the distributions of the data. It is far more informative to know estimates of central tendency (e.g., the mean or median) and the variability of observations (e.g., the 95% confidence interval). Tests of statistical significance can fail to show significance due to small sample sizes or variable measures (or both). However, the reason for the lack of significance is lost when only the p-value is reported. Conversely, large samples can elevate clinically meaningless results to something that is statistically significant. The preferred way to report data is to show the distribution of individual observations in a figure and allow	Statistical methods must be identified in table footnotes, illustration legends, or text explanations. Software programs used for complex statistical analyses must be identified to enable reviewers to verify calculations. For manuscripts in which the study conclusions infer equivalency in treatment effect, a sample size calculation and power analysis should be included. Levels for alpha and beta errors should be clearly stated in the Methods section of the Abstract and text. Authors should state the clinically significant difference that was used to determine the power calculation. The journal strongly advises statistical consultation about data	Describe statistical methods with enough detail to enable a knowledgeable reader with access to the original data to judge its appropriateness for the study and to verify the reported results. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (such as confidence intervals). Avoid relying solely on statistical hypothesis testing, such as P values, which fail to convey important information about effect size and precision of estimates. References for the design of the study and statistical methods should be to standard works when possible (with pages stated). Define statistical terms, abbreviations, and most symbols.

	presentation of results are also recommended: Do not add spurious precision to data so that mean values should be no more than one decimal place more than the original data (e.g., mean log MAR could be 0.12 or 0.124, but not 0.12386). Percentages can often be rounded to the nearest whole number. Report the results of statistics tests (e.g., F or t-value) and degrees of freedom in addition to p-values and give exact p-values to 2 significant figures unless p<0.0001 (e.g., $F_{2,94}=0.31$, p=0.73; $F_{2,4}$ = 4.26, p = 0.015, $F_{1,94}=17.1$, p<0.0001) Always present means (or medians) with standard deviation (SD) or standard error (SE) values (or inter-quartile range and/or full range). Provide SD or SE values in brackets rather than using the ± sign as it avoids any confusion between SD and SE.	readers to see the actual distributions of the data. **Formatting P-values:** As stated above, reporting outcomes as meaningful through the declaration of p-values is discouraged. Nevertheless, when reported, they should be reported along with the actual values of any measured parameters that are compared. Example: The rate of myopia progression was lower among the atropine group (0.10 D; 95% CI: 0.03 to 0.24 D) than among the spectacle lens wearing group (0.45 D; 95% CI: 0.25 to 0.65 D) and this difference was statistically significant (two-sample t (17) = 2.89; P=.01). Authors should report actual p-values rather than categorical values, e.g., P<.05. The format for reporting P values is the capital, italicized letter P, e.g., P = .02, not P = .02, p = .02, or p = .02 All reported statistical parameters (r, P, t, F, etc.) should be italicized denoting them as symbols for the	collection and analysis. We follow The New England Journal Medicine's guidelines for reporting P values: Except when one-sided tests are required by study design, such as in non-inferiority trials, all reported P values should be two-sided (except when one-sided tests are required by study design). In general, P values larger than 0.01 should be reported to 2 decimal places, those between 0.01 and 0.001 to 3 decimal places; P values smaller than 0.001 should be reported as P < 0.001. Notable exceptions to this policy include P values arising in the application of stopping rules to the analysis of clinical trials and genetic-screening studies. For tables comparing treatment or exposure groups in a randomized trial (usually the first table in the trial report), significant differences between or among groups should be indicated by * for P < 0.05, ** for P < 0.01, and *** for P < 0.001 with an	Specify the statistical software package(s) and versions used. Distinguish prespecified from exploratory analyses, including subgroup analyses.

		associated statistic, e.g., r, P t, F; they should not be bold. Report P values to two places past the decimal without a leading 0, e.g., P = .04 not P = 0.041, or three places when rounding would lead one to incorrectly interpret results as insignificant (e.g., P = .046 not .05) Report P values to three places past the decimal when P < .01, e.g., P = .008 not P = .0083. P values are probabilistic and not deterministic and therefore, cannot be 0 or 1. P values reported as 0 by statistical software should be changed to P < .0001. Likewise, P values cannot be 1. P values reported as 1 by statistical software should be changed to P > .99. **Confidence Intervals:** Confidence intervals are the preferred way to report outcome measures and should be combined with a description of the central tendency (e.g., the mean or median).	explanation in the footnote if required. The body of the table should not include a column of P values.	

		Confidence intervals indicate the precision of the estimated population parameter given the study sample characteristics. The 95% confidence interval is most used and overlapping confidence intervals indicates no statistically significant difference. When readers are provided with confidence intervals for observed differences between two groups and the confidence interval of that difference does not contain 0, there is a statistically significant difference between the groups. It is acceptable to abbreviate confidence interval as CI. Report confidence intervals as follows: With positive, the em dash can be used to separate the limits of the interval, e.g. (95% CI: 4.25—9.75). When values reported span above and below 0, report the limits of the interval separated by to and include + and – symbols e.g. (95% CI: –12.25 to +3.00).		

4.7. Study 2- Optometrists' Knowledge, Attitude, and Practice of Statistics

4.7.1. Knowledge, Attitudes, and Practice (KAP) Towards Statistics

Optometry Australia's "Entry-Level Competency Standards 2014" state that skills related to statistics are required for optometrists to practice in Australia. A suggested indicator listed under element 1.1 of the competencies focused on the maintenance of optometry knowledge, clinical expertise and skills lists an ability to "*critically evaluate statistical methods and the scientific basis of research evidence for newly developed and existing clinical procedures, techniques and therapies*" (Kiely & Slater, 2015).

Knowledge, attitudes, and practices (KAP) questionnaires are a popular tool in health-related research. KAP studies typically use a standardized questionnaire to collect information on what is known, believed, and done in relation to a particular topic. KAP studies are useful in health-related research as they facilitate identification of knowledge gaps, prevalent attitudes and beliefs held and common practice patters within a population. Additionally, data obtained using a KAP questionnaire can be analyzed quantitatively or qualitatively (World Health & Stop, 2008). In the previous section we determined the theoretical level of statistical knowledge Australian optometrists require in order to adequately comprehend the published ophthalmic literature. These findings should ideally align with the knowledge of statistics optometrists actually possess. No studies have previously investigated optometrists' KAP towards statistics. The existing literature from other health professions including medicine, physiotherapy, and nursing on KAP towards statistics is summarized in Table 4.10.

Medical practitioners often demonstrated poor understanding and interpretation of statistics when surveyed (Emerson & Colditz, 1983; Reznick et al., 1987; Windish et al., 2007). Studies on physicians showed that their basic mathematical skills and analysis of medical examinations and of relative risk reduction was not satisfactory (Gigerenzer et al., 2007). Windish et al. conducted a study investigating statistical knowledge in medical residents (Windish et al., 2007). Residents scored 41% compared to 72% scored by those with higher research training (Windish et al., 2007). Eighty two percent of residents could interpret relative risk correctly, however, they were less likely to be able to interpret other statistical methods such as adjusted odds ratio from a multivariate regression analysis or deduce results from a Kaplan-Meier analysis (Windish et al., 2007). In addition to measuring knowledge, a questionnaire focused on self-reporting attitudes towards statistics was also conducted (Windish et al., 2007). Whilst 95% of residents believed it was highly important to understand statistical concepts to successfully appraise the literature, 75% percent of residents acknowledged low confidence their statistical understanding for medical literature (Windish et al., 2007). This low level of confidence was reflected by the low scores on the knowledge component (Windish et al., 2007). However, respondents who rated their level of confidence higher on average performed better than those who rated their confidence levels lower (43.6% vs 39.3%) (Windish et al., 2007). The low confidence of statistics in medical practitioners was also reflected in a study by Reznick et al. which reported that 87% of surgical residents recognized that understanding statistical methods was critical in reading articles thoroughly although 57% stated they had poor working knowledge of statistics and 10% said they had no working knowledge of statistics (Reznick et al., 1987). A knowledge based, multiple choice questionnaire was conducted by Wulff et al. sampling 148 Danish doctors (Wulff et al., 1987). A low level of statistical knowledge was also reported, with seven out of eight doctors unable to correctly interpret a significant p-value (Wulff et al., 1987). Only 30% of doctors could correctly interpret standard deviation and only 39% were able to select the correct definition for standard error (Wulff et al., 1987).These results were similar to those of Friedman and Phillips' study where pediatric residents in the United States were unable to correctly answer questions relating to magnitude of p-values and correlation coefficients (Friedman & Phillips, 1981).

Table 4.10 Summary of KAP Surveys in Health

KAP: Knowledge, Attitude, Practice.

Author	*Health field*	*Domains Surveyed*	*Instrument type*	*Type of Item*	*No. of items*	*No. of participants*
Windish et al. (2007) (Windish et al., 2007)	Medicine (residents)	Knowledge and attitudes	Questionnaire	· MCQ for knowledge · Likert scale for attitudes	· 16 MCQ · 9 Likert scale questions	277/367
Reznick et al. (1987) (Reznick et al., 1987)	Medicine (surgical residents)	Attitudes	Questionnaire	· Likert scale	-	-
Wulff et al. (1987) (Wulff et al., 1987)	Medicine (general practitioners, specialists, junior doctors, other)	Knowledge	Questionnaire	· MCQ	· 11 MCQ	148/250
Mehrdad et al. (2012) (Mehrdad et al., 2012)	Nursing	Knowledge and attitudes	Questionnaire	· MCQ and matching questions for knowledge · Likert scale for attitudes	· 17 Likert scale questions · 15 MCQ and 10 matching	70/90

McCleary et al. (2002) (McCleary & Brown, 2002)	Health (nurses, occupational therapists, physiotherapists, psychologists, pharmacists, audiologists and more)	Attitudes	Questionnaire	· Likert scale	· 38 Likert scale questions	283/813
Baghi et al. (2013) (Baghi & Kornides, 2013)	Nursing and health graduates	Knowledge and attitudes	Test for knowledge Interview for attitudes	· Unspecified for knowledge · Likert scale for attitudes	· 40 test questions · 25 Likert scale questions	165
Bookstaver et al. (2012) (Bookstaver et al., 2012)	Pharmacists (residents)	Knowledge, attitude, and confidence	Questionnaire	· MCQ for knowledge · Likert scale for Attitude and confidence	· 27 items: 10 MCQ questions · 10 Likert scale questions	166/214
Polychronopoulou et al. (2011) (Polychronopoulou et al., 2011)	Orthodontic postgraduate students	Knowledge, attitude, and confidence	Questionnaire	· MCQ for knowledge · Likert scale for attitudes and confidence	· 20 items: 10 MCQ questions · 6 Likert scale questions	127/129

Ganasegeran et al., 2019 (Ganasegeran et al., 2019)	Clinicians	Knowledge and confidence	Questionnaire	· Likert scale for knowledge · Likert scale and Yes or No questions for confidence	· 37 items: 31 Likert scale questions · 1 Yes or No question	201/234

Some data was also available regarding the KAP of other health professionals towards statistics. Data of KAP towards statistics in students of health professions was also sometimes reported. Poor knowledge and attitudes towards statistics have been reported amongst nurses and other health practitioners including occupational therapists, physiotherapists, psychologists, pharmacists and audiologists (Emerson & Colditz, 1983; Juzych et al., 1992; Lisboa et al., 2014; McCleary & Brown, 2002; Roush et al., 2015; Zellner et al., 2007). In a study conducted by Mehrdad et al., approximately 80% of nurses had low knowledge of statistical terms such as "relative risks", "odds ratio", "confidence interval", and "systematic bias" (Mehrdad et al., 2012). McCleary et al. surveyed nurses and many other health practitioners (occupational therapists, physiotherapists, psychologists, pharmacists, audiologists) working in a Canadian pediatric hospital (McCleary & Brown, 2002). Over 50% of respondents viewed their understanding of statistics as poor or very poor with only 6.1% believing their knowledge to be very good (McCleary & Brown, 2002). Similar to the results found in medical practitioners, confidence levels in statistics were overall low (McCleary & Brown, 2002). Baghi et al. investigated the knowledge and attitudes towards statistics in 165 healthcare graduates including 58 practicing registered nurses (Baghi & Kornides, 2013). The mean knowledge score in three sections were less than 2.5 out of 5 (Baghi & Kornides, 2013). Attitudes towards statistics also scored low ranging between of 2.16 and 2.90 out of 5 (Baghi & Kornides, 2013). Both knowledge and attitude scores improved following a 10-week statistics course (Baghi and Kornides, 2013). Bookstaver et al. (2012) also reported that pharmacy residents' perception and understanding of biostatistics were poor. Polychronopoulou et al. were surprised when they found that the participants were unable to tell the correct use of the chi-square test (11.8%, 95% CI: 6.1 – 17.5%) (Polychronopoulou et al., 2011). In another study conducted in Northern Malaysia, only 6% of the clinicians had complete confidence in their ability to assess if correct statistical procedures were used to answer research questions (Ganasegeran et al., 2019). Colton (1975) reported the attitude of students to biostatistics as "abhorrence" (4%), "dislike" (31%), and "tolerance" (49%) (Colton, 1975). In a survey of medical students from the United Kingdom, statistics were rated as the first in "difficulty", 17th in "usefulness", and last in "interest" (Juzych et al., 1992; Royal Commission on Medical Education, 1968).

In summary, medical practitioners and other health professionals lack confidence in their abilities to interpret statistics whilst sometimes acknowledging its importance. Knowledge of statistics in medical practitioners and other health professionals was low and largely inadequate to ensure correct appraisal of the literature can be undertaken. The frequent inclusion of junior doctors and/or students and residents in the studies reported above may not allow an accurate representation of the true knowledge of statistics in the health professions. Respondents with higher degree or extra training in statistics tended to exhibit better scores in both knowledge and attitudes, whether they were a medical or other health practitioner. The existing literature on KAP towards statistics suggests that health practitioners' understanding of simple statistical methods is poor. To our knowledge there have been no previous studies conducted on the KAP of optometrists towards statistics.

4.7.2. Aim

This study primarily aimed to measure Australian optometrists' knowledge, attitudes, and practice (KAP) towards statistics. A secondary aim was to explore the relationship between the optometrists' demographics and their KAP score.

4.7.3. Methods: Knowledge, Attitudes and Practice (KAP) Survey

A cross-sectional KAP survey was conducted on a representative sample of Australian optometrists in the period between July and November 2019.

4.7.3.1. Sample Size

The sample size for the KAP study was calculated using an online calculator (Sample Size Calculator (Use in 60 Seconds) // Qualtrics) , with a 95% confidence level, a 10% margin of error and a population size of 5781, which was the number of registered optometrists reported in the Optometry Board of Australia's Registrant Data report (July-September 2019) (Optometry Board of Australia, 2019); the resultant ideal sample size was 95 participants. Based on recent experience (response rate 13% to 20%), we anticipated a response rate of at least 10% (Jalbert et al., 2020). The KAP questionnaires were therefore mailed to a random sample of 1,000 optometrists registered for practice in Australia. Ethics approval was provided by the University of New South Wales (UNSW) Ethics Committee (approval number: HC190463).

4.7.3.2. Recruitment and Inclusion Criteria

Participants were individuals over the age of 18 who were registered as optometrists on the Australian Health Practitioner Registration Agency (AHPRA) register of practitioners (AHPRA, 2018). A random list of participants to invite was generated using a random letter generator, to determine the first two letters of surnames to search for on the online APHRA register of optometrists. A maximum of the first 50 names of any such a combination were included on the random list. This was continued until 1,000 names were generated. Optometry Board of Australia's Registrant Data indicate that there would have been 5,781 optometrists listed on the AHPRA register at the time random sampling occurred. The practitioner data provided on the AHPRA website including name, suburb and postcode was then used to obtain randomly sampled practitioners' addresses from publicly available sources, including the Internet and the yellow pages. An invitation containing a general outline of the study was addressed to each randomly sampled optometrist and mailed to that address with the KAP survey with a reply-paid envelope. Consent was implied through return of the KAP survey, as approved by the UNSW Ethics Committee.

4.7.3.3. Survey

A KAP survey was designed as described in Sections 4.7.3.3.1 to 4.7.3.3.3 below. Two supervisors reviewed a draft version of the instrument for content validity, piloted the survey and provided feedback. Based on feedback, questions were reworded to ensure a balance between "yes" and "no" responses and three questions were added to further assess practice of statistics.

The final KAP survey contained a total of 35 items under the sections of knowledge (17 items), attitudes (11 items of which 3 specifically focused on confidence) and practice (4 items). Three demographic questions about the participant's age, gender and postcode of primary practice were also collected. These items were developed by our research team, except where indicated below. A copy of the complete KAP survey can be found in Appendix 4-1.

4.7.3.3.1. Knowledge

Section 1 contained 17 statistical knowledge items that assessed understanding of statistical methods and study design. These items were developed based on the results of study 1 identifying the most frequently used statistical methods (Appendix 4-1, section 1). The knowledge items addressed statistical methods, confidence intervals, *p* values, and study design. The first 13 knowledge items required participants to identify whether a statement regarding statistics was correct or incorrect. Each item had 3 response options, Yes, No and Unsure.

The next 4 knowledge items (items 14-17) were adapted from Windish et al. (2007) and required participants to identify and match the appropriate statistical method or study design to a given scenario (Windish et al., 2007). These 4 multiple-choice items were clinically orientated with an appropriate eye-related case vignette and had 6 possible response options each with the correct answer scored 1 and all other incorrect answers scored zero. For other knowledge items, correct answers were scored 1, "Unsure" and incorrect answers we given a mark of zero, to give a possible range of 0 to 17 total Knowledge score.

4.7.3.3.2. Attitudes

Section two contained 11 attitude items (including 3 confidence items) regarding thoughts, feelings, and confidence regarding statistics. Many of the attitude and confidence items were adapted from Windish et al. (2007). Attitude questions 2, 3, 5, and 8 were adapted from Windish et al. and modified for use with optometrists. Attitude question 4, and confidence questions 1, 2 and 3 were taken from the Windish et al. survey without modifications (Windish et al., 2007). Attitude questions 1, 6, and 7 were developed by the investigators. Windish et al. adapted their attitudes and confidence questions from surveys on the Assessment Resource Tools for Improving Statistical Thinking (ARTIST) Web site, which is a resource for teaching statistical literacy, reasoning, and thinking (Garfield et al., 2003). Response options for attitude questions were a 5-point Likert scale with descriptors strongly disagree, disagree, neutral, agree, and strongly agree. Response options for confidence questions were a 5-step Likert scale with descriptors none, a little, a fair amount, a lot, and complete confidence.

For the purpose of total score calculations, the attitude and confidence sections were scored on a five-point Likert scale and summed together with total score ranging from 0 to 44. The five-point Likert scale was scored from 0 to 4 for the attitude responses with Strongly Disagree = 0, Disagree = 1, Neither Agree nor Disagree = 2, Agree = 3 and Strongly Agree = 4, and for the confidence responses with None = 0, A little = 1, A fair amount = 2, A lot = 3, and Complete confidence = 4, respectively. Higher scores indicating positive attitudes or greater confidence towards statistics. Attitude questions 1 and 7 were reverse scored.

4.7.3.3.3. Practice

Section three contained 4 practice questions regarding practical application of statistics. The Practice section was scored out of a maximum of 4, with a mark given if participants undertook certain practices. Question 3 of the practice section was negatively scored. Higher scores in this section indicated more positive practices of statistics. These questions were developed by our research team.

4.8. Data Analysis Plan

Results for KAP are reported using descriptive statistics such as frequencies, means, standard deviations, proportion of correct, incorrect, and unsure responses for each question. The Modified Monash Model (MMM) was used to classify optometrists' geographical locations Table **4.11**) based on the postcode of their primary practice location (Australian Government, 2019). The MMM classifies area according to their geographical remoteness and size on a 7-point scale where MM 1 is a major city and MM 7 is very remote.

In order to assess the internal consistency of the Likert questions to see how consistent they are as a scale; Cronbach's alpha was used. A Cronbach's alpha score of 0.7 or above was considered robust (George & Mallery, 2003) and the higher the Cronbach alpha, the more inter-correlated the scale items would be (Sullivan & Artino, 2013).

To see if the demographic variables collected predicted scores on each of the KAP tests, regressions were performed. Demographic predictors such as age, gender and regionality were linearly regressed on the scores of Knowledge and Attitude. Practice was considered in an ordinal manner and thus an ordinal regression model was implemented. Prior to running the analysis variables were tested for assumptions of normality and linearity.

4.9. Results of Study 2- KAP Statistics Survey of Optometrists

4.9.1. Response Rate and Demographics

An error in the printing of labels for survey envelopes meant that the KAP survey was inadvertently sent to 775 optometrists instead of the 1,000 initially planned sample. Two hundred and twenty-five optometrists were also inadvertently mailed an invitation twice. Sixty-nine envelopes were returned to sender. It can thus be assumed that the survey was received by a maximum of 706 optometrists. Ninety-two of 706 surveys were completed and returned (response rate 13%).

The demographics of the participants who completed and returned the survey are summarized in this section. Slightly more females (n=50) participated than males (n=41) (54.3% vs 44.6%) returned the KAP survey. One participant (1%) did not provide gender information. The average age of participating optometrists ranged from 25 to 75 years with an average age of 44.0 years (SD=11.7). The highest represented age group was the 25 - 29 years old group (16.3%) whilst the lowest was 65 years old and above (2.2%) (Figure 4.6) Four (4.3%) participants did not provide their exact age, three of them indicating their ages as "40-50", "50+", and "> 55", and one did not answer the question.

A summary of participants' primary practice location is provided in Figure 4.7. A majority of participants practiced in New South Wales (45.7%). Very few participants practiced in the Australian Capital Territory (1.1%), and there were no participants from the Northern Territory. Data was missing for 2 (2.2%) participants.

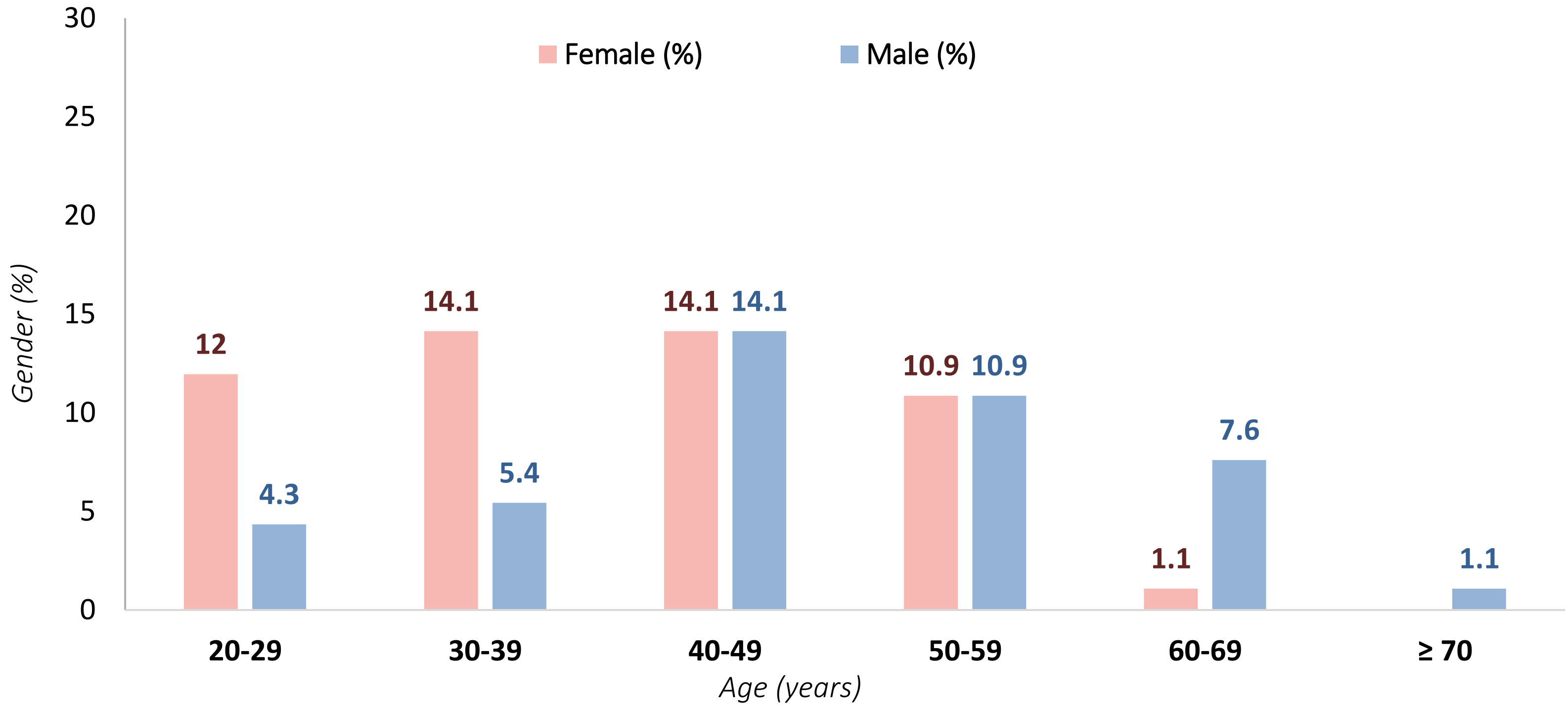


Figure 4.6 Demographics of KAP Respondents (n=92)
One (1.1%) and four (4.3%) did not provide gender and age, respectively.

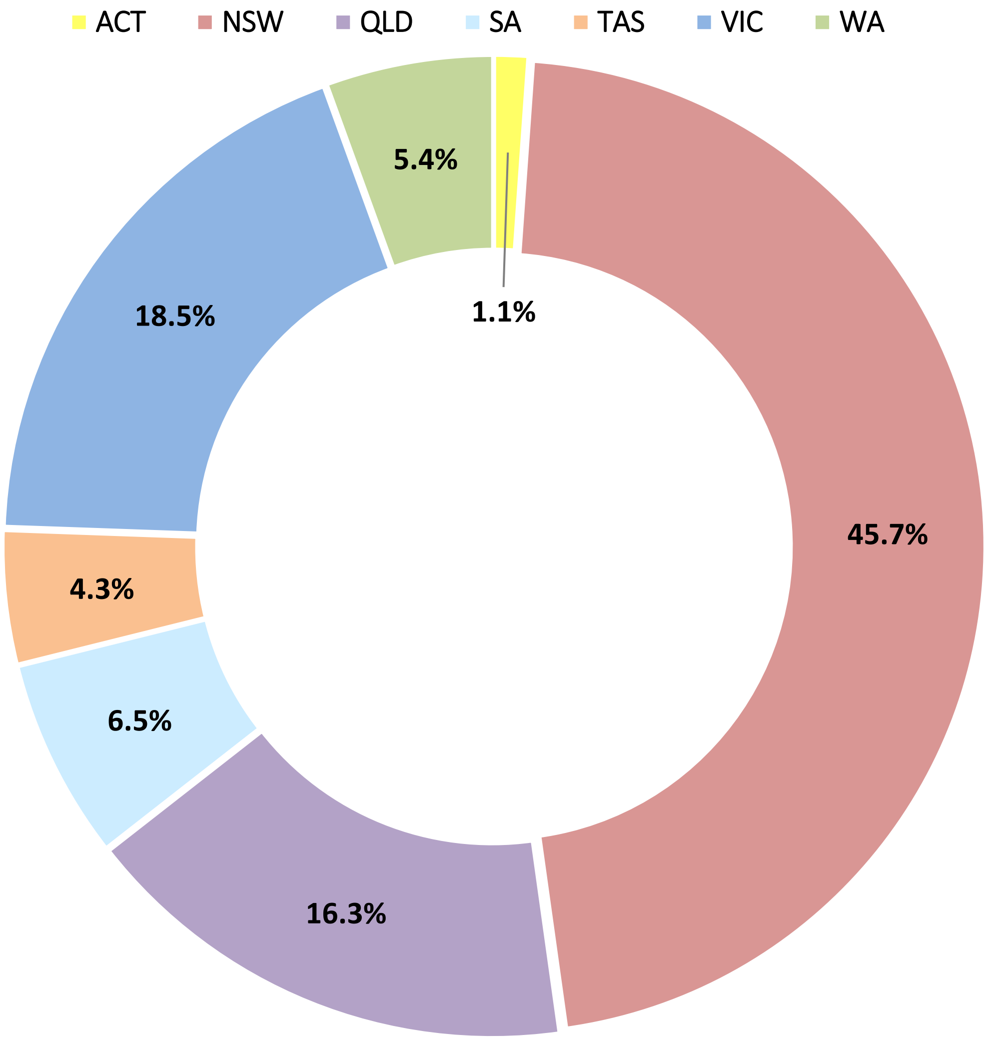


Figure 4.7 Frequency (%) of the KAP Respondents' (n=92) Primary Practice Location (State)

ACT: Australian Capital Territory; NSW: New South Wales; QLD: Queensland; SA: South Australia; TAS: Tasmania; VIC: Victoria; WA: Western Australia. There were no participants from the NT (Northern Territory). Data was missing for 2 (2.2%) participants.

Optometrists participating in the KAP survey primarily practiced in metropolitan regions (MM 1) (68.5%) (Table **4.11**). Fifteen (16.3%) optometrists practiced in regional centers (MM 2) and seven (7.6%) in small rural towns (MM 5). Two (2.2%) optometrists practiced in large rural towns (MM 3), and another two (2.2%) participants did not provide their primary practice location (postcode). Only one optometrist practiced in a remote community (MM6). No participant practiced in a very remote community (MM 7).

Table 4.11 KAP Study Participants' Primary Practice Location Categorized by Modified Monash Model Category (MMM, 2019)

Modified Monash Model Category (MMM, 2019)	*The Australian Standard Geographical Classification – Remoteness Area (2016)*	*KAP participants primary practice location n (%)*
MM 1	Metropolitan	63 (68.5)
MM 2	Regional centers	15 (16.3)
MM 3	Large rural towns	2 (2.2)
MM 4	Medium rural towns	2 (2.2)
MM 5	Small rural towns	7 (7.6)
MM 6	Remote communities	1 (1.1)
MM 7	Very remote communities	0
Not specified by the participant		2 (2.2)
	Total	90 (97.8)

Two participants (2.2%) did not specify the postcode of their primary practice location.

4.9.2. Knowledge

Table 4.12 presents frequencies of correct responses for the knowledge section of the KAP survey, which was scored from 0 to 17. The possible answers to the knowledge section (Appendix 4-1, section 1) include options of Yes, No, or Unsure. Any incorrect or unsure response was scored as zero and the correct response was scored as one. All 92 (100%) participants responded to the Knowledge section questions and there were no missing data. For the 92 participants the overall mean (SD) was 8.39 (3.45) from a possible total of 17, demonstrating a poor to moderate level of statistical knowledge that is just below an arbitrary pass mark of 50% or 8.50 out of 17. The overall Cronbach alpha was above 0.7 (at 0.77) indicating an internally consistent scale.

Figure 4.8 presents a stacked bar chart with the correct, incorrect, and unsure responses to each question of the knowledge section of the KAP survey. Participants had the most knowledge of measures of central tendency and spread of the data (mean, mode, confidence interval, distribution, and SEM corresponding to items 1, 2, 4, 8, and 9) and the least knowledge of study design (based on incorrect responses corresponding to item 17) and Chi-Square statistics (based on incorrect + unsure responses corresponding to item 15). There was most uncertainty regarding statistical tests and their application (items 7, 14, 15, and 16). There were no incorrect responses regarding knowledge of t-test (item 5).

Table 4.12 Optometrists' Knowledge of Statistics

Frequency of correct responses (n) and percentage (%) of participants for the Knowledge section of the KAP survey.

Item no.	*Knowledge questions*	*Frequency (%)*
1	The mean is the middle score when scores are ranked in order	71 (77.2)
2	The mode is the score that occurs most commonly in the data set	79 (85.9)
3	P > 0.05 means that the probability of an outcome occurring is less than 1 in 20 if the study was repeated	49 (53.3)
4	A 95% confidence interval indicates a 95% chance that the calculated confidence interval contains the true mean	68 (73.9)
5	A t-test is used to determine if there is a significant difference between the means of two groups	51 (55.4)
6	A significant P-value gives valuable information about the size of the difference or effect between two means or proportions	40 (43.5)
7	Pearson's chi-square test is used to determine whether there is a relationship between different categorical variables	24 (26.1)
8	A histogram that shows normal distribution is symmetrical and bell-shaped	72 (78.3)
9	Standard error of the mean (SEM) is a measure of variability from the mean	72 (78.3)
10	An interquartile range is a range from the 25th percentile to the 75th percentile	47 (51.1)
11	The null hypothesis states that an effect is present, i.e., there is a significant difference between groups	52 (56.5)
12	The correlation coefficient (r) is always found between +/- 1	49 (53.3)
13	A correlation coefficient (r) is determined to be -0.99. This means there is poor or no correlation between x and y variables	31 (33.7)
A prospective study looked at AMD, diet, and smoking on individuals. Which of these statistical methods would be MOST appropriate to demonstrate:		
14	That mean age does not vary across 4 groups of individuals with AMD	16 (17.4)
15	That multivitamin use does not vary across the 4 groups of individuals with AMD	7 (7.6)
16	That mean level of AMD is the same for the high vitamin and low vitamin consumption group	19 (20.7)
17	To determine if smoking is associated with glaucoma, data from 40 patients with glaucoma were collected. These patients were matched for age, sex, and race to patients without glaucoma. The investigators then reviewed whether these patients were previous smokers. This study type	21 (22.8)

is known as	
Overall Mean M (SD)	*Cronbach alpha (α)*
8.39 (3.45)	0.77

Scores range; 0 to 17.

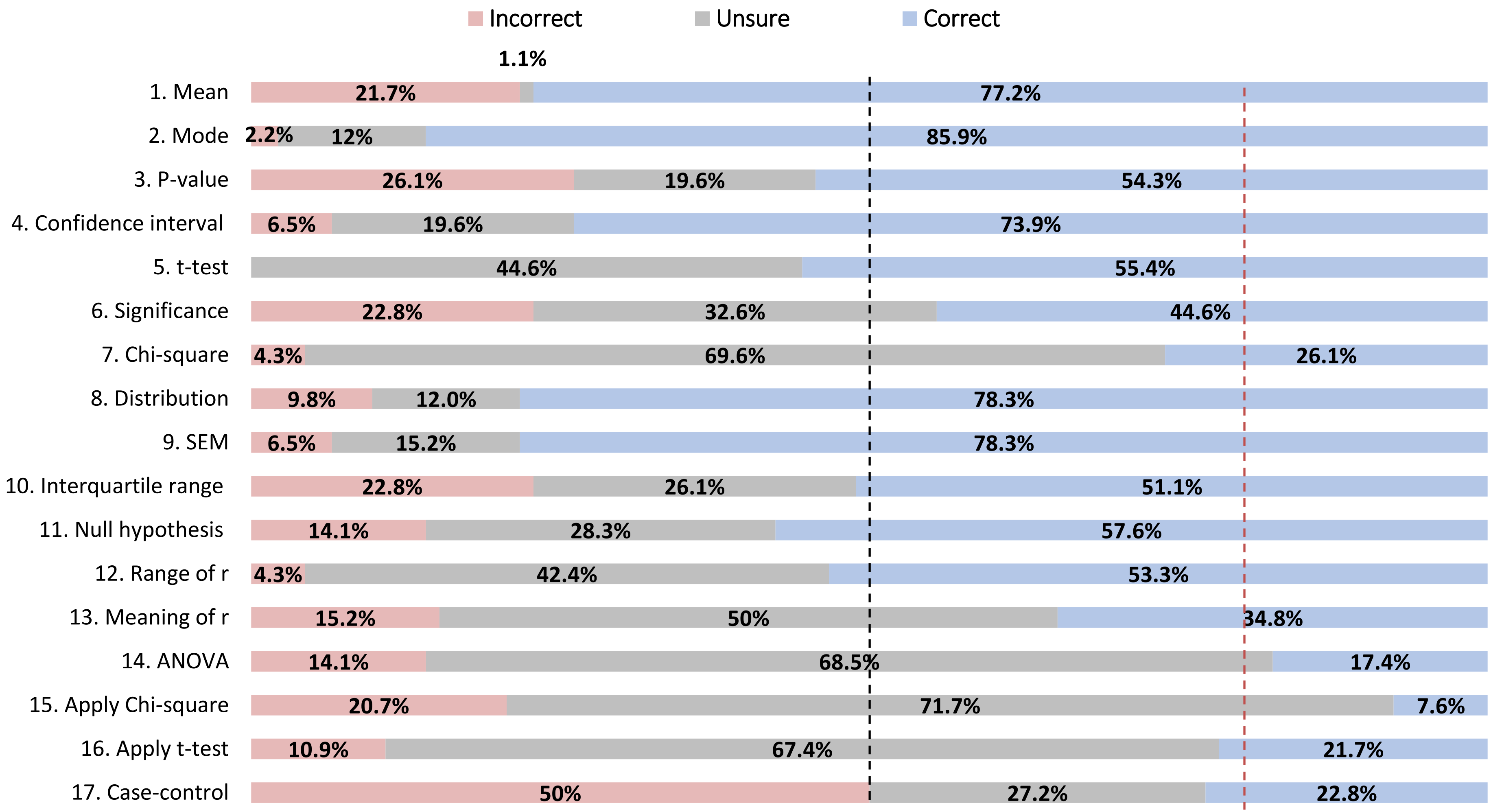


Figure 4.8 Frequency (%) of Correct (Blue), Incorrect (Red) and Unsure (Grey) Knowledge of Statistics Responses (n=92)

Questions are abbreviated for the purpose of clarity of the figure (see Appendix 4-1). Vertical dashed lines are presented to assist with visualizing which questions scored more than 50% correct responses (black, vertical, dashed line) or only 20% correct responding (orange, vertical, dashed line). For example, the blue bar for question 3, p value, sits to the left of the black dashed line indicating more than 50% correct responding, whereas for question 14, ANOVA, the blue bar ends on the right of the dashed orange vertical bar indicating less than 20% correct responses.

4.9.3. Attitude

All 92 (100%) participants completed the attitude questions (Appendix 4-1, section 2) and there were no missing data. Descriptive and statistical data are presented in Table 4.13, Table 4.14, and Figure 4.9. Overall, participants displayed a poor attitude to statistics (M=20.59, SD=6.41) out of a maximum positive possible score of 44, with a mean score of 20.59 that is just below the mid-point of the total Attitude score (22 of 44). Cronbach alpha was above 0.7 (α=0.81) indicating an internally consistent scale.

Attitude items 4, 5, 7 and 8 had the highest rates of agreement, with over 75% of participants agreeing or strongly agreeing with each statement (noting that for item 7 a high level of agreement indicates a negative attitude and was reverse scored accordingly). Questions 3 had the highest disagreement rate with 75.0% of participants disagreeing or strongly disagreeing with the statement (Table 4.14). Participants displayed the most confidence at assessing the correctness of statistical procedures and the least confidence at interpreting statistics or statistical power.

Table 4.13 Optometrists' Attitudes to Statistics
Frequency of responses (n) and percentage (%) of participants for the Attitude section of the KAP survey.

Attitude questions				
Strongly Disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*
1. I am uncomfortable/put off by statistics*				
8 (8.7)	21 (22.8)	25 (27.2)	26 (28.3)	12 (13.0)
2. I have the knowledge and skills required to interpret all descriptive statistics in journal articles (mean, standard deviation, histograms)				
11 (12.0)	36 (39.1)	12 (13.0)	25 (27.2)	8 (8.7)
3. I have the knowledge and skills required to interpret all inferential statistics in journal articles (t-tests, contingency tables, non-parametric tests)				
26 (28.3)	43 (46.7)	10 (10.9)	12 (13.0)	1 (1.1)
4. To be an intelligent reader of the literature, it is necessary to know something about statistics				
2 (2.2)	4 (4.3)	5 (5.4)	61 (66.3)	20 (21.7)
5. I see the relevance of statistics in shaping my clinical decision making as an optometrist				
1 (1.1)	7 (7.6)	14 (15.2)	54 (58.7)	16 (17.4)
6. Adequate education regarding statistics was provided during my optometry training				
10 (10.9)	24 (26.1)	21 (22.8)	34 (37.0)	3 (3.3)
7. I have previously had a better understanding of statistics than I do now but have forgotten due to lack of use/other reasons*				
3 (3.3)	8 (8.7)	7 (7.6)	37 (40.2)	37 (40.2)
8. Given the chance, I would like to have a better understanding of statistics				
0	5 (5.4)	14 (15.2)	57 (62.0)	16 (17.4)
Confidence questions				
None	*A little*	*A fair amount*	*A lot*	*Complete confidence*
Rate your confidence in your current level of ability in the following activities:				
9. Interpreting the results of a statistical method used in research				
2 (2.2)	11 (12.0)	29 (31.5)	45 (48.9)	5 (5.4)
10. Assessing if the correct statistical procedure was used to answer a research question				
2 (2.2)	6 (6.5)	15 (16.3)	31 (33.7)	38 (41.3)
11. Identifying factors that influence a study's power				
4 (4.3)	6 (6.5)	27 (29.3)	47 (51.1)	8 (8.7)

**Questions 1 and 7 are reversed scored.*

Table 4.14 Optometrists' Attitudes to Statistics
Likert scale descriptive statistics for the Attitude section of the KAP survey (n=92).

Median (Mdn)	*Interquartile range (IQR)*
Attitude questions	
1. I am uncomfortable/put off by statistics*	
Neutral	2.00
2. I have the knowledge and skills required to interpret all descriptive statistics in journal articles (mean, standard deviation, histograms)	
Disagree	2.00
3. I have the knowledge and skills required to interpret all inferential statistics in journal articles (t-tests, contingency tables, non-parametric tests)	
Disagree	2.00
4. To be an intelligent reader of the literature, it is necessary to know something about statistics	
Agree	0.00
5. I see the relevance of statistics in shaping my clinical decision making as an optometrist	
Agree	0.00
6. Adequate education regarding statistics was provided during my optometry training	
Neutral	2.00
7. I have previously had a better understanding of statistics than I do now but have forgotten due to lack of use/other reasons*	
Disagree	1.00
8. Given the chance, I would like to have a better understanding of statistics	
Agree	0.00
Confidence questions	
Rate your confidence in your current level of ability in the following activities:	
9. Interpreting the results of a statistical method used in research	
a little	1.00
10. Assessing if the correct statistical procedure was used to answer a research question	
a little	2.00
11. Identifying factors that influence a study's power	
a little	1.00
Overall Mean M (SD)	*Overall Cronbach alpha (α)*
20.59 (6.41)	*0.81*

Scores range; 0-44.
**Questions 1 and 7 are reversed scored.*

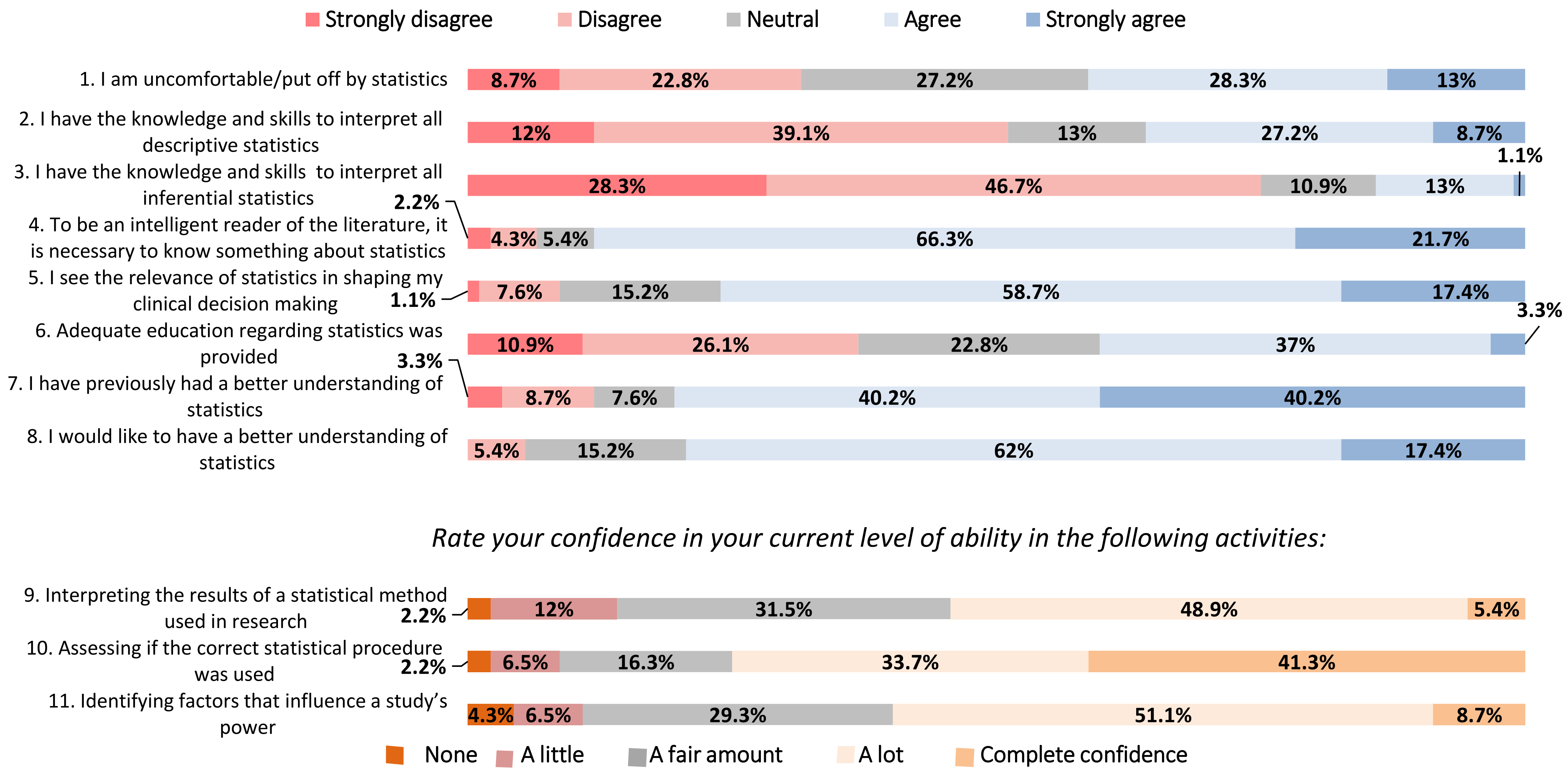


Figure 4.9 Frequency (%) of the Attitude (items 1 to 8) and Confidence (items 9 to 11) Section of the KAP Responses (n=92) for Each Question

Questions are abbreviated for the purpose of clarity of the figure (see Appendix 4-1, Section 2).

Questions 1 and 7 are reversed scored in the calculation of a total Attitude score.

4.9.4. Practice

Table 4.15 presents frequencies, means, standard deviations for the practice section of the KAP survey which was scored from 0 to 4. The answers of the Practice section (Appendix 4-1, section 3) of the KAP survey ranges between Yes, No, or Unsure. We scored any wrong or unsure response to the practice questions as zero and the correct response got a score of one. As question three was worded in the negative it was reverse scored for the calculation of the total Practice score.

For the 92 (100%) participants the overall mean 1.24 with of SD of 1.23 out of a total 4, demonstrating a poor level of statistical practice in our KAP survey that is below an arbitrary pass mark of 50% of 2 out of 4. The overall Cronbach of 0.64 was considered "good" for a four-item scale, indicating an internally consistent scale. The smallest Cronbach alpha was associated with question four (α=0.52), which when deleted did not significantly alter the total Cronbach alpha.

Participants demonstrated good practice of statistics for only one of four items sampled: a slight majority of participants (52.2%) reported applying their statistical knowledge to make clinical decisions. Only 12.0% of participants indicated that they actively kept up to date with statistical knowledge (item 4). Additionally, 59.8% did not critically appraise articles from optometric journals (item 2), whilst 66% of participants indicated that they tend to ignore or skip the statistics section in journals (item 3). The frequency of each response in each of the four questions are shown Figure 4.10.

Table 4.15 Optometrists' Practice of Statistics

Frequency of (Yes) responses (n) and percentage (%) of participants for the Practice section of the KAP survey.

Question no.	*Frequency (%)*	*Mean (SD)*
1	**I use my statistical knowledge in forming opinions or making decisions as an optometrist**	
	48 (52.2)	0.52 (0.50)
2	**I critically appraise scientific articles that I read in optometry journals such as Optometry Vision Science and Clinical Experimental Optometry**	
	28 (30.4)	0.30 (0.46)
3	**I tend to ignore or skip the statistics section when reading scientific articles and focus on the results**	
	27 (29.3)	0.29 (0.46)
4	**I try to keep my knowledge of statistics up to date**	
	11 (12.0)	0.12 (0.33)
	Overall Mean M (SD)	*Cronbach alpha (α)*
	1.24 (1.23)	*0.64*

Score range; 0-4. Question 3 is reverse scored, that is 29.3% of people did not skip the stats section.

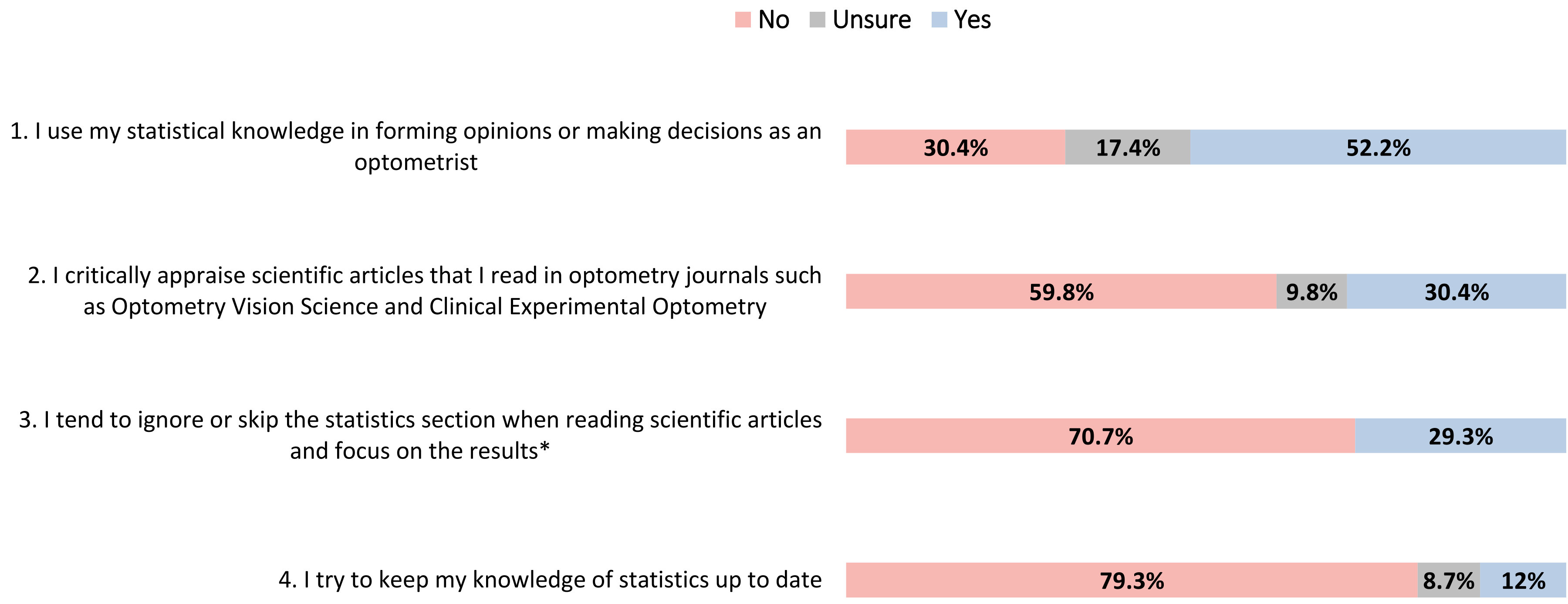


Figure 4.10 Frequency (%) of the Practice Section of the KAP Responses (n=92) for Each Question (Appendix 4-1, section 3)
**Question 3 is reversed scored such that the pink bar shows 70.7% gave a response of skipping the statistics section.*

4.9.5. Summary of KAP Frequencies

The following figures (Figure 4.11 to Figure 4.19) summarize the frequency data results for the KAP survey. KAP results are presented by age groups (Figure 4.12, Figure 4.13, Figure 4.14, and Figure 4.15), gender (Figure 4.16) and location (Figure 4.17, Figure 4.18, and Figure 4.19) prior to conducting regressions in the next section (Section 4.9.6).

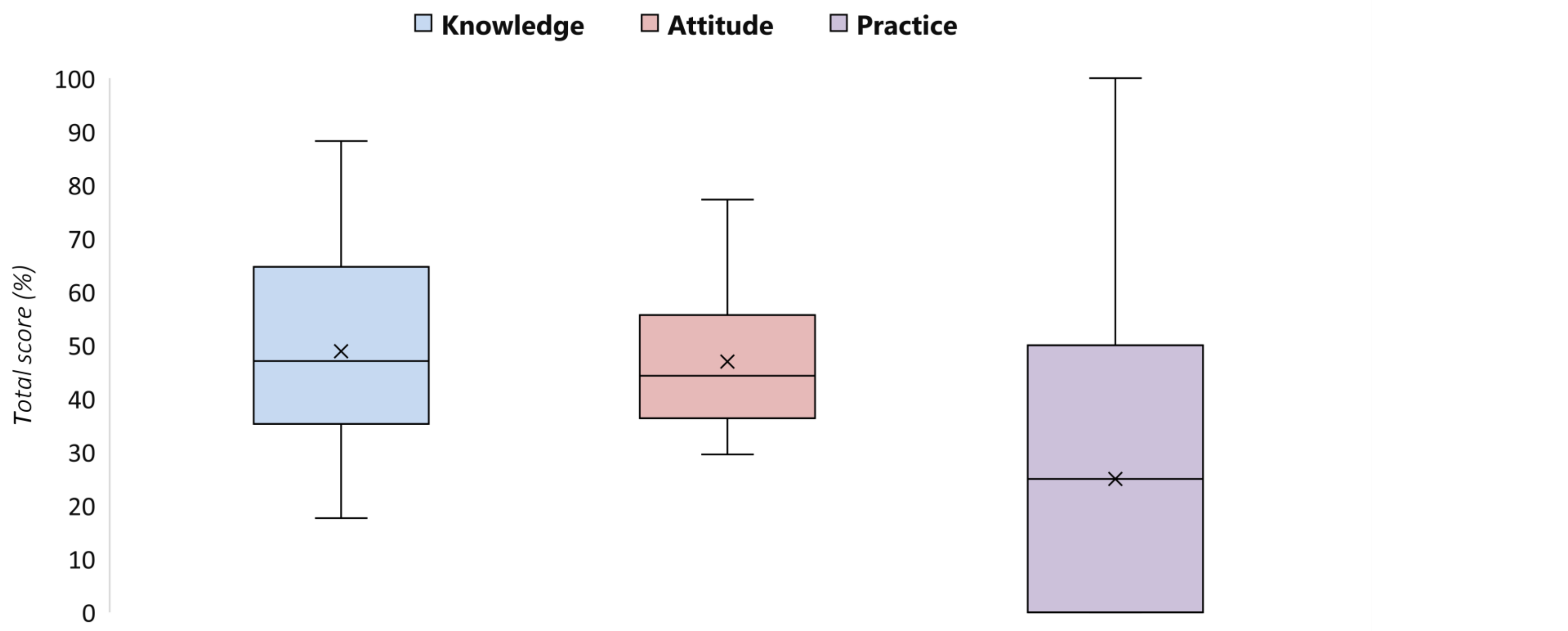


Figure 4.11 Knowledge, Attitude, and Practice of Statistics Total Scores Presented as Percentages to Allow for Comparison (n=92)

4.9.5.1. *Age KAP Graphs*

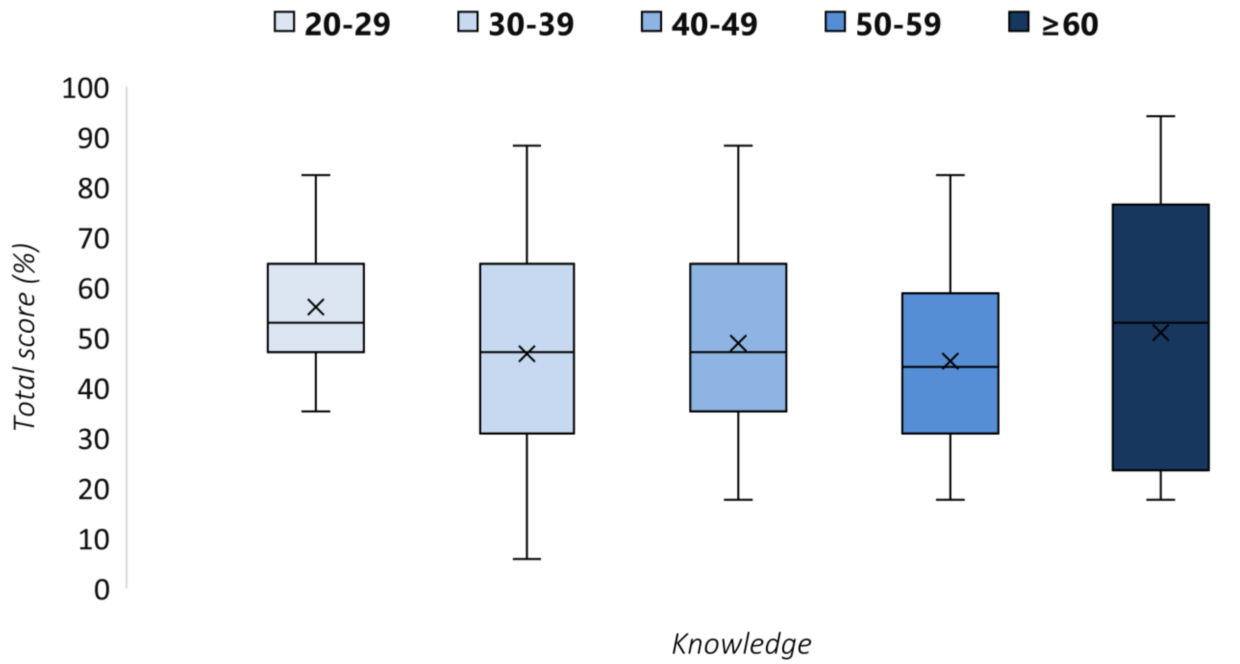


Figure 4.12 Knowledge of Statistics by Age (n=88)
Ages of four participants (4.3%) were "Missing".

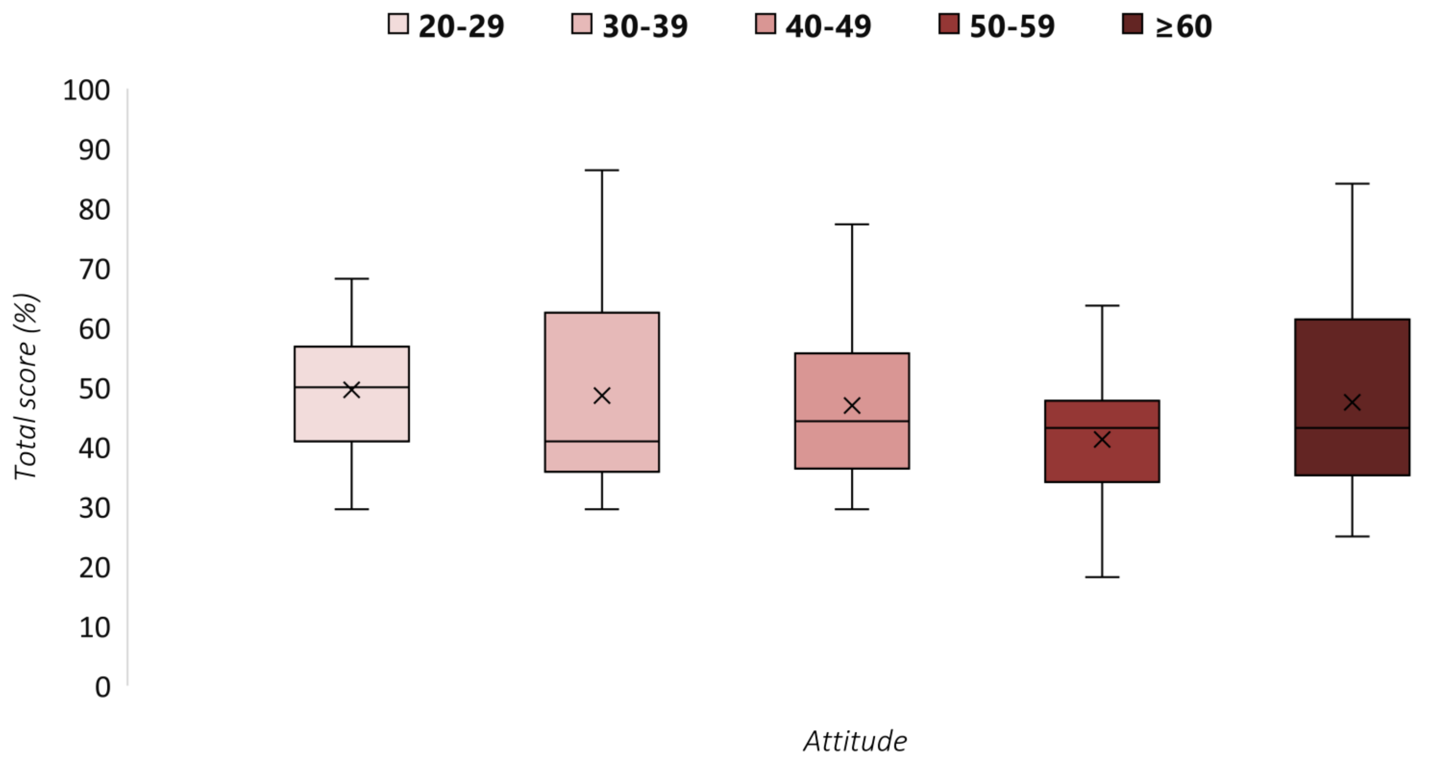


Figure 4.13 Attitude and Confidence in Statistics by Age (n=88)

Ages of four participants (4.3%) were "Missing".

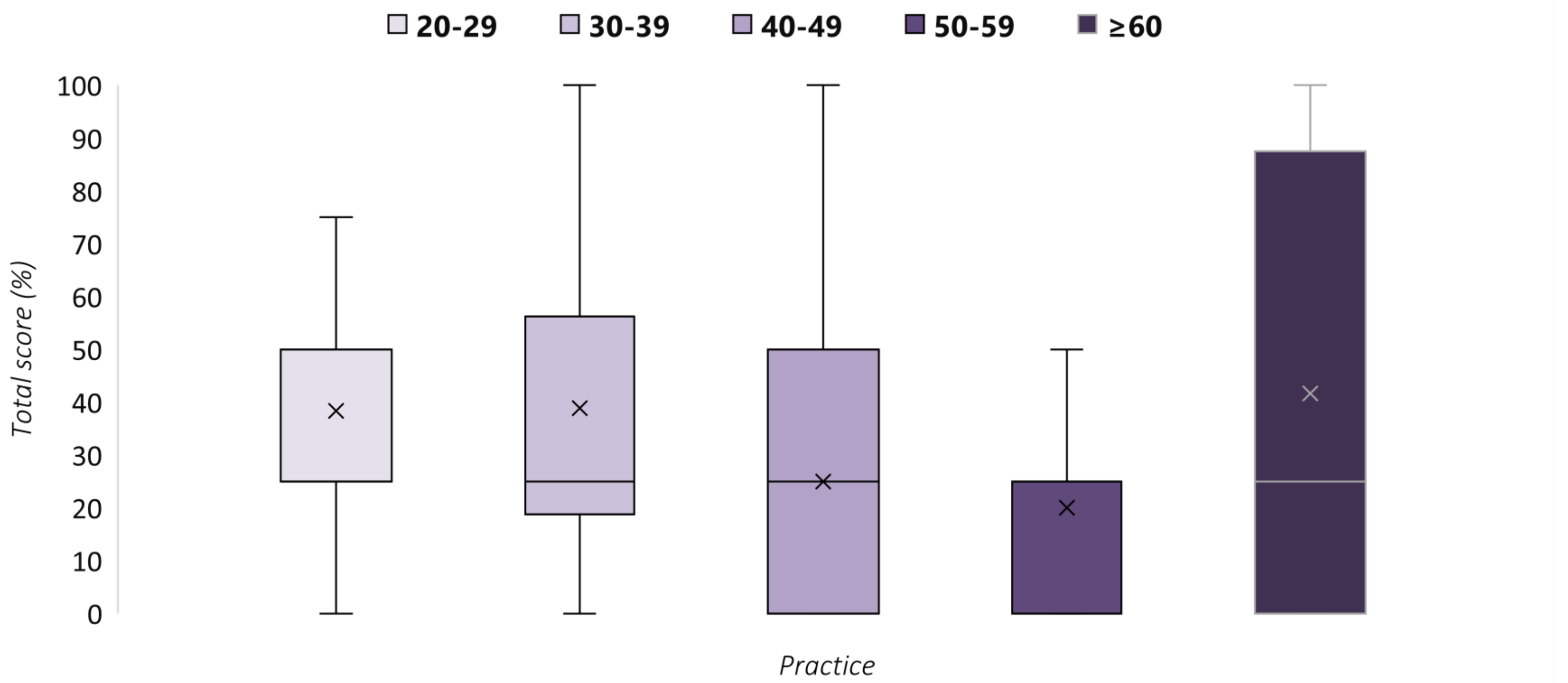


Figure 4.14 Practice of Statistics by Age (n=88)
Ages of four participants (4.3%) were "Missing".

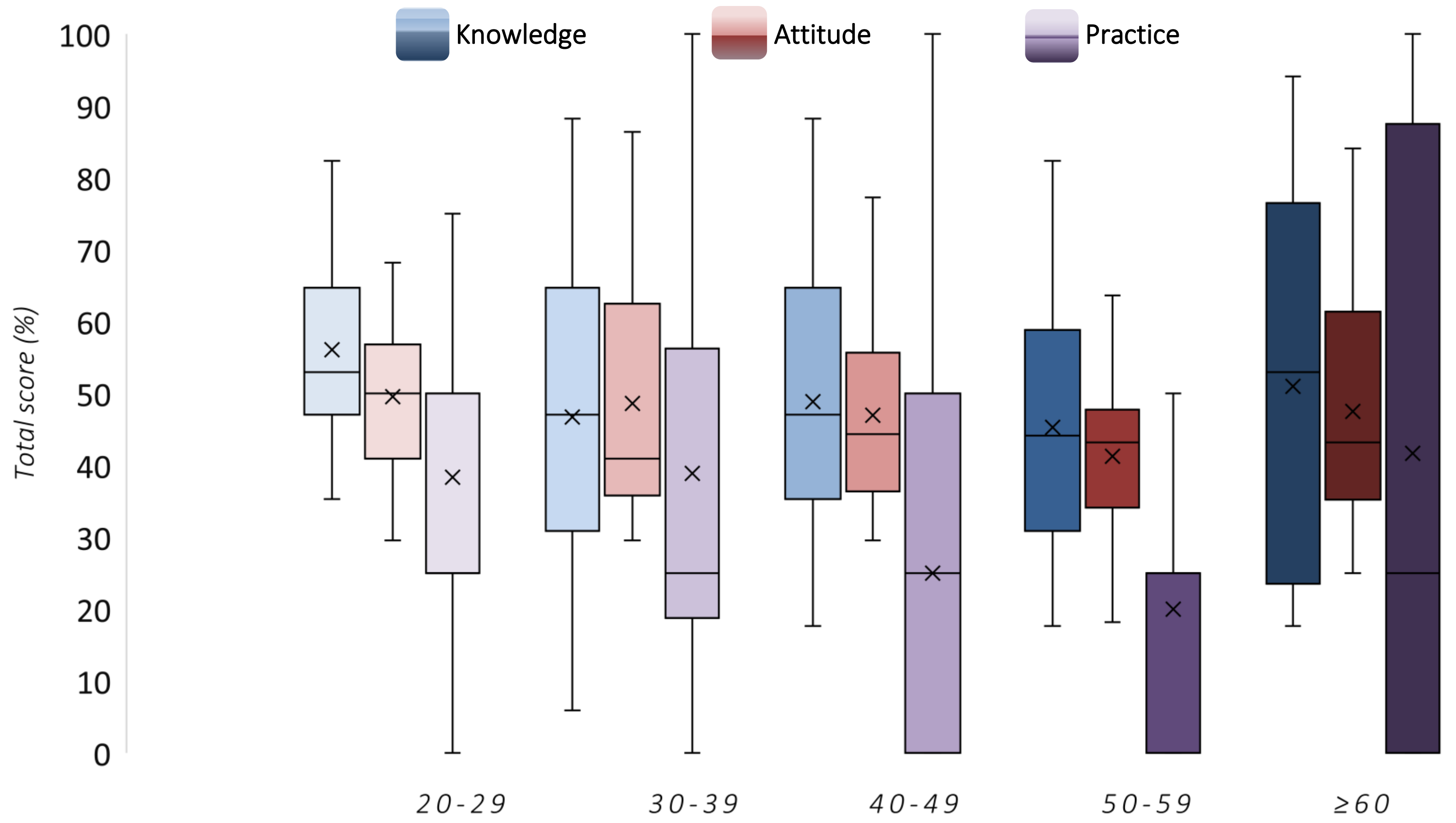


Figure 4.15 Knowledge (Blue Colors), Attitude (Red Colors), and Practice (Purple Colors) of Statistics (Normalized) by Age (n=88)
Ages of four participants (4.3%) were "Missing".

4.9.5.2. Gender KAP Graphs

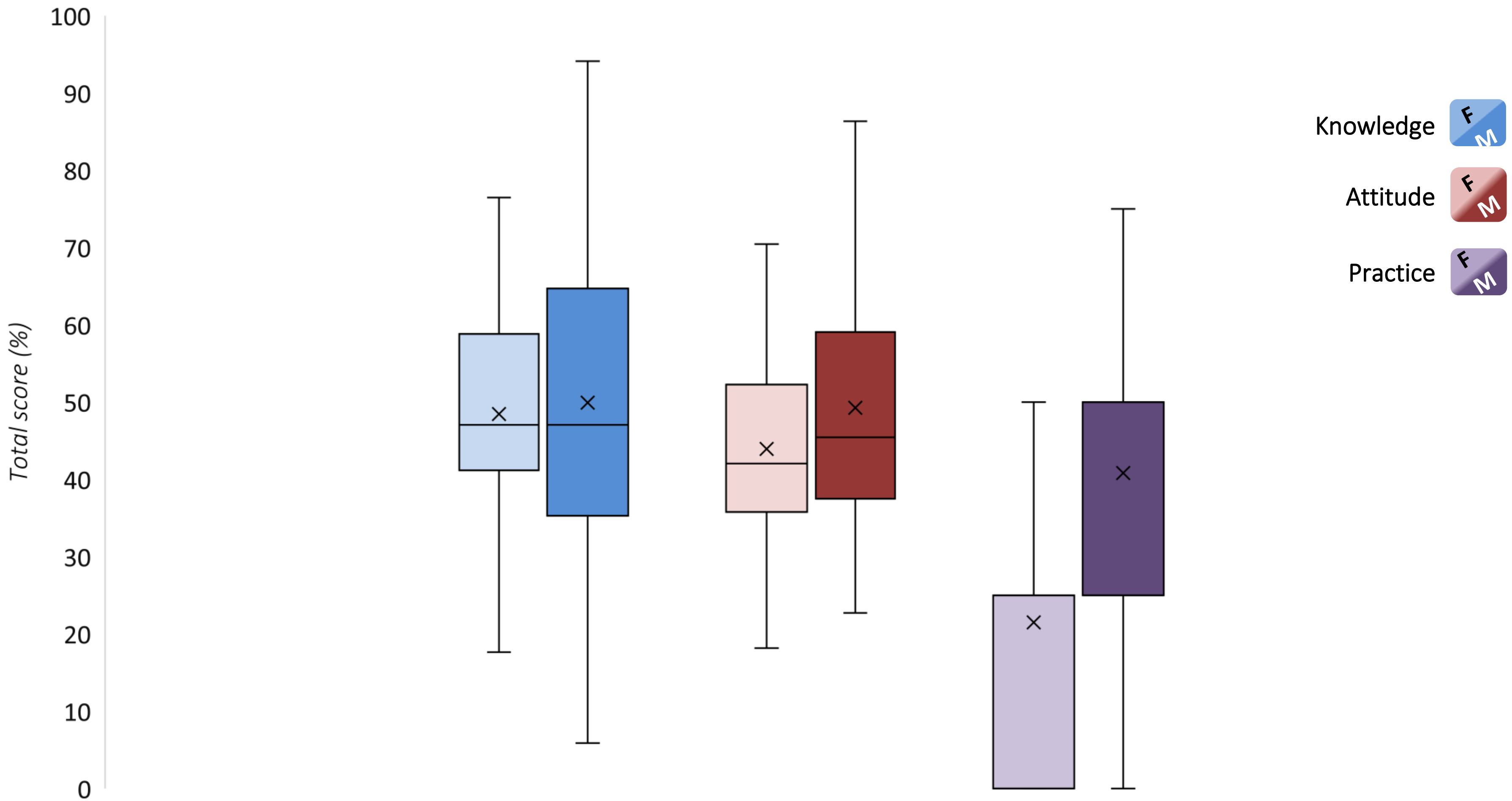


Figure 4.16 Knowledge, Attitude, and Practice of Statistics (Normalized) by gender (n=91)
One participant (1.1%) did not provide Gender type.

4.9.5.3. MM graphs

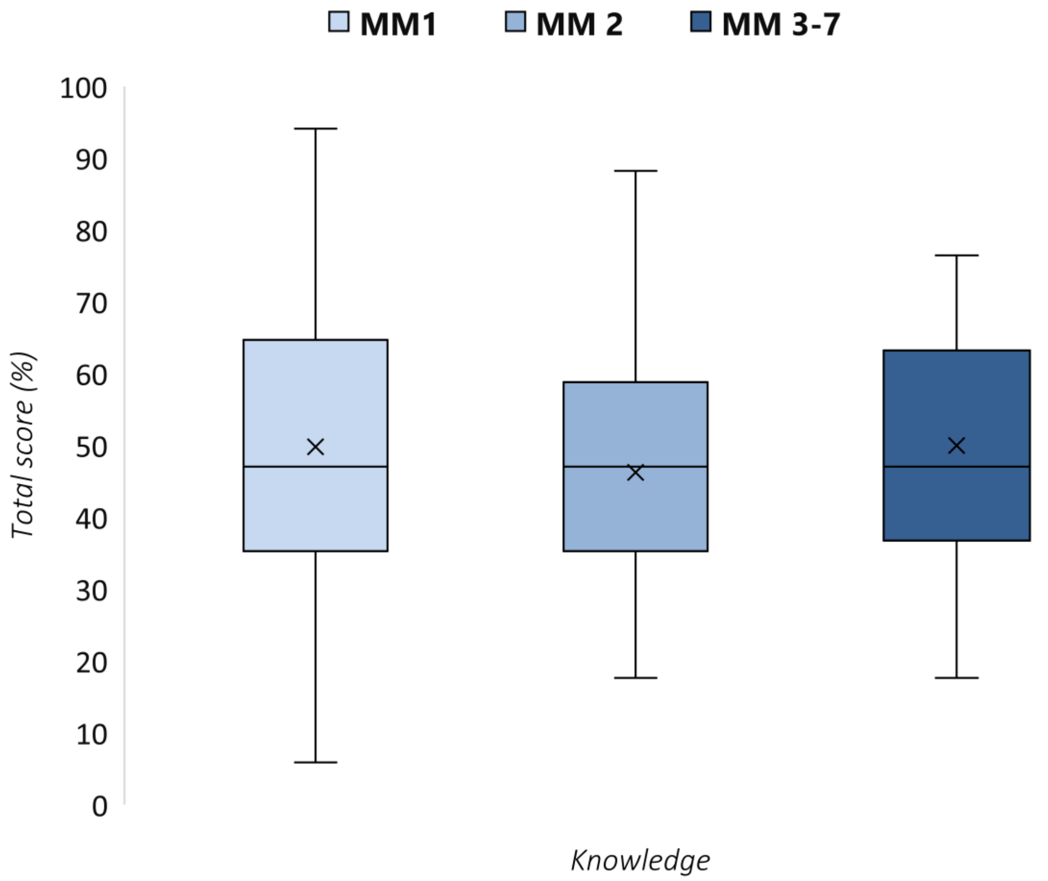


Figure 4.17 Knowledge of Statistics by Postcode of Primary practice in the MMM Categorization (n=90)

MMM: Modified Monash Model (2019).

MM 1: Metropolitan area, MM 2: Regional centers, MM 3: Large rural towns, MM 4: Medium rural towns, MM 5: Small rural towns, MM 6: Remote communities, MM 7: Very remote communities.

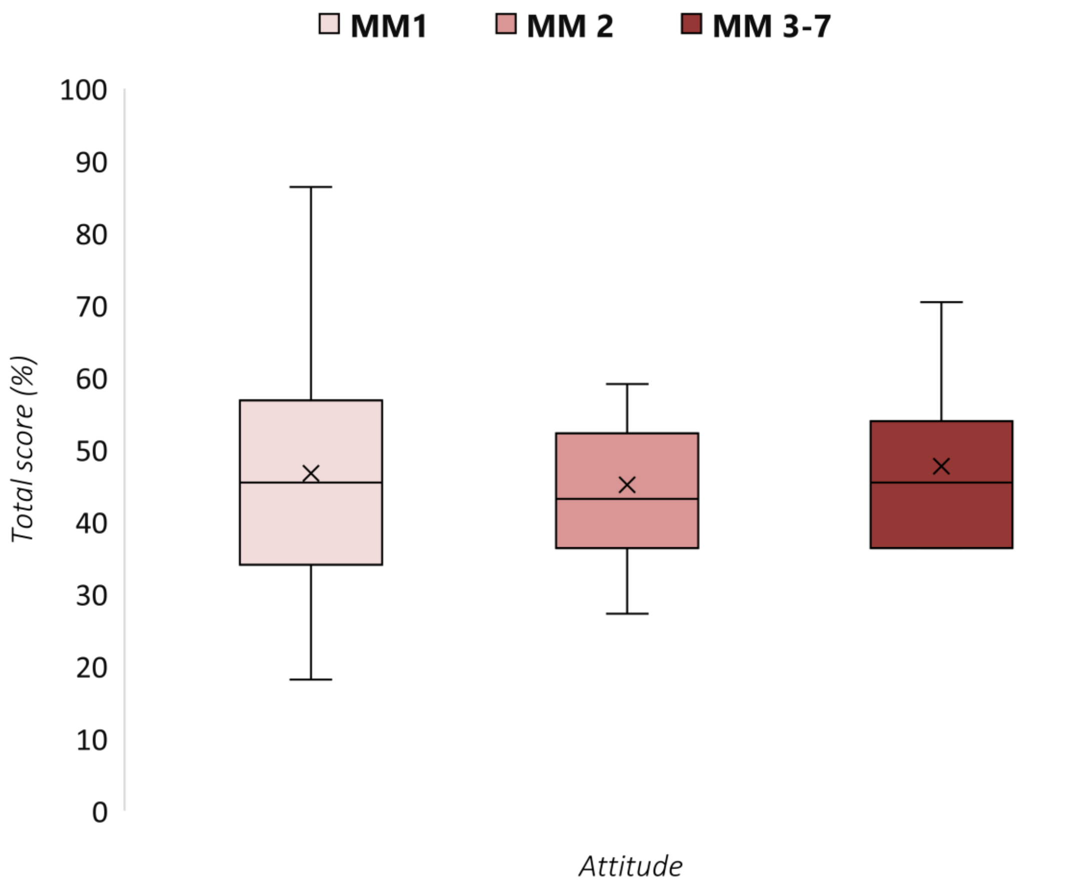


Figure 4.18 Attitude of Statistics by Postcode of Primary Practice in the MMM Categorization (n=90)

MMM: Modified Monash Model (2019).

MM 1: Metropolitan area, MM 2: Regional centers, MM 3: Large rural towns, MM 4: Medium rural towns, MM 5: Small rural towns, MM 6: Remote communities, MM 7: Very remote communities.

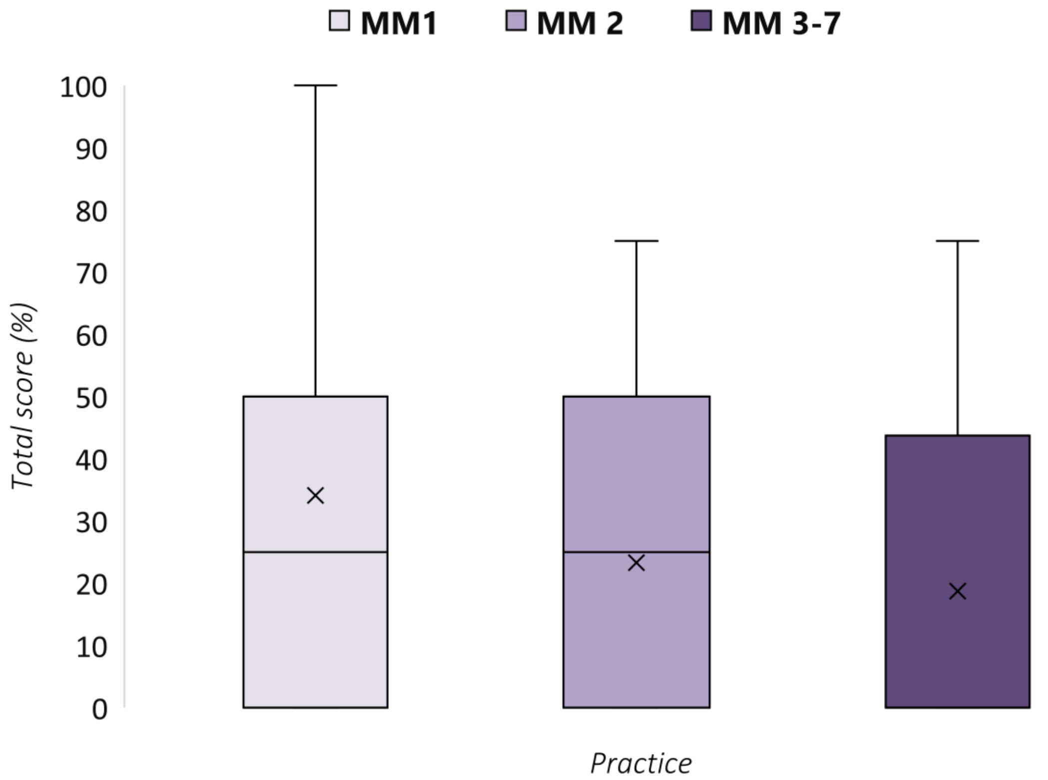


Figure 4.19 Practice of Statistics by Postcode of Primary Practice in the MMM Categorization (n=90)
MMM: Modified Monash Model (2019).
MM 1: Metropolitan area, MM 2: Regional centers, MM 3: Large rural towns, MM 4: Medium rural towns, MM 5: Small rural towns, MM 6: Remote communities, MM 7: Very remote communities.

4.9.6. Regression Results

In order to see if the demographic variables collected predicted scores on each of the KAP tests, regressions were performed. Our theoretical question was to explore the cumulative effect of the 3 variables (age, gender, and postcode of primary practice) regression describes the variance accounted for, not just individual significance. Therefore, demographic predictors such as age, gender and regionality were linearly regressed on the scores of Knowledge and Attitude. Practice was considered in an ordinal manner and thus an ordinal regression model was implemented here. Due to only 12 people (13 %) responding from areas outside of metropolitan and regional centers (see Table **4.11**), MM levels 3 to 7 were collapsed into a category called rural or remote for regression analyses. The three categories analyzed were:

1) Metropolitan (MM 1).
2) Regional center (MM 2).
3) Rural or Remote (MM 3, MM 4, MM 5, MM6 and MM 7).

4.9.6.1. Linear Regression Results for Knowledge, Attitude and KAP

Regressing the Knowledge score onto demographics revealed that age alone does not significantly predict scores on the Knowledge test. Neither did gender or location. Combining the three variables together also did not predict one's Knowledge score.

With respect to the Attitude linear regression, being female alone significantly predicts a lower Attitude score than males (b=-2.57, p=0.048). Combining all variables in the full statistical model revealed significant effects for both gender and age. Female respondents again showed significantly lower scores than males (b=-3.760, p=0.008). Also, for each year of age the Attitude score decreased by 0.12 points (b=-0.12, p=0.0493).

For overall KAP score, the only significant predictor was being female (Table 4.16). When all other variables were considered, female respondents showed lower scores than males (b=-5.49, p=0.0166). We are interested in exploring the effect of the variables together, that is why we input all the variables in Table 4.16.

Table 4.16 Linear Regression Results for the Predictors of Age, Gender and Regionality on Knowledge Scores, Attitude Scores and Total KAP Score. Ordinal Logistic Regression Results of Demographics on Practice Score were also Included

Significance was set at alpha 0.05. KAP: Knowledge, Attitude, Practice.

Model	*Knowledge*			*Attitude*		
Individual variables	**Estimated *b***	**95% CI**	***p***	**Estimated *b***	**95% CI**	***p***
Age	-0.02	[-0.08, 0.04]	0.54	-0.06	[-0.17, 0.05]	0.29
Female	-0.39	[-1.87, 1.10]	0.61	-2.57	[-5.07, -0.06]	0.0480*
Metropolitan	-0.53	[-2.78, 1.72]	0.64	-0.15	[-4.05, 3.75]	0.94
Regional Centre	-1.13	[-3.86, 1.59]	0.42	-0.95	[-5.68, 3.77]	0.69
All variables in model	**Estimated *b***	**95% CI**	***p***	**Estimated *b***	**95% CI**	***p***
Age	-0.03	[-0.10, 0.04]	0.39	-0.12	[-0.23, 0.00]	0.0493*
Female	-0.76	[-2.39, 0.87]	0.37	-3.76	[-6.47, -1.05]	0.0080*
Metropolitan	-0.69	[-2.97, 1.59]	0.55	-0.81	[-4.60, 2.98]	0.68
Regional Centre	-1.27	[-4.02, 1.49]	0.37	-1.66	[-6.25, 2.93]	0.48

Table 4.16 **continued:**

Model	*Practice*			*Total KAP Score*		
Individual variables	**Estimated *b***	**Odds Ratio [95% CI]**	***p***	**Estimated *b***	**95% CI**	***p***
Age	-0.02	0.98 [0.95, 1.01]	0.25	-0.09	[-0.26, 0.09]	0.34
Female	-0.59	0.55 [0.37, 0.82]	0.0037*	-3.72	[-7.77, 0.33]	0.08
Metropolitan	0.06	1.07 [0.50, 2.26]	0.87	0.08	[-6.19, 6.35]	0.98
Regional Centre	-0.73	0.48 [0.20, 1.14]	0.10	-1.79	[-9.37, 5.80]	0.65
All variables in model	**Estimated *b***	**Odds Ratio [95% CI]**	***p***	**Estimated *b***	**95% CI**	***p***
Age	-0.04	0.96 [0.92, 1.00]	0.0275*	-0.17	[-0.36, 0.02]	0.08
Female	-0.87	0.42 [0.26, 0.67]	0.0002*	-5.49	[-9.88, -1.09]	0.0166*
Metropolitan	-0.03	0.97 [0.44, 2.12]	0.93	-0.87	[-7.02, 5.27]	0.78
Regional Centre	-0.66	0.52 [0.21, 1.28]	0.15	-2.83	[-10.27, 4.61]	0.46

4.9.6.2. Ordinal Regression Results for Practice

The four practice questions required Yes, No, Unsure responses with No and Unsure being coded as zero and Yes as one point. The total score for Practice is ordinal with 0, 1, 2, 3 and 4 as possible scores. Ordinal logistic regression results (Table 4.16) showed an association between gender and Practice score in the simple and full statistical models. In both models, female respondents showed lower odds of having a high score of 4 than male respondents. In the full model, female respondents showed a 59% decrease in odds of higher scores than males (OR=0.419, p=0.0002). In the full model, age was also associated with Practice score, such that the odds of a higher score decrease by about 4% (1 - 0.958= 0.042) with each year of age increase. This was also seen in Table 4.17 where the probability of having a low Practice score increased as age increased. Frequencies and percentages of the total practice scores recorded for females and males are presented in Table 4.17. Of female respondents, 46% gave a total Practice score of 0 compared to 20% of males. Whereas a high proportion of male respondents (15%) had a score of 4 whilst only 1 female (2%) scored 4. The proportions of responses in each Practice total score category within region category are presented in Table 4.17. A higher proportion of respondents in Remote locations (58%) showed a score of 0 than either of Metropolitan (29%) or Regionally (40%) located Optometrists.

Table 4.17 Frequencies (%) of the Total Practice Survey Scores Recorded for the Gender, Age, and Practice Location

	Gender		*Age*					*Location*		
Total Practice score	Male	Female	20-29	30-39	40-49	50-59	>60	MM1: Metro	MM2: Regional	MM3-7: Remote
0	8 (20)	23 (46)	3 (20)	4 (22)	11 (42)	9 (45)	3 (33)	18 (29)	6 (40)	7 (58)
1	13 (32)	16 (32)	5 (33)	6 (33)	6 (23)	8 (40)	2 (22)	21 (33)	5 (33)	2 (17)
2	12 (29)	7 (14)	4 (27)	4 (22)	8 (31)	2 (10)	1 (11)	14 (22)	3 (20)	2 (17)
3	2 (5)	3 (6)	2 (13)	2 (11)	0 (0)	0 (0)	1 (11)	3 (5)	1 (7)	1 (8)
4	6 (15)	1 (2)	1 (7)	2 (11)	1 (4)	1 (5)	2 (22)	7 (11)	0 (0)	0 (0)
Total	41 (100)	50 (100)	15 (100)	18 (100)	26 (100)	20 (100)	9 (100)	63 (100)	15 (100)	12 (100)

4.10. Discussion: KAP of Optometrists Towards Statistics

An assessment of optometrists' KAP of statistics was conducted for the first time on a large representative sample, using a new instrument developed for this study. Australian optometrists' KAP towards statistics was measured.

4.10.1. Knowledge

The statistical Knowledge of optometrists was assessed using a 17-item test and average performance was poor (Mean (SD)= 8.39 (3.45)). Performance was particulary weak in relation to ANOVAs, application chi square tests, case control studies and the application of t-tests, with less than 23% of respondents correctly responding to these items. Importantly, 75% of optometrists did not feel they had the "the knowledge and skills required to interpret all inferential statistics in journal articles (t-tests, contingency tables, non-parametric tests)". Only 36% of people said that they have the knowledge and skills required to interpret all descriptive statistics in journal articles (mean, standard deviation, histograms). It is also noteworthy that for this cohort, many knowledge questions were answered with 'unsure' as opposed to selecting an incorrect answer, which may be indicative of a reluctance to guess an answer.

Participants had the lowest scores in items 7 and 15 to 17 (Knowledge section) when asked to select the most appropriate statistical method to use in given scenarios. This is reflected by questions 3 (Attitude section) and 10 (Confidence section), which had the two highest rates of disagreement (75%) to an attitude statement stating that they had the knowledge to interpret all inferential statistics in journal articles, as well as assessing whether a correct statistical procedure was used in a research question. We hypothesize that this may be due to inadequate training in statistics during optometry education in Australian universities. This is supported by less than half of participants believing that they received adequate education regarding statistics during their optometry training (item 6- Attitude section). In addition, the poor statistical knowledge in this cohort may be due to knowledge of statistics being forgotten over time, not being reinforced once an optometrist has graduated from the university training. CPD in statistics if offered appears to have not addressed that gap and should perhaps be incorporated more frequently in CPD programs for optometrists in Australia. In support of this, more than 80% of participants indicated that they previously had a better understanding of statistics than they do now (item 7-Attitude section).

Participants also had low knowledge regarding the chi-square test (item 7-Knowledge section), with only 25% of participants answering correctly. Interestingly, item 15 (Knowledge section), which had the lowest proportion of correct answers (8%) required participants to identify the chi-square test as the most appropriate statistical method to use in a given scenario. Given contingency tables (which is inclusive of the chi-square test) were the third most commonly used statistical method in our audit of the literature, found in 32% of optometric and ophthalmic journals, perhaps there should be a greater focus on improving the teaching of this particular topic.

4.10.2. Attitude

The Attitude survey revealed that the majority (75%) of optometrists surveyed saw statistics as important and clinically relevant, however they were keen to gain a better understanding of statistics. Optometrists did not report having forgotten statistical information. However, their confidence was very low as the median response to all confidence questions was "a little". Regressions revealed that being female significantly predicted a lower Attitude score than males. Also, aging significantly reduced Attitude test score.

Items 4, 5 and 8 (Attitude section) had the highest rates of agreement in the attitudes section and highlight positive attitudes towards statistics. Eighty-seven percent of participants believed that it was important to understand statistical concepts to be an intelligent reader of the literature, 77% saw the relevance of statistics in shaping the clinical decision making as optometrists and 78% would like a better understanding of statistics. These attitudes are reflective of those reported by medical and surgical residents as well as by other allied health practitioners (nurses, occupational therapists, physiotherapists, psychologists, pharmacists and audiologists), highlighting the perceived significance of statistics across a multitude of health professionals (McCleary & Brown, 2002; Reznick et al., 1987; Windish et al., 2007).

4.10.3. Practice

The average score in the four Practice items was low (Mean=1.24, SD=1.23). Female respondents showed a 59% decrease in odds of higher scores than males. Age was also associated with Practice score, such that the odds of a higher score decrease by about 4% with each year of age increase.

Despite poor knowledge and poor confidence, 52% of optometrists reported using statistics in their clinical decision making and 30% claimed to critically appraise evidence. This is despite 71% of optometrists indicating that they skip the statistics section when reading scientific articles. Interestingly, although positive attitudes were reported by most optometrists, only 12% of them answered that they kept up to date with statistical knowledge (item 4-Practice section). Other studies found similar discrepancies between doctors' positive attitudes towards statistics and low self-assessment of statistical knowledge (Swift et al., 2009; West & Ficalora, 2007). Conversely, Reynolds (2011) showed that emergency medicine residents' negative attitudes toward statistics – varying from dislike to anxiety – drove them to increase their proficiency in statistics (Reynolds, 2011).

Taken together, these findings appear to indicate that optometrists self-report that they use statistical knowledge but that despite this they feel as they are not keeping up to date or being critical. It is possible that this could be due to a lack of CPD offering regarding statistics for optometrists, rather than not keeping up to date due to poor attitudes towards statistics. A positive attitude towards statistics does not automatically lead to increased proficiency in statistics and may not be sufficient to overcome other barriers to statistical knowledge.

4.11. Generalizability

The random sample of 92 optometrists enrolled in this KAP study represented the population of Australia optometrists well, indicating that likely good generalizability of the results. Table 4.18 highlights the similarities between the demographic characteristics of Australian Optometrists published by the Optometry Board of Australia (2019) and the study participants.

Table 4.18 Summary of Demographical Data (Age, Gender and State) of the KAP Survey Participants (n=92) versus the OBA Practicing Registrants (2019) (Optometry Board of Australia, 2019)

States	*ACT*		*NSW*		*NT*		*QLD*		*SA*		*TAS*		*VIC*		*WA*		*Not provided*[1]			***Age group: KAP Total n (%)***	***Age group: OBA Total n (%)***
Age Group	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*Missing*		
< 25 - 29	0	0	7	3	0	0	1	1	2	0	0	0	1	0	0	0	0	0	0	15 (16.3)	1421 (24.9)
30 - 39	0	0	7	2	0	0	1	0	1	0	0	0	4	2	0	1	0	0	0	18 (19.6)	1423 (24.9)
40 - 49	0	1	4	3	0	0	4	5	1	0	0	1	2	3	2	0	0	0	0	26 (28.3)	1204 (21.1)
50 - 59	0	0	4	6	0	0	2	1	0	2	0	0	2	0	1	1	1	0	0	20 (21.7)	1007 (17.6)
60 - 69	0	0	0	4	0	0	0	0	0	0	1	2	0	1	0	0	0	0	0	8 (8.7)	586 (10.3)
≥ 70s	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 (1.1)	69 (1.2)
Missing[2]	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	4 (4.3)	-
Gender: KAP n (%)	0	1 (1.1)	23 (25.0)	19 (20.7)	0	0	8 (8.7)	7 (7.6)	4 (4.3)	2 (2.2)	1 (1.1)	3 (3.3)	10 (11.9)	7 (7.6)	3 (3.3)	2 (2.2)	1 (1.1)	0	1 (1.1)		
Gender: OBA n (%)	52 (0.9)	39 (0.7)	1102 (19.3)	804 (14.1)	21 (0.4)	18 (0.3)	599 (10.5)	533 (9.3)	193 (3.4)	159 (2.8)	49 (0.8)	56 (1.0)	875 (15.3)	664 (11.6)	212 (3.7)	233 (4.1)	52 (0.9)	49 (0.8)	-	92 (100.0)	
Practice location: KAP n (%)	1 (1.1)		42 (45.7)		0		15 (16.3)		6 (6.5)		4 (4.3)		17 (18.5)		5 (5.4)		2 (2.2)		1 (1.1)		5710 (100.0)
Practice location: OBA n (%)	91 (1.6)		1906 (33.4)		39 (0.7)		1132 (19.8)		352 (6.2)		105 (1.8)		1539 (26.9)		445 (7.8)		101 (1.7)		-		

OBA: Optometry Board Australia. F: Female, M: Male. 1: "Not provided" for the KAP participants and no primary practice location for the OBA registrants. 2: Participants answered 40-50, 50+, and > 55, or did not provide an answer to the age question.

4.12. Alignment Between Use of Statistics in Ophthalmic Literature and KAP Towards Statistics

When considering the responses on the Knowledge items section of the KAP and comparing these to the frequency of use of statistical methods in the ophthalmic literature, very weak knowledge was displayed for at least 3 of the top 5 ranked methods (Table 4.19). The first ranked method in the literature, Descriptive statistics/Normal distribution (see Table 4.6) yielded 73% to 86% of respondents correctly answering 4 knowledge items in this area (see Table 4.12). However, the second ranked item, t-test (see Table 4.6), saw knowledge scores drop as low as 22% was for applied t-test item (range for all 4 items 22% to 55%, see Table 4.12). Only 26% and 8% of optometrists correctly answered the 2 items related to Contingency tables/chi-square (see Table 4.12); this is problematic considering these were ranked second in the Ophthalmology literature (see Table 4.6). Only 17% of optometrists correctly answered the 5th most important method in the ophthalmic literature (ANOVAs) (see Table 4.6 and Table 4.12).

When considering the responses on the Attitude items section of the KAP and comparing these to the frequency of use of statistical methods in the ophthalmic literature, optometrists displayed a low level of positivity towards 4 of the 5 top ranked tests in the ophthalmic literature (see Table 4.6 and Table 4.13).

Table 4.19 Alignment Between Statistical Methods Used in The Ophthalmic Literature and KAP of Optometrist Towards Statistics
KAP: knowledge, attitudes, practices.

Overall	*Statistical method*	*Combined Optometric rank*	*Ophthalmology rank*	*KAP knowledge Items*	*KAP Mean % correct*
1	Descriptive statistics/Normal distribution	1	1	1, 2, 4, 9	Range 73% to 86%
2	t-tests	2	3	3, 5, 6, 16	Range 22% to 55%
3	Contingency tables/ chi-square	5	2	7, 15	26%, 8%
4	Non-parametric tests	3	7	No exact questions, but looking at attitudes -no confidence here	
5	Analysis of variance (ANOVA)	4	10	14	17%
6	Diagnostic Proportions: Odds ratio / Sensitivity / Specificity	12	6	No KAP items	
7	Survival analysis / Life table: Kaplan-Meier plots / Breslow's Kruskal-Wallis / log rank / Cox proportional hazards regression model	15.5	4	No KAP items	
8	Multivariate regression analysis	15.5	5	No KAP items	
9	Multiple linear regression	6	15.5	No KAP items	
10	Pearson's correlation	7	13	12, 13	53% and 35%

4.13. Strengths and Limitations

Our audit of optometric and ophthalmic journals did not account for other concepts that would also be required to critically appraise the literature, such as for example study design and bias. Additionally, while we used a random sample to recruit participants for the KAP survey, we recognize that participants that have very positive or very negative attitudes towards statistics may have been more likely to participate. The knowledge questionnaire was administered as an “open book” examination, where participants were able to refer to notes, textbooks, and online material while completing questionnaire items. Knowledge gains may thus not be solely attributable to the CPD intervention.

4.14. Conclusion

In conclusion, our audit identified the most used statistical methods in the ophthalmic literature. Understanding of a multitude of these methods would be required for optometrists to successfully comprehend the literature. This highlights that optometrists, who are also health care practitioners, require adequate knowledge of statistical methods to be successful evidence-based practitioners. Australian optometrists have positive attitudes towards statistics but a lack of understanding and interpretation of basic statistical concepts, such as the chi-square test, which are commonly used in optometric and ophthalmic journals. This highlight both the need and some gaps in statistics for optometrists.

Results from the KAP survey suggest that undergraduate and postgraduate optometry education programs in Australia should consider modifying their current training on statistics, and more importantly, that CPD programs should consider incorporating more training on statistics so that optometrists can increase their repertoire of statistical knowledge for adequate comprehension of the literature. Future CPD programs could capitalize on the positive attitude towards statistics in optometrists measured in this study.

The results of these studies provide useful information for educators; the results inform the design of optometry training programs including any CPD programs focused on critical appraisal and statistics and help to identify the level and breath of statistical knowledge that is required to be taught to optometrists in order for them to continue to be effective lifelong learners.

4.15. Appendices

4.15.1. Appendix 4-1: KAP Survey

Correct answers of the Knowledge section of the KAP survey are highlighted and scores of each answer are noted: scores in Blue = correct, Red = incorrect, Brown=numeric assignment to the Likert scale

1. Age _ _ _ _ years
2. Gender ☐male ☐female ☐other
3. What is the postcode of your primary practice? __ __ __ __

Section 1: Knowledge – Questions about statistics:

1. The mean is the middle score when scores are ranked in order.
   ☐yes (0) ☒no (1) ☐unsure (0)
2. The mode is the score that occurs most commonly in the data set.
   ☒yes (1) ☐no (0) ☐unsure (0)
3. P>0.05 means that the probability of an outcome occurring is less than 1 in 20 if the study was repeated.
   ☐yes (0) ☒no (1) ☐unsure (0)
4. A 95% confidence interval indicates a 95% chance that the calculated confidence interval contains the true mean.
   ☒yes (1) ☐no (0) ☐unsure (0)
5. A t-test is used to determine if there is a significant difference between the means of two groups.
   ☒yes (1) ☐no (0) ☐unsure (0)
6. A significant P-value gives valuable information about the size of the difference or effect between two means or proportions.
   ☒yes (1) ☐no (0) ☐unsure (0)
7. Pearson's chi-square test is used to determine whether there is a relationship between different categorical variables.
   ☒yes (1) ☐no (0) ☐unsure (0)
8. A histogram that shows normal distribution is symmetrical and bell-shaped.
   ☒yes (1) ☐no (0) ☐unsure (0)
9. Standard error of the mean (SEM) is a measure of variability from the mean.
   ☒yes (1) ☐no (0) ☐unsure (0)
10. An interquartile range is a range from the 25th percentile to the 75th percentile.
   ☒yes (1) ☐no (0) ☐unsure (0)
11. The null hypothesis states that an effect is present, i.e. there is a significant difference between groups.
   ☐yes (0) ☒no (1) ☐unsure (0)
12. The correlation coefficient (r) is always found between +/- 1.
   ☒yes (1) ☐no (0) ☐unsure (0)
13. A correlation coefficient (r) is determined to be -0.99. This means there is poor or no correlation between x and y variables.
   ☐yes (0) ☒no (1) ☐unsure (0)

A prospective study looked at AMD, diet, and smoking on individuals. Which of these statistical methods would be MOST appropriate to demonstrate:

14. that mean age does not vary across 4 groups of individuals with AMD.
   ☐t-test (0) ☒ANOVA (1) ☐correlation (0) ☐chi-square (0) ☐logistic regression (0) ☐unsure (0)
15. that multivitamin use does not vary across the 4 groups of individuals with AMD.
   ☐t-test (0) ☐ANOVA (0) ☐correlation (0) ☒chi-square (1) ☐logistic regression (0) ☐unsure (0)
16. that mean level of AMD is the same for the high vitamin and low vitamin consumption group.
   ☒t-test (1) ☐ANOVA (0) ☐correlation (0) ☐chi-square (0) ☐logistic regression (0) ☐unsure (0)
17. To determine if smoking is associated with glaucoma, data from 40 patients with glaucoma were collected. These patients were matched for age, sex, and race to patients without glaucoma. The investigators then reviewed whether these patients were previous smokers. This study type is known as:
   ☐cross-sectional (0) ☐concurrent cohort (0) ☒case-control (1) ☐retrospective cohort (0) ☐randomised clinical trial (0) ☐unsure (0)

4.15.1.1. Appendix 4-1: Continued

Section 2: Attitude – Questions about your thoughts and feelings regarding statistics:

1. I am uncomfortable/put off by statistics.

☐strongly disagree (4) ☐disagree (3) ☐neutral (2) ☐agree (1) ☐strongly agree (0)

2. I have the knowledge and skills required to interpret all descriptive statistics in journal articles (mean, standard deviation, histograms).

☐strongly disagree (0) ☐disagree (1) ☐neutral (2) ☐agree (3) ☐strongly agree (4)

3. I have the knowledge and skills required to interpret all inferential statistics in journal articles (t-tests, contingency tables, non-parametric tests).

☐strongly disagree (0) ☐disagree (1) ☐neutral (2) ☐agree (3) ☐strongly agree (4)

4. To be an intelligent reader of the literature, it is necessary to know something about statistics.

☐strongly disagree (0) ☐disagree (1) ☐neutral (2) ☐agree (3) ☐strongly agree (4)

5. I see the relevance of statistics in shaping my clinical decision making as an optometrist.

☐strongly disagree (0) ☐disagree (1) ☐neutral (2) ☐agree (3) ☐strongly agree (4)

6. Adequate education regarding statistics was provided during my optometry training.

☐strongly disagree (0) ☐disagree (1) ☐neutral (2) ☐agree (3) ☐strongly agree (4)

7. I have previously had a better understanding of statistics than I do now but have forgotten due to lack of use/other reasons.

☐strongly disagree (4) ☐disagree (3) ☐neutral (2) ☐agree (1) ☐strongly agree (0)

8. Given the chance, I would like to have a better understanding of statistics.

☐strongly disagree (0) ☐disagree (1) ☐neutral (2) ☐agree (3) ☐strongly agree (4)

Rate your confidence in your current level of ability in the following activities:

1. Interpreting the results of a statistical method used in research

☐none (0) ☐a little (1) ☐a fair amount (2) ☐a lot (3) ☐complete confidence (4)

2. Assessing if the correct statistical procedure was used to answer a research question.

☐none (0) ☐a little (1) ☐a fair amount (2) ☐a lot (3) ☐complete confidence (4)

3. Identifying factors that influence a study's power

☐none (0) ☐a little (1) ☐a fair amount (2) ☐a lot (3) ☐complete confidence (4)

Section 3: Practice – Questions about your use of statistics:

1. I use my statistical knowledge in forming opinions or making decisions as an optometrist.

☐yes (1) ☐no (0) ☐unsure (0)

2. I critically appraise scientific articles that I read in optometry journals such as *Optometry Vision Science* and *Clinical Experimental Optometry*.

☐yes (1) ☐no (0) ☐unsure (0)

3. I tend to ignore or skip the statistics section when reading scientific articles and focus on the results.

☐yes (0) ☐no (1) ☐unsure (0)

4. I try to keep my knowledge of statistics up to date.

☐yes (1) ☐no (0) ☐unsure (0)

4.16. References

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Chapter 5. Summary and Recommendations

5.1. Thesis Summary and Discussion

Across three studies this thesis collected novel data on the knowledge, attitudes, and the reported practices (KAP) of Australian optometrists towards CPD. Specifically, we measured optometrists' perspectives of CPD, the effectiveness of a specific CPD activity delivered adaptively and non-adaptively, its impact on knowledge and knowledge retention, and measured optometrists' capability in analyzing the most frequently presented statistical methods in representative ophthalmic journals.

A modified conceptual model of CPD provided a framework to characterize CPD and its outcomes, namely practitioner knowledge, attitudes and skills, practice behavior and clinical practice outcomes (Marinopoulos & Baumann, 2009). The CPD literature has focused mostly on CPD activity type, revealing that it is most effective when the activity includes mixed media, interactive delivery techniques, and multiple exposures. There is a paucity of information regarding CPD in the specific context of optometry.

From available determinant frameworks the Cabana approach toward improving clinical practice was chosen to help summarize optometrists' perspectives of CPD (Cabana et al., 1999). Qualitative data analysis in Chapter 2 found that optometrists' attitudes towards CPD was modulated by their outcome expectancy, self-efficacy, the inertia of previous practice and their desire for self-improvement. One's attitude towards CPD was not the only factor that influenced their capacity to change practice behavior. External factors such as CPD characteristics and environmental context, resources, knowledge, skills, and belief about consequence also impacted implementation of CPD. Optometrists reported that awareness of knowledge does not necessarily lead to familiarity with knowledge; optometrists were aware of the need for CPD but felt that they were not necessarily familiar with all knowledge.

Baseline data collected in Chapter 3 further enumerated attitudes of optometrists towards CPD. Optometrists' attitudes towards CPD were positive (score 20 out of 28) and well aligned with views expressed in Chapter 2, where optometrists generally displayed a positive attitude and general agreement with CPD. Focus group participants were at times hesitant about their level of knowledge and this was supported by Chapter 3's empirical data collected on optometrists' self-efficacy in the topic of Choroidal lesions. Participants reported only moderate and often times weak confidence or belief in their ability.

In consideration of the knowledge gain resulting from a CPD activity, for the first time in the literature, Chapter 3 made a robust prospective comparison between two online CPD experiences offered to optometrists. Although optometrists' immediate knowledge score was not significantly different between the Adaptive and Traditional CPD interventions, there was a significant drop in knowledge for the traditional group 12 weeks after the intervention which did not occur for the Adaptive group. Adaptive participants reported that the adaptive CPD was more interesting, worthwhile, and fun than those who were randomized to the Traditional non-interactive CPD. However, fewer Adaptive participants returned to the post 12-week session. Taken together, this led us to conclude, similar to Deslauriers et al. (2019), that although it was fun to learn adaptively, it was harder work cognitively) (Deslauriers et al., 2019). Despite Deslauriers et al.'s interactive participants demonstrating more knowledge than the comparison traditional group, their feeling was that they had learned less. The possibility also then exists that optometrists interrogate in focus group (see Chapter 2) who were hesitant of their knowledge and skills might be mirroring this 'inverse effect' proposed by Deslauriers et al. (Deslauriers et al., 2019)

As highlighted in Chapter 1, the exponential explosion in volume of literature present in the field of eyecare presents a challenge for optometrists wanting to keep their professional development up to date through CPD. In Chapter 2 optometrists were aware of the need for CPD but felt that they were not necessarily familiar with all knowledge. The ability of optometrists to critically evaluate new journal article information is critical to their ability to apply new research findings and new knowledge into clinical practice. An important aspect of critical appraisal of literature involves understanding of the statistical methods used in the contemporary published scientific literature. In Chapter 4, our audit identified the most used statistical methods in the ophthalmic literature. This allowed us to delve more deeply in the outcomes of CPD. Chapter 4 examined the alignment between the level of statistical knowledge required to successfully appraise the ophthalmic literature and what was self-reported by optometrists with regards to their knowledge, attitude, and practice (KAP) of statistics. In contrast to their attitudes to CPD displayed in earlier chapters, Australian optometrists displayed a moderately positive attitude towards statistics. Optometrists also showed a lack of understanding and interpretation of basic statistical concepts, such as the chi-square test, yet these were commonly used in optometric and ophthalmology journals. This highlighted both the need and some gaps in statistics for optometrists. Given the increasing use of complex statistical methods, addressing this gap in KAP towards statistics is an imperative for the profession of optometry, in order to enable practitioners to continue their

CPD journey through their lifetime, for the benefits of their patients. Moreover, results from the KAP survey suggested that professional university optometry educational programs in Australia should consider strengthening their current training on statistics. But perhaps more importantly, CPD programs for optometry should consider incorporating more frequent and regular training on statistics so that optometrists can gradually increase their repertoire of statistical knowledge, thus ensuring better and/or continuing adequate comprehension of the relevant published scientific literature. Future CPD programs could and should capitalize on the positive attitude towards statistics displayed by optometrists involved in this thesis.

Taken together, the findings of the thesis indicate both qualitatively and quantitatively that optometrists have a positive attitude to learning and expanding their CPD across their lifetime. Any gaps in knowledge or practice should not be attributed to a lack of desire to learn. Based on the combined results of this thesis, it is proposed that in order to most effectively provide CPD training for optometrists in the area of statistics, small group, journal club style workshops be employed. These should be repeat exposure CPD type events that have a combination of clinically relevant content and input from a statistical expert. Positive experiences with CPD activities that are engaging, and fun may have long term effects encouraging participants to return to future training sessions allowing for repeat exposure effects to be implemented. That is, if the experience is not enjoyed, optometrists may not be keen to engage in additional CPD beyond that which is required. As we know that repeat expose to CPD is effective at improving health outcomes (see Table 1.1. in Chapter 1) making CPD sessions enjoyable is likely to be beneficial.

5.2. References

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