A Critical Review of the Current Portrayal of Metamorphopsia Captured In Print

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Statement:

This research was undertaken under the University of Wales: Trinity Saint David and was submitted in partial fulfilment for the award of a MPhil in the Faculty of Art & Design

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DECLARATION

This work has not previously been accepted in subsidence for any degree and is not being concurrently submitted in candidature for any degree.

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Abstract

Subjective visual distortion resulting from congenital, degenerative or traumatic eye conditions, can significantly impact upon an individual's quality of life, particularly reading activities. Reading problems associated with metamorphopsia are reported in literature as well as in pictorial depictions highlighting print legibility issues. The accuracy of current pictorial depictions of metamorphopsia featuring print in relation to patients' experiences is open to question, especially concerning the quantifying of metamorphopsia which could be instrumental in determining the accuracy of current depiction practice. Therefore, this research considers whether quantification of distortion plays a role within current depictions of metamorphopsia published in both clinical and lay literature. Throughout this study it appears that much of the popular published pictorial depictions purporting to represent distortion related reading problems- i.e. metamorphopsia captured in print, rely more upon artistic license than applied scientific/clinical rigour. This said, an emergent grounded theory surfaced implying that quantification of distortion can coexist with the qualitative expression of metamorphopsia via pictorial depiction creation, potentially leading to greater insights into viewing of such depictions.

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Glossary

Congenital	Of a disease or physical abnormality, present from birth.
Intravitreal	Within the vitreous body of the eye.
Opto-types	Test letters
Photoreceptor	A nerve end-organ or receptor sensitive to light.
Retina	A layer at the back of the eyeball containing cells sensitive to light
Scotoma	A partial loss of vision or blind spot in an otherwise normal visual field.
Saccadic	Involuntary movement of the eye as it moves from one point to point

1 Introduction

‘Reading plays a key role in maintaining a quality of life that helps people with visual impairment to overcome some of the daily limitations they face’ (Creaser, et al, 2012, p.35).

The above quote resonates with the ‘fear’ that the subjective visual disorder of metamorphopsia, can seemingly transform an individual’s normal vision into a spatially distorted world, from which there is little or no prospect of escape. Crucially, it is reported that metamorphopsia can significantly impact on daily vision related activities, including reading. While the severity of metamorphopsia can be self-evident to sufferers, the ramifications of inadequate expression of patient’s visual impairment exhibiting metamorphopsia may influence many facets of patient’s lives, including the monitoring of patients’ medical treatment, vision rehabilitation strategies, or even litigation situations. Factoring in reading problems and associated print legibility issues and the role of pictorial depiction of metamorphopsia emerges as a valuable visualisation aid, so one surmises. However while qualitative measures surface in metamorphopsia depiction, expression of quantitative measures of metamorphopsia I the context of pictorial depiction has yet to be explored by literature, hence this study.

1.1 The Research Question

‘Is metamorphopsia, captured in print, quantified’? This question inquires if qualitative and quantitative measures of metamorphopsia coexist in current pictorial depictions of metamorphopsia featuring print. With an absence in literature confirming or refuting the case, this study aims to address this thought provoking and challenging question. The definitions of qualitative and quantitative measures below principally convey two means of expressing metamorphopsia.

Quantitative: ‘The expression or measurement of the quantity of something’ (oxforddictionaries.com, 2018a)

Qualitative: ‘Relating to, measuring or measured by the quality of something rather than its quantity’ (oxforddictionaries.com, 2018b)

There is precedence in asking this research question, for in recent years, the quantification of metamorphopsia has become a hot topic within clinical research; (Achiron et al., 2015; Arimura et a., 2007; Bae et al., 2015; Kinoshita, 2015; Krøyer, et al., 2008; Midena & Vujosevic, 2016; Nassar et al., 2015; Nowomiejska et.al., 2013).

1.2 Selection Of Research Methodology

On the premise that the question. ‘is Metamorphopsia, Captured in Print, Quantified’ is a valid, open ended and unresolved question, allowing reasoned responses, this study breaks new ground within the field of metamorphopsia depiction. With no prior empirical evidence directly addressing this question, this investigation explores complex issues. These issues concern the communication and interpretation of subjective vision. Table 1 below; give an insight into the predicament which patient's and clinicians encounter in communicating and interpreting loss of vision, involving metamorphopsia.

	Known to Patient	Not Known to Patient
Known to clinician	Open *(Distorted vision is open to interpretation)*	Blind *(A clinician's visualised interpretation of patient's distorted vision)*
Not known to clinician	Hidden *(The patient's view of their distorted vision)*	Unknown *(Are the patient's/clinician's interpretations of distorted vision consistent and valid)*

Table 1 The Johari Window: (Adapted here) Sullivan and Wyatt (2005).

In Table 1, the bracketed italic text introduced here, compliments Sullivan and Wyatt's (2005) own interpretation of Joseph Luft and Harrington Ingham's (1955) interpersonal awareness relations graphic model, called the Johari Window. Sullivan and Wyatt utilised the Johari Window to demonstrate how medical information relevant to both patients and doctors can be categorised as 'unknown knowns'. In this study's case, the unknown relates to both the role if any, that quantification plays in the pictorial depiction of metamorphopsia. With this in mind, a flexible research methodology sets objectives to examine the inter-relationships of information spanning the disciplines of art and science. With art seemingly linked to qualitative expression of metamorphopsia, and science linked to quantitative measures of metamorphopsia, aspects of Grounded Theory methodology are well suited to the nature of this research.

1.2.1 Aspects Of Grounded Theory Methodology Applied

Glaser and Strauss (1967) developed a full complement of 'methods' of research within the practice of Grounded Theory methodology. Strauss & Corbin (1998) describe the strengths found in various 'principles' within grounded theory methodology. Two principles stand out; constant comparison, and qualitative assessment using coding assigned to sampled information. As such these are the core principles applied to the investigative process underpinning this study.

Figure 1 conveys the research outline, utilising aspects of coding and comparison of grounded theory methodology underpinning this study. The left hand schematic drawing indicates the main principles within grounded theory methodology as published by Rose, et al., (2014). As Birks & Mills (2011) indicate, the coding of information is critical to sifting information which has been gathered to saturation point, in order to demonstrate thorough coverage of information researched. In investigating current online pictorial depictions of metamorphopsia featuring print, the selection of Age related Macular Degeneration (AMD) as the case study satisfied the prime objective thought necessary to examine online eye health information for a common causation of metamorphopsia. This was supplemented by further in depth online searches for other eye diseases/disorders within the search engines of; TRIP, Medscape, PubMed, academic databases of Google Scholar, and Google.com. This also revealed a vast range of images, the majority not featuring depictions of metamorphopsia in the context of print. On refining the search criteria concerning metamorphopsia, using the following key phrases proved effective.

Key word search using; metamorphopsia reading, metamorphopsia quantification, wet macular degeneration-reading.

Phase 1 of inquiry;

This initial phase of the investigative process explores via open coding, the interrelationships between clinical literature, and online UK eye health literature containing narratives of metamorphopsia. Initially low- level coding samples information quickly (Creswell, 2009). Further to this, the sampling of information, concerning eye disease/disorders to which metamorphopsia is symptomatic, is undertaken. Subsequently axel coding, as in more refined coding (Allan, 2003), explores the interrelationships of a range of distortion signifiers found in descriptions in clinical and UK eye heath literature.

Phase 2 of inquiry;

This phase of the inquiry explores the juxtaposition of qualitative measures and quantification measures within metamorphopsia portrayal. Here commonalties and differences are explored, in order to indicate the existing framework of knowledge to which metamorphopsia pictorial depiction practice utilises.

Phase 3 of inquiry:

This phase of the inquiry explores interrelationships between the quantification of metamorphopsia and that of current pictorial depiction practice found online worldwide. Aspects of interactive grids for metamorphopsia detection, nullification and inverse interpretation of pictorial depictions are explored. On the emergence of a potential grounded theory, this sets to resolve an objective in order to ascertain if quantitative and qualitative measures can co-exist in pictorial depiction of metamorphopsia featuring print. This leads to a response to the original research question.

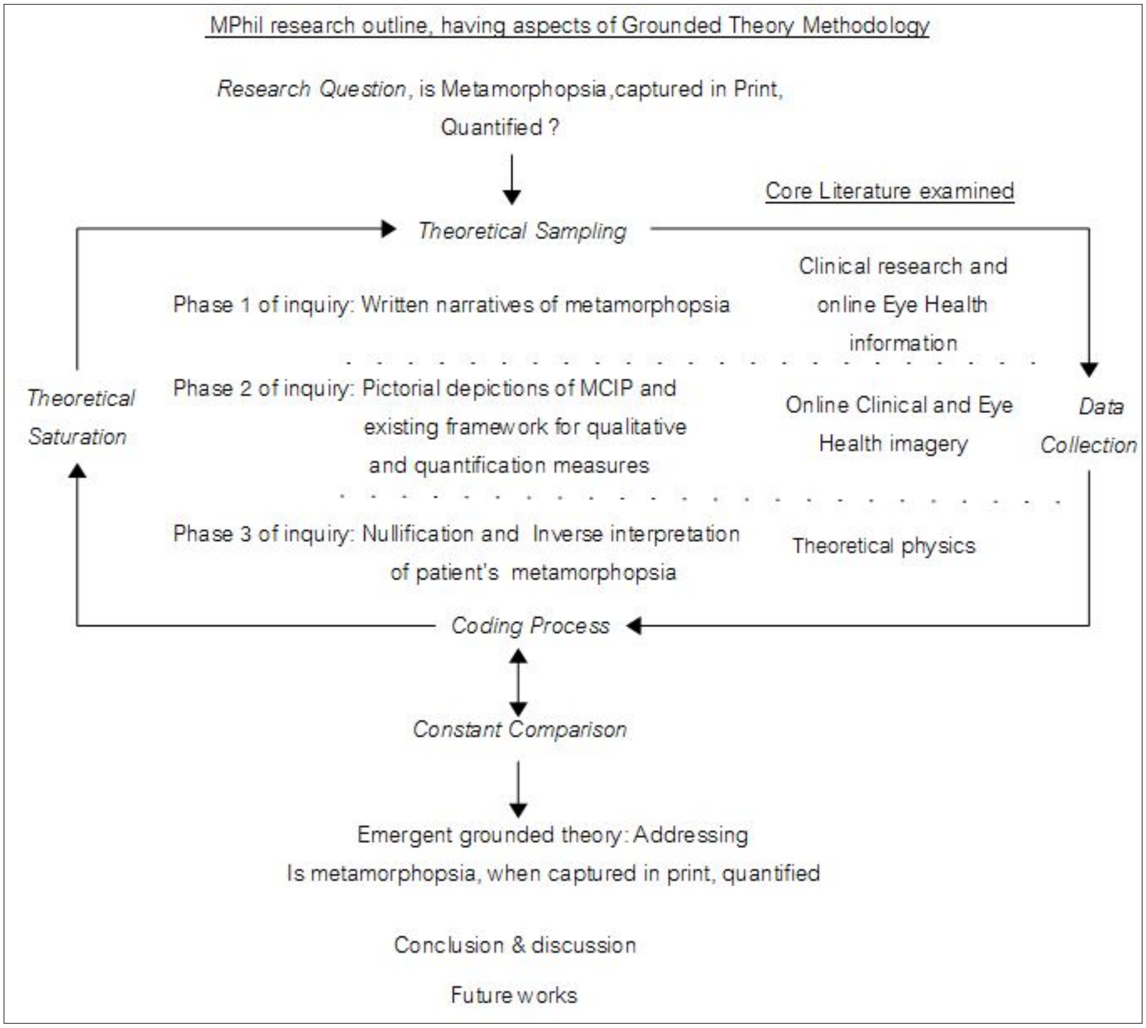

Figure1: Research outline

2 Insights into Metamorphopsia

‘...Metamorphopsia ... a ‘severe and distressing’ symptom’ (Haes, 2013, p.2)

The reference above from Haes (2013), relates the stance which National Institute for Health and Clinical Excellence (NICE) took in approving an intra-vitreal injection as treatment for patients encountering metamorphopsia.

Oxford Dictionaries definition of metamorphopsia conveys the intrinsic part that perceptual vision plays in such manifestations of distorted vision,

‘Defective visual perception in which objects appear distorted in shape, size, etc.’ (Oxforddictionaries.com, 2018).

Early historical accounts of perceived visual disturbance akin to metamorphopsia, span at least two thousand years (Blom, 2010), with the term metamorphopsia having Greek origins i.e. metamorphoun (to change the form), and opsis (seeing) (Enacademic.com, 2014).

Marmor (2000) in his paper entitled; A brief history of macular grids: from Thomas Reid to Edvard Munch and Marc Amsler, relates the 1764 account of Scottish philosopher Thomas Reid’s description of a musical staff appearing distorted. In modern times, Bae et al, (2015) defines metamorphopsia in terms of lines being perceived as curved or irregular, with Achiron, et al, (2015) also defining metamorphopsia in similar terms, see references below;

‘In the patients with metamorphopsia, a straight line appeared curved or irregular’ (Bae et al, 2015. p. 3)

‘In patients with metamorphopsia, a straight line is recognized as a curved line’ (Achiron, et al, 2015. p. 649)

Definitions of metamorphopsia can also include subcategory traits of distortion, namely micropsia and macropsia. The National Health Service (NHS) can use the International Statistical Classification of Diseases: ICD-10 code of H53.15 to record metamorphopsia, micropsia and macropsia collectively.

Cohen et al., (1994) describes vision having micropsia as exhibiting shrinkage, and macropsia as distortions featuring enlargement. Midena, & Vujosevic (2015) elaborate further on these perceptual anomalies with descriptions of line curvatures, see reference below;

‘.. parallel lines are separated from each other by an outward curve..’ and ‘The opposite is found in micropsia’ (Midena, & Vujosevic, 2015. p.27)

2.1 Metamorphopsia Defined As 'Reading Problems'

From the perspective of the ophthalmic profession, patients and the general public, effective communication is paramount in gaining insights and empathy into metamorphopsia. A patient's print legibility issues, often expressed in general terms of reading problems as indicated in Figure 2, may seem slight. Yet the nature of degenerative eye diseases to which metamorphopsia is symptomatic, often profoundly affects reading ability. This is noted by Midena and Vujosevic (2015), in discussing the implications of metamorphopsia on reading activities;

'Metamorphopsia also dramatically deteriorates reading abilities' (Midena, & Vujosevic, 2015, p.27)

Against this background of open expression of metamorphopsia affecting reading ability, accounts of metamorphopsia are often described as reading problems, see reference below;

'With macular degeneration, print may appear distorted and segments of words may be missing' (Axel & Levent, 2003. p. 59)

The hindrance that eye diseases such as AMD place on patients' reading ability is highlighted in a paper entitled 'The emotional and physical impact of wet age-related macular degeneration'. Here the authors Varano, et al., (2016) conducted a survey of nine hundred and ninety individuals diagnosed with wet Age Related Macular Degeneration. Although the term metamorphopsia does not feature in this paper, references to distortion of lines, shapes and face distortions do, as listed under B (symptom), in Figure 3.

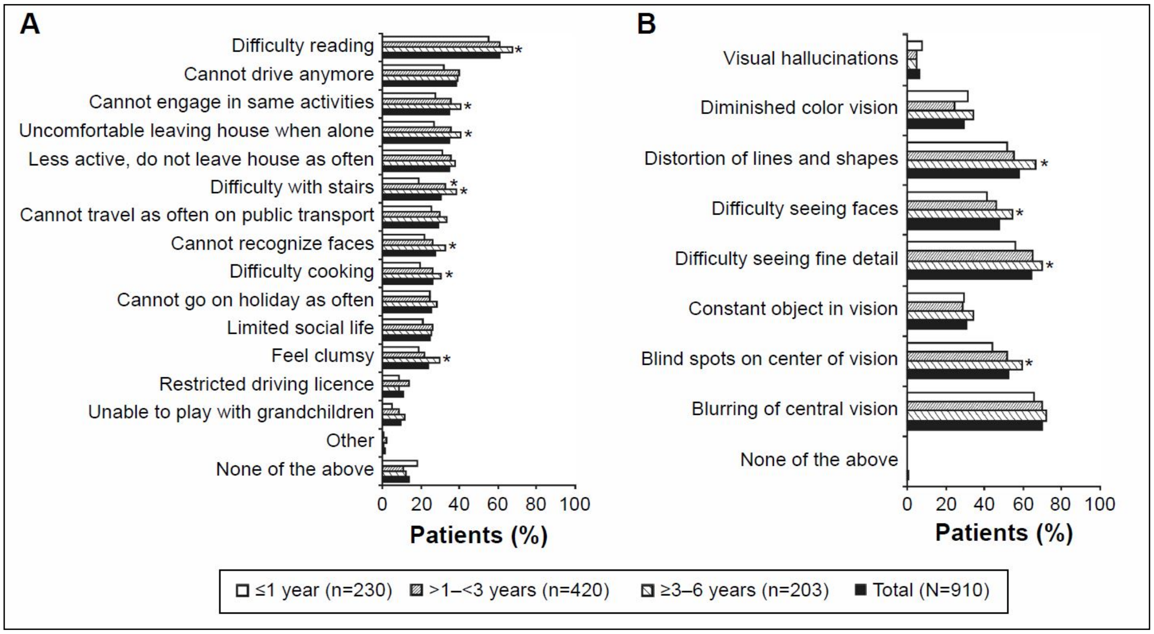

Figure 2: Patient's wet AMD limitations in daily activities (A) and (B) symptoms by Varano, 2016.

Interestingly although this survey does not differentiate between the types of symptoms behind each specific limitation listed, sixty percent plus of patients are said to have encountered vision distortion. Likewise visual distortion obviously contributes to the overall daily life limitations faced by sufferers, which in turn adds to the stresses involved in caregivers' provision of suitable assistance (Varano et al, 2016).

2.2 Metamorphopsia, A Communication Challenge

In the context of current UK healthcare practice, effective communication between patients and physicians is considered a core aspect of professional development (Burt et al., 2016). Yet situations arise whereby patients are presented with medical information i.e. prescriptions that do not take into consideration if patients can read the information provide to them, with this concern highlighted by Drummond and Dutton (2014).

'Although medical information is often communicated in writing, little attention is given as to whether patients can read it' (Drummond, & Dutton, 2004. p.1541)

With metamorphopsia arising in conditions such as Age Related Macular Degeneration, issues surrounding good communication and accurate interpretation of patient's vision, arise. This is demonstrated by the author Winther (2016) in relating a typical vision assessment case scenario, see reference below;

'A patient suffering from AMD a common opening remark is *"I can´t see anything".* When the ophthalmologist ask the patient to explain a bit more the answer is often *"I can´t read"* and after a while, *"well, it´s difficult to read.'"*(Winther, 2016. p.9)

The overriding sentiment in both references above identifies the need for 'effective' communication to take place between patients and physicians. Such communication has to bridge both ophthalmic knowledge, and that of the layperson's interpretation of their vision loss. Striving for effective communication is often amidst a patient's anguish concerning sudden loss of vision. This is contrary to the typically carefree attitude to vision until something goes wrong, principally conveyed by Drentlaw (2013) in the reference below;

‘ Vision is often taken for granted’ (Krissa & Drentlaw, 2013. p.1)

Crucially, the possession of normal vision may well hinder an individual’s consideration of what vision is to others, outside his or her own experiences, inclusive of conditions such as metamorphopsia. Fundamentally, the comparison of vision is complex, as previously indicated in Table 1. Mosher (1998) also highlights complacency in interpreting others’ vision;

‘Most people assume everyone sees the world the same way’ (Mosher, 1998. p.1)

Intrinsic to the nuances of metamorphopsia, even normal vision is open our own unique visual interpretation. This unique aspect of vision interpretation is detailed from a physiological stance, in the quote below;

‘None of us actually see the same way as any other individual’ (Dan, 2003. p.168)

A key principle in fostering insights into metamorphopsia between patients, the ophthalmic profession and general public, is the provision of standards by which to conduct vision comparison.

In the case of monocular visual acuity (VA) assessment, the Snellen chart utilises standardisation in order to communicate the patient’s capacity to see various sizes of print characters, see reference below;

‘Standardization permits a comparison of current screening results with previous results’ (Chaplin, & Bradford, 2011. p.222)

And

‘Clinicians have long used the expression *“lines gained”* or *lines lost”* to indicate changes in visual ability’ (Precision vision, 2016)

Importantly patients encountering vision loss, including metamorphopsia, in clinical settings are initially faced with visual acuity testing i.e. via the Snellen chart. Yet quantitative insight into the visual characteristics of print ‘not’ recognisable due to distortion, falls beyond the remit of such vision appraisals. A particularly relevant comment with regards to metamorphopsia;

‘Visual acuity is not sufficient in gauging reading ability’ (Holz.et.al., 2012. p.288)

The term ‘gauging’ in the reference above by Holz (2012) highlights the crux of the problem, a mean of comparison i.e. a datum is essential to gauge a patient’s perceptions involving metamorphopsia. Mosher’s (1998) comment below is particularly poignant to the dilemma faced by metamorphopsia sufferers;

‘... people are not able to compare what they see to what someone else sees..’ (Mosher, 1998. p.1)

Worldwide the ophthalmic profession ‘compares’ patients’ visual acuity to set norms, utilising print as a visual stimulus within set ‘standards’ of practice of vision testing. This process is intrinsic to the universally understood communication of patient’s visual acuity, see quote below;

‘Standardization permits a comparison of current screening results with previous results’

(Chaplin, & Bradford, 2011. p.222)

Interestingly despite standards of clinical rigour being applied to visual acuity testing, the exact nature of what patients observe or not, can be blurred so to speak. For intuitively as suggested by McClure, et al., (2000), patients may subconsciously or consciously apply estimation in acuity testing, see reference below;

‘word identification as a measure of near visual acuity may be prone to subjective estimation where only some letters are seen and the whole word is guessed.’ (McClure, et al., 2000. p 249)

It is not hard to envisage the frustrations when sufferers of metamorphopsia struggling to recognise print characters on a Snellen chart, are informed that the qualitative appearance of the print they strive to recognise unsuccessfully, is disregarded. Indeed patients’ records typically only indicate what lines of letters are recognisable (Precision vision, 2016)

2.3 Correlations Within Clinical Research And Eye Heath Information Online

Within clinical research literature, various terms and distortion signifiers, i.e. lines used to relate characteristics of vision, surface in the initial review of literature. Table 2 is a collation of these terms used for vision traits and distortion across the clinical literature mentioning metamorphopsia in relation to eye diseases/disorders.

Clinical research literature	Term Metamorphopsia	Vision traits	Distortion signifiers					
			Reading problems	Print	Lines	Grids	Faces	Other scenes
unyong et al. (2017)	*	Distortion	*	*	*	*	*	*
Kuiper et al. (2015)	*							
Bae et al. (2015)	*	Irregular			*	*		
Sáez Moreno et al. (2015)	*							
Achiron et al. (2015)	*	Curved			*	*		
Kinoshita et al. (2015)	*				*	*		
Issa et al. (2013)	*	Distortion				*		
Arimura et al. (2017)	*	Bending			*	*		
Inagaki et al., (2014)	*							
Davies et al. (2017)	*							
Khatib et al. (2014)	*							
Georgalas et al. (2011)	*	Distortion						
Lina, et al. (2015)	*	Tilt			*	*		
Manabe et al. (2017)	*	Distorted			*	*		
Bergman & Nallasamy. (2014).	*	Wavy			*			
Lescrauwaet et al., (2017)	*		*				*	

Table 2: Vision traits and signifiers found in sampled clinical literature

Interestingly on seeking correlation between clinical research literature and that of UK online eye heath literature, the term metamorphopsia is not utilised in the samples in the popular ten UK online eye heath information websites sampled. However the prominence of the eye disease of Age related Macular Degeneration being related to visual distortion, see Table 5; defined the scope of information reviewed in the ten websites detailed in Table 3. The ten popular UK main online eye health information websites are; NHS Choices, Patient and Boots WebMed, with their information periodically reviewed by medical practitioners (Westcott 2016), the Royal National Institute of Blind (RNIB) and Macular Society spearheading the UK voluntary sector of organisations providing eye health information (McBride 2015), with the other five providers; Optical Express, Scrivens Opticians, Specsavers, Tesco Opticians and Vision Express, all commercially orientated reflecting national high street optician services (Mintel, 2017)

UK Online Eye Health information Websites	Term Metamorphopsia	Vision traits	Distortion signifiers					
			Reading problems	Print	Lines	Grids	Faces	Other scenes
Patient info		Wavy, Crooked	*		*	*	*	
NHS Choices		Wavy, Crooked	*	*	*		*	
RNIB		Wavy	*		*			
Macular Society		Bent	*	*	*	*		*
Boots WebMeD		Distorted	*		*		*	
0pticalexpress		wavy	*					
Scrivens Opticians		wavy	*		*		*	
Specsavers		wavy	*		*			
Tesco opticians		Distorted	*					
Vision Express		Bent	*		*			

Table 3: Vision traits and signifiers assigned to AMD symptoms in online eye health information.

Within clinical literature, it is evident that references to reading problems and print only occur in the literature of Kunyong et al. (2017), likely reflecting the nature of the vision functionality discussed in the publication. Predominantly lines and dots feature in most of the other literature, with commonplace vision trait description such as ‘distortion’ and ‘wavy’. However UK online eye health information mainly highlights reading problems, closely followed by line distortion in describing symptoms of AMD. This shift from clinical to laypersons’ interpretation of different aspects of functional loss is apparent in the introduction of faces of people, replacing a dominance of grids and lines in clinical literature regarding distortion signifiers.

3 Eye Diseases/Disorders Leading To Metamorphopsia

'...in patients with vitreomacular traction, metamorphopsia is one of the most disabling visual symptoms' (Midena & Vujosevic, 2016. p. 35)

The reference above indicates how besides AMD, metamorphopsia presents in patients having vitreomacular traction. In exploring the scope of eye diseases/disorders in which metamorphopsia is symptomatic, the evidence -based medicine search engine of Turning Research into Practice (TRIP) proves useful. TRIP facilitates sourcing and filtering of millions of online medical articles (Meats, 2008). This encompasses the journals and images published by the Lancet, British Medical Journal (BMJ), Journal of the American Medical Association (JAMA), and MEDLINE (Montori & Ebbert 202). The key word search of 'metamorphopsia' via TRIP reveals at least seventeen eye diseases/disorders of which metamorphopsia is symptomatic as listed here in Table 4. Interestingly, differing nomenclature and acronyms span clinical and online UK eye health information relating the same Eye diseases/disorders, also recorded in Table 4.

Clinical literature ref:	Clinical Nomenclature of eye disease/disorders	Online eye Health nomenclature of eye disease/disorders	Acronym
Kunyong et al. (2017)	Age-related Macular Degeneration Nonexudative / neovascular	Age-related Macular Degeneration Dry / Wet	dry/wet/AMD
Kuiper et al. (2015)	Birdshot chorioretinopathy	Birdshot Uveitis	BSCR
Bae et al. (2015)	Central serous chorioretinopathy	Central serous retinopathy	CSCR
Sáez Moreno et al. (2015)	Hydroxychloroquine retinopathy	Bull's eye maculopathy	BEM
Achiron et al. (2015)	Diabetic retinopathy	Diabetic retinopathy	DRP
Kinoshita et al. (2015)	Epiretinal membrane.	Macular Pucker	MP
Issa et al. (2013)	Idiopathic Juxtafoveal Telangiectasis	Macular telangiectasia	JFT
Arimura et al. (2017)	Macular hole	Macular hole	MH
Inagaki et al.,(2014)	Macular Oedema	Macular Oedema	MO

Davies et al. (2016)	Poppers maculopathy	Popper retinopathy	PRP
Khatib et al. (2014)	Photic retinopathy	Solar retinopathy	SRP
Georgalas et al. (2011)	Pseudoxanthoma elasticum	Pseudoxanthoma elasticum	PXE
Lina, et al. (2015)	Retinal detachment	Retinal detachment	RD
Manabe et al. (2017)	Retinal vein occlusion	Retinal vein occlusion	RVO
Bergman & Nallasamy. (2014).	Vitelliform dystrophy	Best disease	BVMD
Lescrauwaet et al., (2017)	Vitreomacular traction syndrome	Vitreomacular traction syndrome	VMT

Table 4: Eye diseases/disorders for which metamorphopsia is symptomatic

3.1 Eye Diseases/Disorders Spanning Clinical And UK Online Eye Health Literature

Clinical literature reveals a large number of eye diseases/disorders for which metamorphopsia is symptomatic. How such authoritative knowledge concerning eye diseases/disorders filters into UK online eye heath information, emerges in Table 5

Of the ten UK online eye health webpages detailing eye conditions and symptoms, strikingly the Patient.UK website extensively covers all but three of the eye disorders previously listed in Table 4. The NHS Choices website is surprising in that it only caters for the commonest eye diseases/disorders. The RNIB website fares better than that of the Macular Society website in relating a broad scope of eye diseases and conditions. The high street opticians' website coverage of eye diseases/ disorders is very limited, with Optical Express displaying the most comprehensive coverage. The apparent absence of information regarding Bull's Eye Maculopathy, Macular Telangiectasia and Vitreomacular Traction syndrome, points to the rarity of these eye complaints. Overall AMD and Diabetic Retinopathy (DRP) feature prominently within UK online eye health information sampled here. However AMD has extensive literary coverage, with written descriptions of symptoms. Hence this eye disease was chosen as case study material.

Eye disease/disorders	Patient.UK	NHS Choices	RNIB	Macular Society	Boots WebMeD	Optical express	Scrivens Opticians	Specsavers	Tesco opticians	Vision Express
AMD	*	*	*	*	*	*	*	*	*	*
BSCR	*		*							
BRVO	*		*							
CRVO	*		*	*		*				
CSCR	*		*			*				
BEM										
DRP	*	*	*	*	*	*	*	*	*	*
MO										
MP	*			*		*				
IIH	*									
MH	*	*	*	*	*	*				
MacTel										
PRP	*									
PXE	*		*	*						
RD	*	*	*		*	*	*			
SRP	*									
BVMD	*		*	*						
VMT										

Table 5: Prominence of Eye disease/disorders in sampled UK online eye health websites

3.2 Anatomical/Neurological/Physiological Aspect Of Metamorphopsia

Of the sixteen eye diseases/disorders for which metamorphopsia is symptomatic, listed in Table 2, the exact nature by which metamorphopsia is manifested is complex (Midena & Vujosevic, 20150; Manabe,et al, 2016; Manabe et al., 2017) However retinal photoreceptor displacement is commonly implicated (Ugarte et al., 2013) This typically occurs through abnormal retinal vessel growth linked to AMD (Winther, 2016) Similarly retinal scaring is also known to be a contributing factor to the presentation of metamorphopsia (Winther, 2016) Bennett (2011) eloquently describes retinal distortion in reference to Macula pucker, see reference;

‘The retina can be described as having a smooth, shiny surface… When this scar tissue forms, it contracts, causing that smooth surface to become wrinkled and appear more like a crinkled sheet of cellophane. This crinkling can distort vision, resulting in metamorphopsia.’ (Bennett 2011. p.1)

Retinal structure while skirted over with simple descriptive terms, actually is extremely complex, with approximately one hundred and forty-six million photoreceptor cells embedded in the retinal surface (Arden et al., 2005). Kroyer et al., (2005) suggests changes to the normal spatial alignment of photoreceptor cells plays a key role in disorders such as Epiretinal Membrane where metamorphopsia manifests, see reference below;

‘Metamorphopsia arises when a localized shift in the spatial projection of an element of the retina occurs, presumably because of photoreceptor displacement’ (Kroyer et al 2005. p.1017)

Neurological changes implicated in the manifestation of metamorphopsia are similarly complex to decipher, as implied by Wiecek et al., (2015), with Madill, & Riordan-Eva (2004) also linking neurological disease to metamorphopsia, see reference;

‘The results suggest instead that metamorphopsia involves top down information, knowledge about the scene, and perhaps, cortical reorganization.'(Wiecek et al., 2015. p. 9)

And

'Metamorphopsia can occur in posterior visual pathway disease' (Madill, & Riordan-Eva, 2004. p. 12)

3.3 Metamorphopsia Incidence And Prevalence Rates

The extent to which metamorphopsia is encountered UK population wise is not so easily ascertained. Strange as it may seem, an absence of information concerning metamorphopsia incidence and prevalence rates prevails, in the UK and possibly worldwide. Incidence and prevalence rates, in being two measures utilised in epidemiological studies, are defined in the following references,

Incidence relates: '…measures of occurrence within defined numbers of populations within defined periods of time' (Rothman, 2002)

Prevalence rates indicate: '...only what is happening at a certain point' (Shields & Twycross, 2003. p. 50)

The collation of metamorphopsia incidence rates falls within the remit of epidemiological study. In the United Kingdom both the NHS and private healthcare providers can utilise the internationally recognised medical coding of Statistical Classification of Diseases, Injuries and Causes of Death (ICD -10) to record incidence of metamorphopsia. As previously stated, ICD -10 medical coding for metamorphopsia is H53.15; this coding is implementable in patient's records through administrative processing of hospital admission data. However, in practice the United Kingdom's Hospital Episode Statistics (HES), Primary Care Trusts (PCT), General Ophthalmic Service (GOS), NHS commissioned medical practising organisations including NHS Wales Informatics Service Patient Episode Database for Wales (PEDW), fail to collate incidence rates of metamorphopsia. The explanation to this absence is two-fold, firstly metamorphopsia is a symptom and not a cause of visual impairment (Owen et al., 2003), also see reference below;

'Subjective visual disturbances' (H.53.1) including 'Metamorphopsia' would rarely appear as the main cause of vision loss since mainly associated with macular degeneration' (Zekite, 2014)

Of note, the reference above provided by Moorfield's Eye Hospital Database for Epidemiological Data collection via the Visual Impairment Certificates (DEVICE) services, is a good example of the explanation given in the above paragraph.

Secondly, there is no 'mandate' in the UK to utilise sub-levels of medical coding which would specifically identify metamorphopsia from a raft of subjective visual disturbance symptoms, see reference below. The UK Health and Social Care Information Centre (HSCIC) elaborates further on this matter by revealing the extra level of coding available as six digits, see reference,

'Clinical coders recording activity have the opportunity to record up to 6 characters in the diagnosis code field. However, only the recording of the first 4 characters is mandated ...

The recording of diagnosis in any format in the outpatient data set is not mandated at all.'(Ali, 2014)

Overall the lack of epidemiological evidence indicating the extent to which individuals encounter metamorphopsia, belies knowledge of patients presenting themselves to the ophthalmic profession with such symptoms (Wiecek et al. 2015), see reference below;

'Patients with macular disease regularly experience and report metamorphopsia (visual distortion), yet the prevalence and variation of this symptom has not yet been reported' (Wiecek et al. 2015. p.1)

3.3.1 Wet AMD Prevalence Rates Implies Metamorphopsia Is Common

AMD features prominently across both clinical, UK online eye health literature and that of broadsheet and tabloid literature, see reference;

'Blindness Epidemic' (Daily Express, 2012)

'One of the earliest symptoms of AMD is the occurrence of metamorphopsia' (Déruaz et al. 2008. p.21)

And

'Metamorphopsia, a hallmark of wet AMD' (Saigal et al., 2011. p.1)

"Age-related macular degeneration is a very common cause of bilateral visual loss in the developed world" (Du Toit, 2013. p.499)

'The projected number of people with age-related macular degeneration in 2020 is 196 million.., increasing to 288 million in 2040...' (Wong et al., 2014. p.106)

Within the reference above, two principle classifications of AMD are combined, i.e. dry and wet AMD (Wong et al., 2014). Subsequent investigation reveals prevalence rates of wet AMD are estimated to range from 10% NHS Choices, (2015); Lowth, (2016), to 15% cited by RNIB (2013), and 18.9 % by Shanahan (2017). Thus estimates of wet AMD prevalence rates surface in literature as indicated by Lowth, (2016), see reference;

'There are around 70,000 new diagnoses in the UK each year' (Lowth, 2016)

Further to the prediction of cases of wet AMD in the UK, predictions of severity Europe-wide, by Shanahan (2017) are equally alarming in that;

'It is expected that 2.53 million cases of AMD, or 18.9 % of all AMD cases in Europe, are considered severe or late stage AMD '(Shanahan, 2017. p.5)

It should be noted that the prevalence of metamorphopsia occurring in wet AMD remain undetermined, other than being regarded as commonly occurring.

4 Qualitative Example Of Metamorphopsia Captured In Print

Here in this chapter, pictorial depictions of MCIP from both clinical and online eye health are gathered and presented for visual comparison. This phase of the investigation seeks to gain insight in current principles of depiction practice, and whether aspect of quantification of severity of metamorphopsia emerge within the images. 4.1 An artisan pictorial depiction

In a paper entitled Neuroscience, Biology, and Brain Evolution in Visual Art the author Zaidel (2011) conveys how famous artists have unintentionally or intentionally captured their visual impairment in their works of art, see reference below:

‘.. eye-related issues affect pictorial representation’ (Zaidel, 2011. p.46)

This quote is significant in that aside learnt artistic styles, artist’s works of art, including their preparatory sketches/drawings, can reveal unique characteristics of the artist’s vision, and one such case is that of Edvard Munch. In a paper entitled, A Brief History of Macular Grids: From Thomas Reid to Edvard Munch and Marc Amsler, (Marmor, 2000) discusses how the artist Edvard Munch’s expressed his vision loss, including metamorphopsia by drawing what he monocularly perceived, as conveyed by the reference below:

‘ Munch’ s description of his... careful drawings of well-demarcated scotomas and his sketch that shows letters to be tilted (metamorphopsia) as well as obscured’ (Marmor, 2000, p.4)

The quote above, indicates Edvard Munch’s right eye haemorrhage was of sufficient fearful concern as to self-monitor the changes in vision, including reading ability, see reference below;

'Munch was deeply frightened by the ocular haemorrhage' (Marmor, 2000. p.4)

In essence Edvard Munch's drawing; see Figure 3, screenshot from Marmor's (2000) paper even today provides valuable insights into metamorphopsia's effects on handwriting/print readability. Of note the screenshot in Figure 3, conveys a sense of scale of this depiction in relation to how this is presented in Mamor's paper.

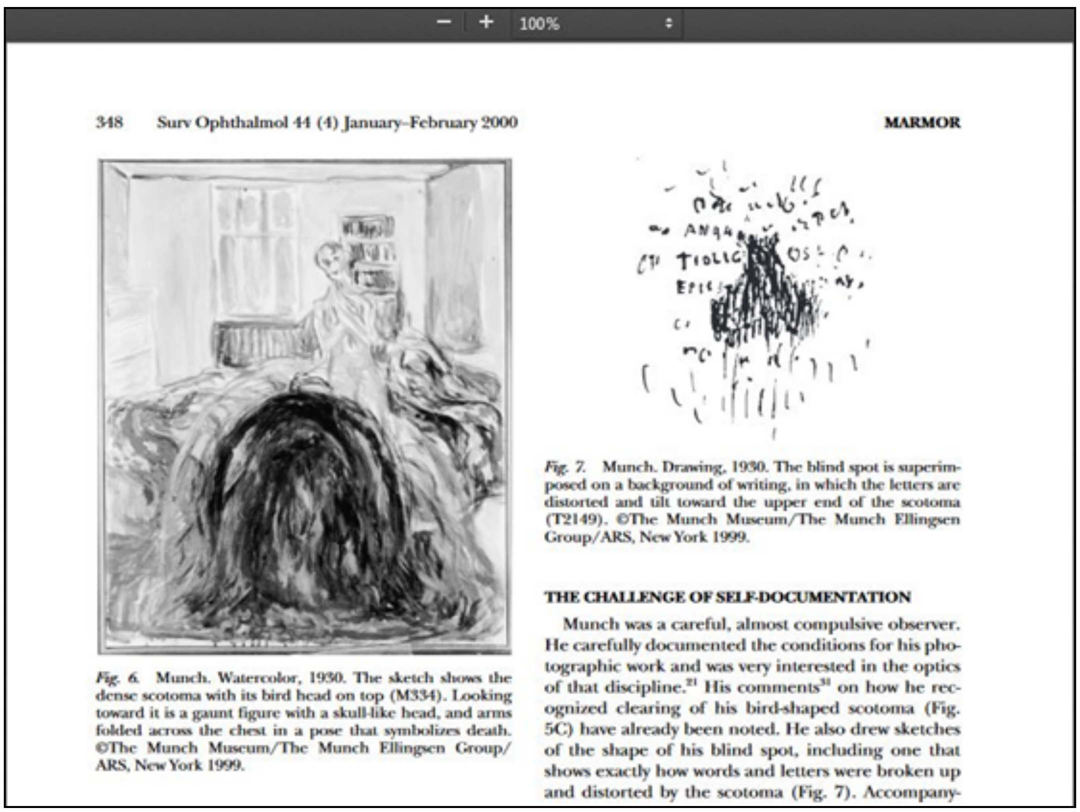

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Fig. 6. Munch. Watercolor, 1930. The sketch shows the dense scotoma with its bird head on top (M334). Looking toward it is a gaunt figure with a skull-like head, and arms folded across the chest in a pose that symbolizes death. ©The Munch Museum/The Munch Ellingsen Group/ARS, New York 1999.

Fig. 7. Munch. Drawing, 1930. The blind spot is superimposed on a background of writing, in which the letters are distorted and tilt toward the upper end of the scotoma (T2149). ©The Munch Museum/The Munch Ellingsen Group/ARS, New York 1999.

THE CHALLENGE OF SELF-DOCUMENTATION

Munch was a careful, almost compulsive observer. He carefully documented the conditions for his photographic work and was very interested in the optics of that discipline.[21] His comments[31] on how he recognized clearing of his bird-shaped scotoma (Fig. 5C) have already been noted. He also drew sketches of the shape of his blind spot, including one that shows exactly how words and letters were broken up and distorted by the scotoma (Fig. 7). Accompany-

Figure 3: Screenshot, Edvard Munch's, 1930 drawing/watercolour. (Marmor, 2000)

It is evident that Edvard Munch's handwriting is only visible on the periphery of the obscured region depicted in this drawing. This indicates a significant area of vision loss, i.e. a scotoma. Liu et al., (2016) as describes similar scotoma phenomena, with the peripheries known to exhibit metamorphopsia, also noted by Davies, et al.(2017). Importantly, Edvard Munch's drawing offers insight into the severity of vision loss including metamorphopsia. With the artist's presumed accuracy through his drawing skills, a sense of scale of the scotoma and surrounding metamorphopsia is captured in this drawing. Yet interestingly Edvard Munch's watercolour to the left of the drawing, also from the 1930s entitled Disturbed Vision (Marmor 2012), is 80 by 64 cm in size, thus significantly larger than the drawing. Thus a disparity in the scotoma size relative to the drawing and watercolour sizes emerges. This is consistent with the artist superimposing the scotoma on the painting from a different viewing distance.

4.2 Simulations Of Metamorphopsia Derived from Clinical Research

Eighty eight years on from Edvard Munch depiction of his vision, published illustrations of metamorphopsia featuring print are still extremely rare occurrences. Marmor & Marmor's (2010) research investigated the simulation of vision with and without macular disease. This included the simulation of metamorphopsia while observing print, see Figure 4, a screen capture featuring their published simulation;

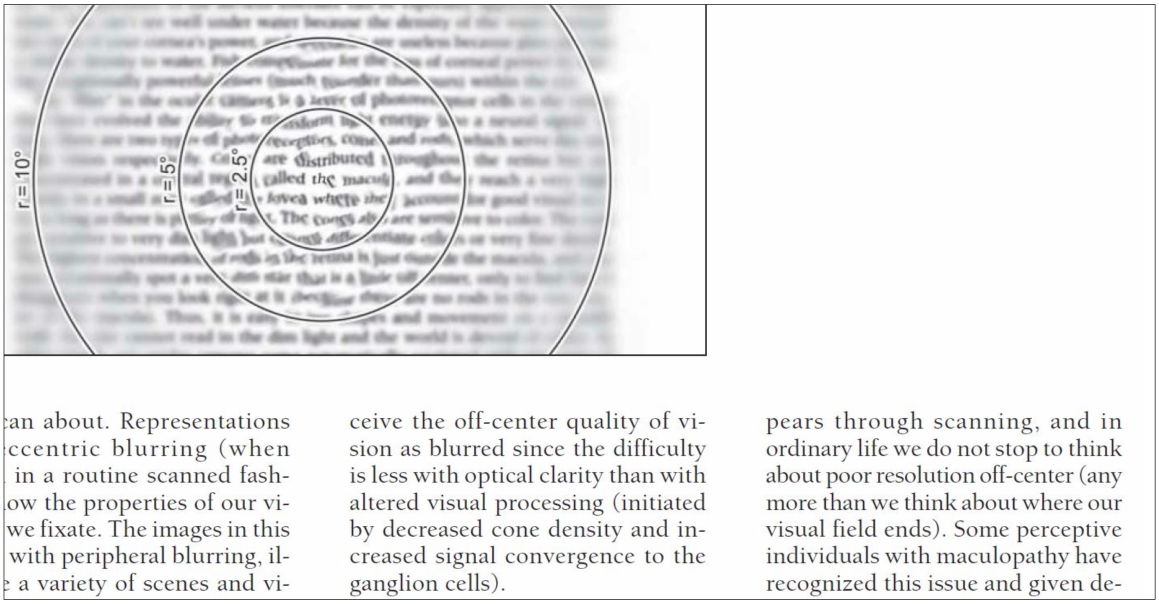


Figure 4: Region of irregular distortion by Marmor & Marmor 2010.

Essentially Marmor & Marmor's (2010) investigations explored how vision is subconsciously manifested through multiple fixations and saccadic eye moments, resulting in the illusion of clear vision throughout the visual field, as in photographs. To this end the authors utilised scenes occurring in typical daily life situations to explore how current depictions of vision related to a single instance of vision captured in images, see reference;

"These simulations show the nature of momentary vision for life tasks such as reading, facial recognition, and walking in the street" (Marmor & Marmor, 2010. p.117)

However, the authors noted that in truth, human single fixations technically encounter peripheral blurring. On this basis Marmor & Marmor (2010) simulated vision algorithmically, using a single fixation view point, thus detailing print as influenced by metamorphopsia. Of note Marmor & Marmor (2010) indicate that these simulations may not reflect unique nuances encountered in perceptual vision, see reference;

'Even these images may not be entirely realistic, however, because the psychological perception of peripheral vision is somewhat indistinct' (Marmor & Marmor, 2010. p.6)

Yet rightly, the visual acuity fall off rates utilised by Marmor & Marmor (2010) are recognized throughout the ophthalmic profession, even though it contradicts our daily vision experiences which mask the phenomenon of peripheral blur.

4.2.1 Vision Metrics Linked To Depiction Viewing Distance

The aspect of conveying the original viewing distance and visual stimuli size used in the creation of the images is exemplified by Marmor & Marmor (2010) incorporating concentric circles indicating the vision angles of r = 2.5, r= 5 and r =10 and the optimum viewing distance of 36 cm. In Marmor & Marmor's simulation, maintaining this ratio of image size projected on the retina, to that of the authors intended simulation viewing distance is critical. The critical nature of this ratio maintains the spatial locations of areas of defective vision within retinal areas critical to central vision, thus facilitating calculations to account for different viewing distances. Furthermore Legge & Bigelow (2011) convey how this ratio is important in relation to assessing reading ability, see reference below;

'Angular size of print requires careful specification of both physical print size on the page and the reader's viewing distance' (Legge & Bigelow, 2011. p.19)

In Figure 5 below, the relationship between the visual angle and retinal projection size estimations are calculable by trigonometry, as indicated in the reference below;

'Given an object size (s) and a viewing distance (d)…... visual angle? Can be calculated as: '$\theta = 2 \arctan (s / 2 / d)$' (Healey & Sawant, 2012)

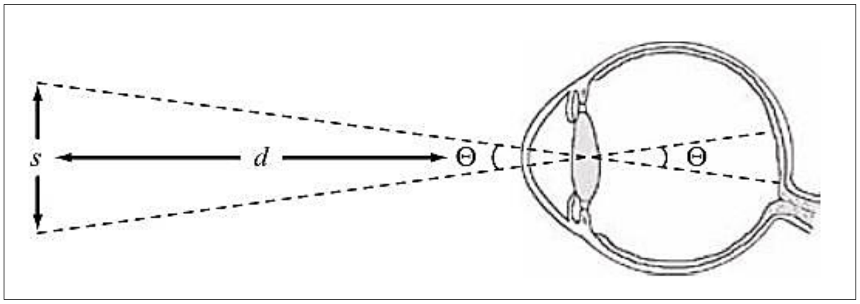


Figure 5: Subtended visual angle, Healey & Sawant 2012

The illustration above also demonstrates how the retinal projections become 'inverted' to that of the scene viewed, as is common knowledge, Atchison et al., (2000) Importantly, Marmor & Marmor (2010), as indicated by their provision of viewing guidance for their simulations, impart a sense of clinical rigour in presentation of their imagery.

Konkle & Oliva, (2007) in the reference below state that;

'Objects can appear at almost any size in the visual field depending on how close or far you stand in relation to them' (Konkle & Oliva, 2007. p.1)

Reviewing these set ophthalmic vision assessment ratios contrasts with those images found online, which neglect to address this principle of vision depiction

4.2.2 Typography And Its Role In Vision Assessment

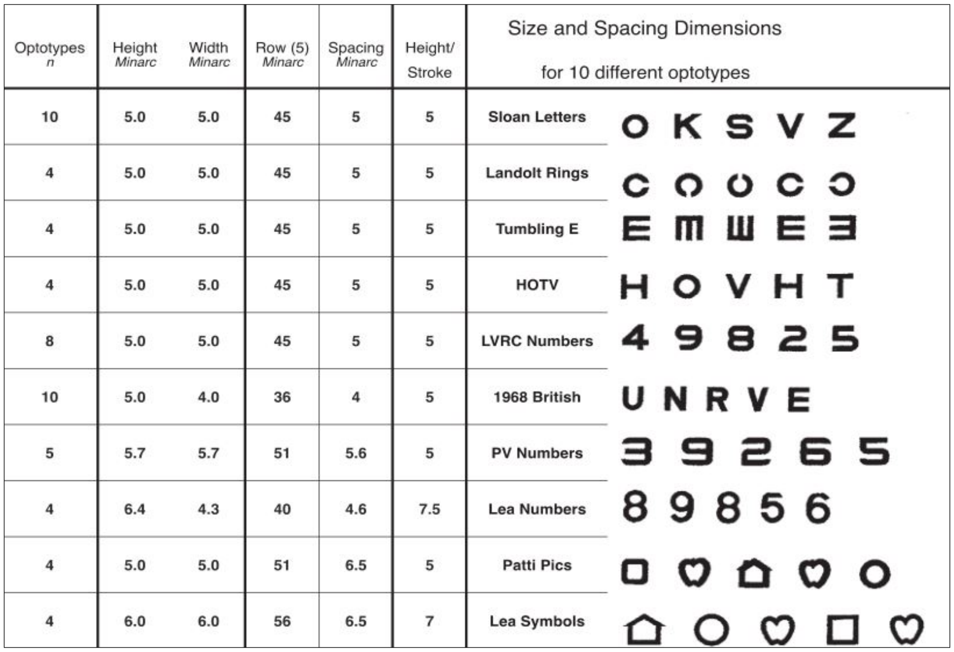
Marmor & Marmor's (2010) simulation of observing print affected by metamorphopsia raises the important issue pertaining to use of print standardisation in vision testing. Chaplin & Bradford, (2011), in general terms of vision assessment indicate the need of standards to gauge changes in vision, see reference;

'Standardization permits a comparison of current screening results with previous results' (Chaplin, & Bradford, 2011. p.222)

The selection of a print typefaces for depicting metamorphopsia if left to judgment on an artistic basis, could be open to numerous possibilities of typefaces used. Empirical data concerning the number of typefaces in circulation throughout the world appears not to exist. However the following quote conveys the myriad of typeface designs, released in just one year;

'…1,800 new commercial typefaces were released in 2006 alone…' (Coles, 2011)

In the ophthalmic profession, various 'optotypes' have been developed to meet the increasing needs of accuracy and standardisation in assessing vision acuity i.e. Snelling, Sloan, British, LEA symbols, Tumbling E and Landolt C (Colenbrander, 2001. p.24), see Figure 6;



Optotypes *n*	Height *Minarc*	Width *Minarc*	Row (5) *Minarc*	Spacing *Minarc*	Height/ Stroke	Size and Spacing Dimensions for 10 different optotypes	
10	5.0	5.0	45	5	5	Sloan Letters	O K S V Z
4	5.0	5.0	45	5	5	Landolt Rings	[Landolt ring symbols]
4	5.0	5.0	45	5	5	Tumbling E	[Tumbling E symbols]
4	5.0	5.0	45	5	5	HOTV	H O V H T
8	5.0	5.0	45	5	5	LVRC Numbers	4 9 8 2 5
10	5.0	4.0	36	4	5	1968 British	U N R V E
5	5.7	5.7	51	5.6	5	PV Numbers	3 9 2 6 5
4	6.4	4.3	40	4.6	7.5	Lea Numbers	8 9 8 5 6
4	5.0	5.0	51	6.5	5	Patti Pics	[Patti Pics symbols]
4	6.0	6.0	56	6.5	7	Lea Symbols	[Lea Symbols]

Figure 6: Optotypes utilised in vision assessment.

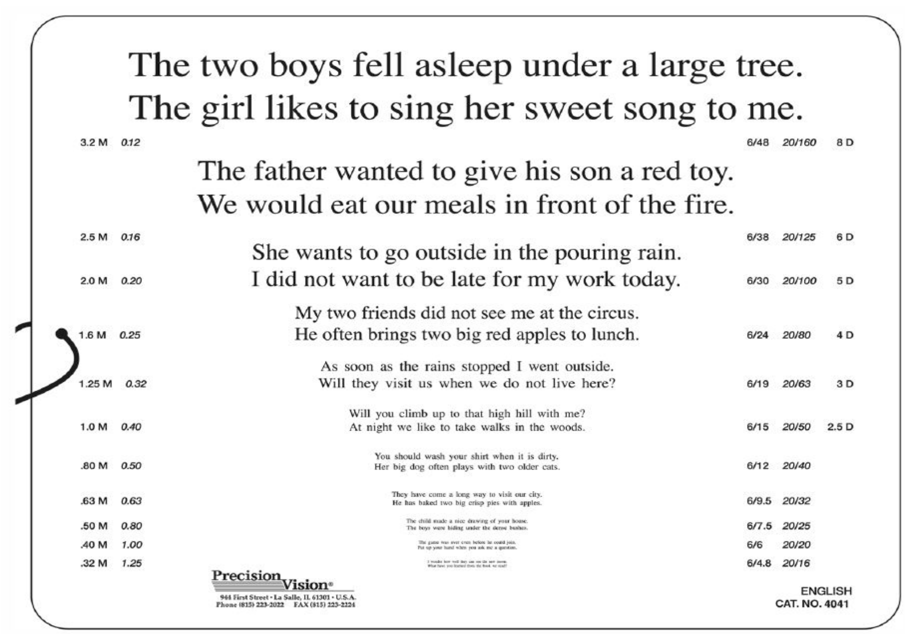


Figure 7: Colenbrander English Continuous Text Near Vision Cards. Radner 2016

It is interesting to note that in Figure 7, a visual acuity test based on a reading exercise called the Colenbrander English Continuous Text Near Vision Card, sentences are the basis for vision assessment. Importantly such charts as this still utilise standards of visual acuity measures underpinning Snellen charts.

Standardisation of print outside of the remit of the ophthalmic profession is limited. However one standard has emerged in recent years, that of ‘Clear Print’. Waller (2011) describes the universal nature of Clear Print, in terms of standardisation of metric size, see reference below;

‘Clear Print calls for a minimum x-height * of 2mm, and is intended to make reading easier for general readers, not just people with visual impairment:’(Waller, 2011. p.2)

The UK Government Equality Act directions, in adopting Clear Print for its government publications intended for public viewing, sends a clear message that anomalies of print sizing associated with point size can be minimised. Point size, a typical measure used for fonts in the publishing industry, exhibits different sizes of print according to typefaces selected (Legge, & Bigelow, 2011).

On examination of worldwide online eye health related depictions of metamorphopsia featuring print, clinical standards or even Clear Print seemingly do not feature in the sample depictions.

4.3 Global online eye health related depictions of metamorphopsia featuring print

Utilising the information in Table 5 identifying AMD as the case study for this literary review process, the screenshots presented below are intended to capture the context in which AMD jointly with metamorphopsia affecting print, are pictorially depicted. Of note the enlarged views of the subject matter are accompanied by other images if available, indicating their 'origins' before image manipulation.

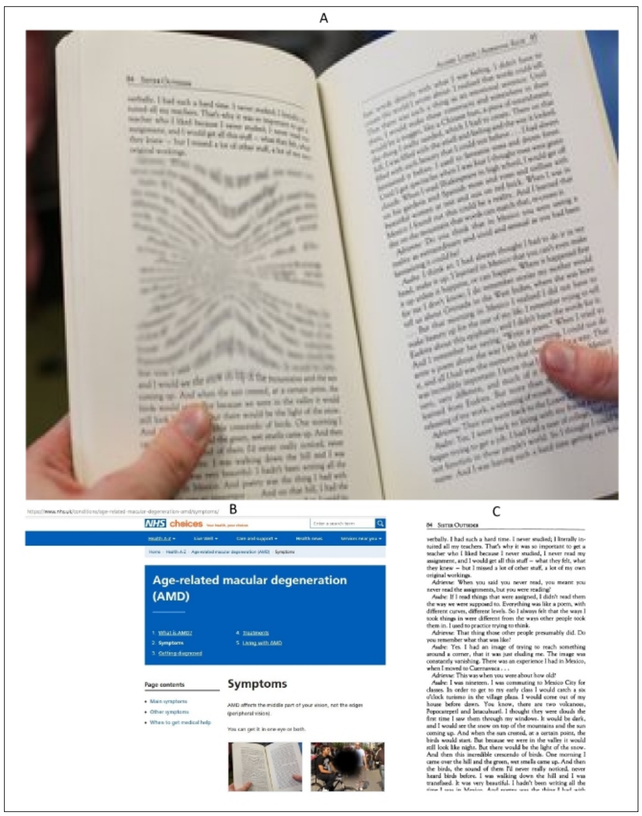


Figure 8: Screenshots (A, B), NHS Choices,2018.(C)Sister Outsider book. Audre Lorde (2012)

Figure 9: Screenshots (A, B) Macular degeneration: mivision.2014. (C) Young businessman.... Shutterstock.com 2018.

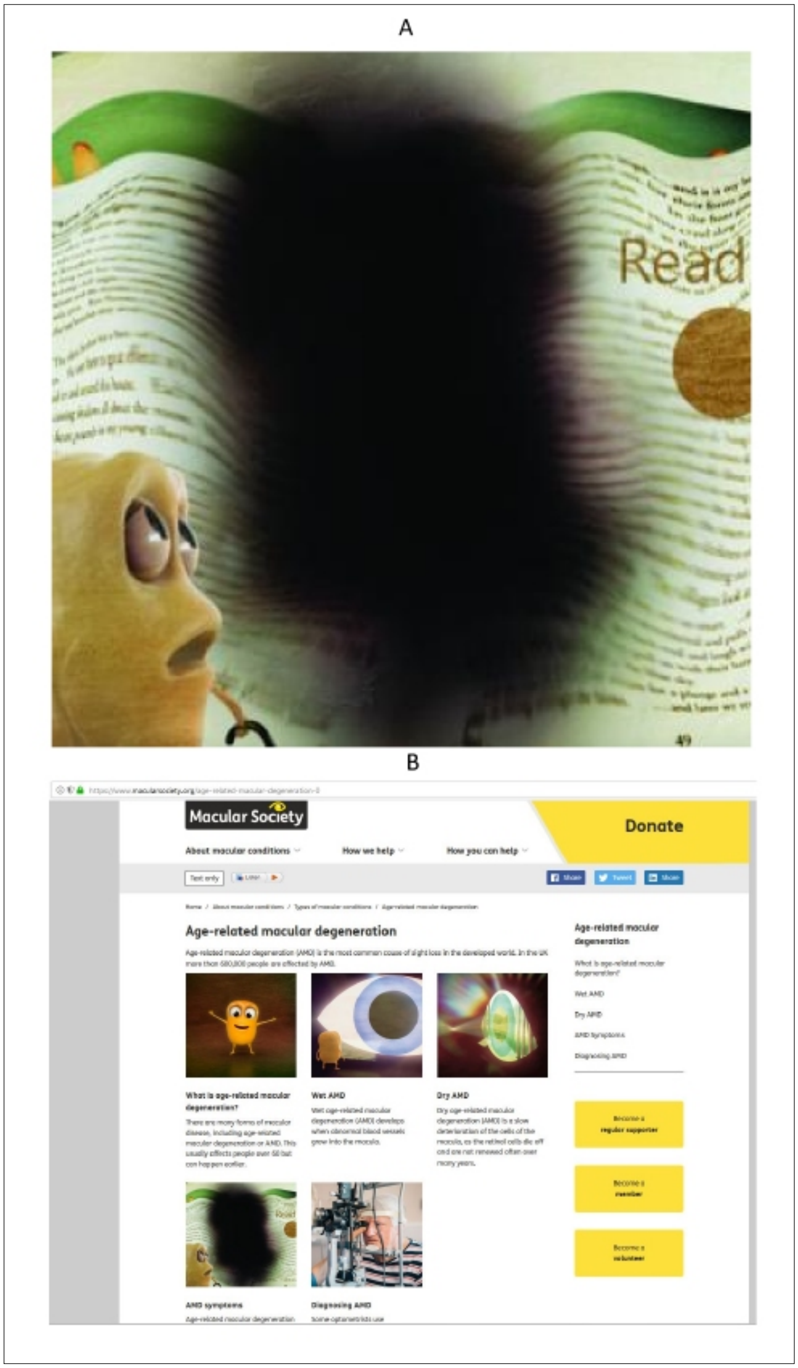


Figure 10: Screenshots (A, B), Age-related macular degeneration Macular Society 2018

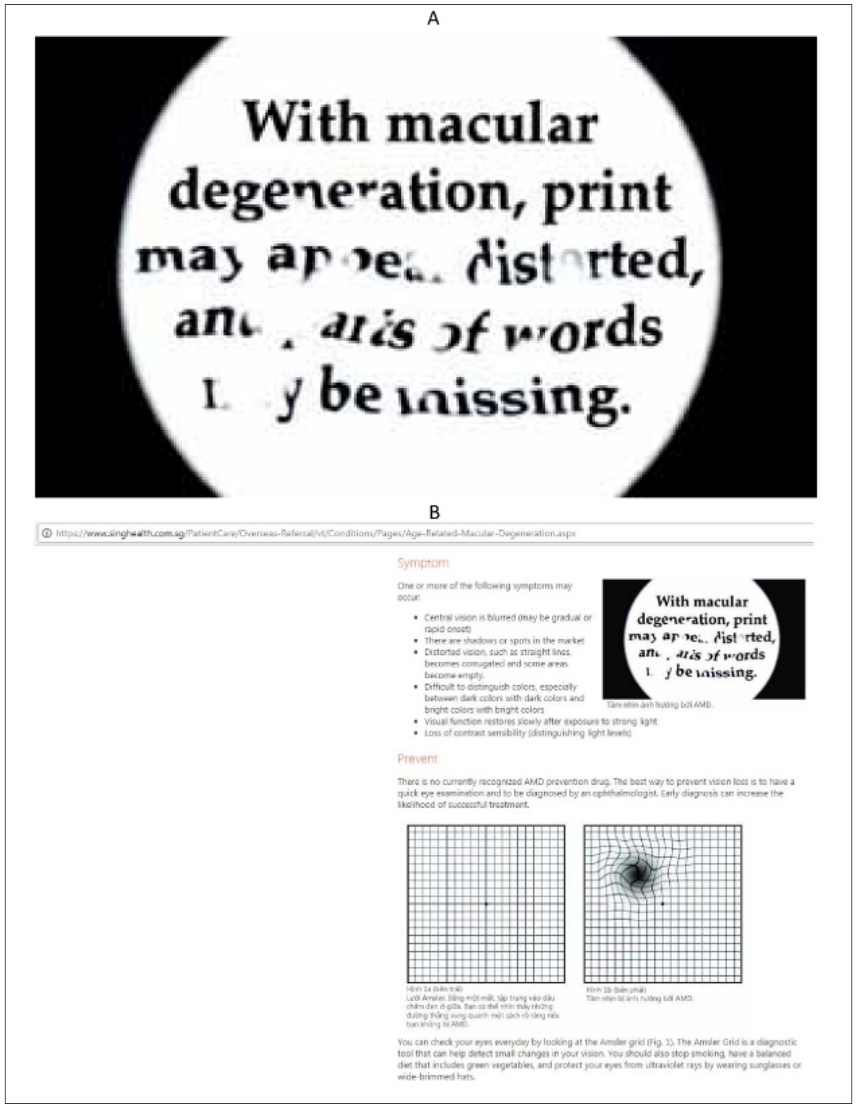


Figure 11: Screenshots (A, B), Age-related macular degeneration symptom, Singhealth.2018

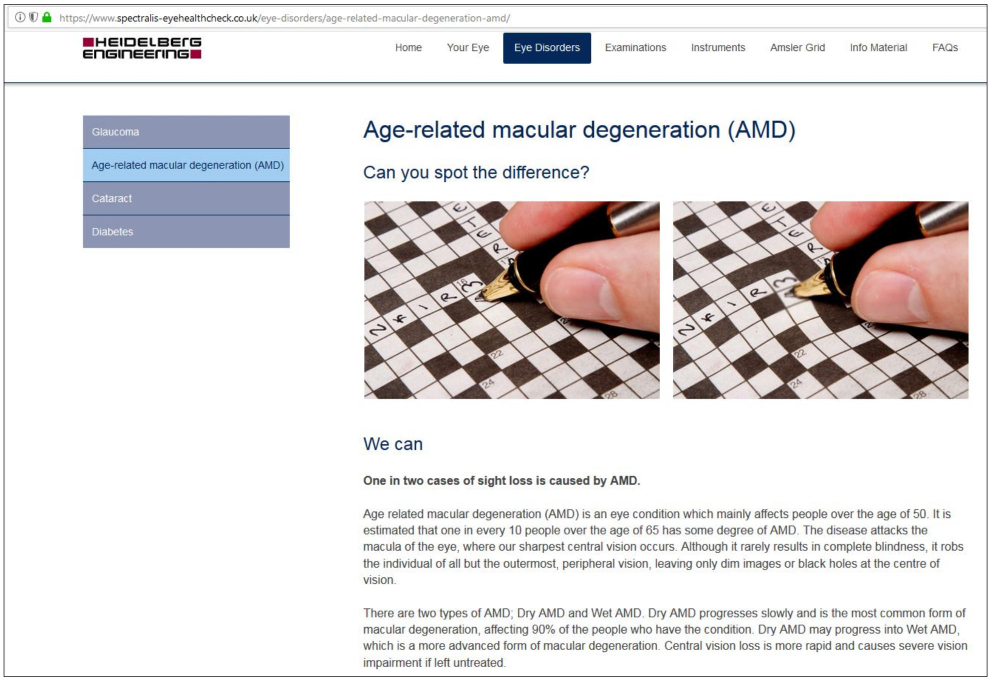


Figure 12: Screenshot, Age-related macular degeneration (AMD), Heidelberg Engineering 2018.

4.4 Evaluation Of All Sampled Depictions

In collating the images sampled reporting symptoms of AMD, a comparison of the scene features helps to ascertain the roles art or science play in current metamorphopsia depiction practice. The rigour of clinical research conducted by Marmor & Marmor (2010) is utilised here in Table 6 as a benchmark to aid this phase of the investigation.

Sampling of metamorphopsia pictorial depictions featuring print	Current pictorial depiction practice					
	Personal account	Simulation	Monocular vision	Binocular vision	Viewing distance	Visual stimuli size
Artisan literature						
(Marmor, 2000)	*		*			
Clinical literature						
(Marmor & Marmor, 2010)		*	*		*	*
Online Eye Heath literature						
(NHS Choices.2018)					*	*
(Mivision, 2014)					*	*
(Macular Society 2018)		*				
(Heidelberg Engineering, 2018)					*	*
(Singhealth, 2018)						

Table 6: Sampling of pictorial depictions of metamorphopsia featuring print

The division between clinical and online eye heath information is apparent in terms of expression of viewing guidance. For Marmor (2000) indicated in this presentation of Edvard Munch's depiction that this was a personal account of vision loss. With Marmor & Marmor (2010) also declaring their imagery as being monocular vision simulations, The Macular Society on opting for an obvious caricature based illustration removes the doubt as to it being a personal account. This is in contrast to the other images which remain elusive as to an individual's real life representation of vision loss. The question as to whether monocular or binocular vision is portrayed might seem elementary, but unlike Marmor (2000), and Marmor & Marmor's (2010) direct references to monocular vision, vagueness prevails across all the other depictions. With NHS Choices (2018), Mivision (2014) and Heidelberg Engineering (2018) opting for human representation i.e. fingers, and head and torso, this offers a vague appreciation of viewing distances, alongside a book, newspaper and crossword for gauging the original scene sizes, retrospectively. The Singhealth (2018) image of distorted print is ambiguous as to both original viewing distance and print size. Fundamentally even with the limitations listed above, these images do convey print legibility issues manifesting within metamorphopsia.

4.5 Qualitative Measures Within the Gold Standard of Metamorphopsia Assessment

Patients and the general public could be forgiven for enquiring if the Amsler chart featured in Singhealth (2018) webpage, Figure 11, and that on Optiquebonot (2018) website, see Figure 13; is an accurate measure of visual distortion. It could be assumed that the distortion within the thumbnail Amsler chart in the right hand area of Figure 13, featuring print also distorted is based on exact measurements, perhaps even derived from patients examinations. Indeed it could also be assumed that the severity captured in depiction form is derived from clinical quantification of metamorphopsia. However, the following references cast doubt as to the role quantification currently plays in pictorial depictions of metamorphopsia;

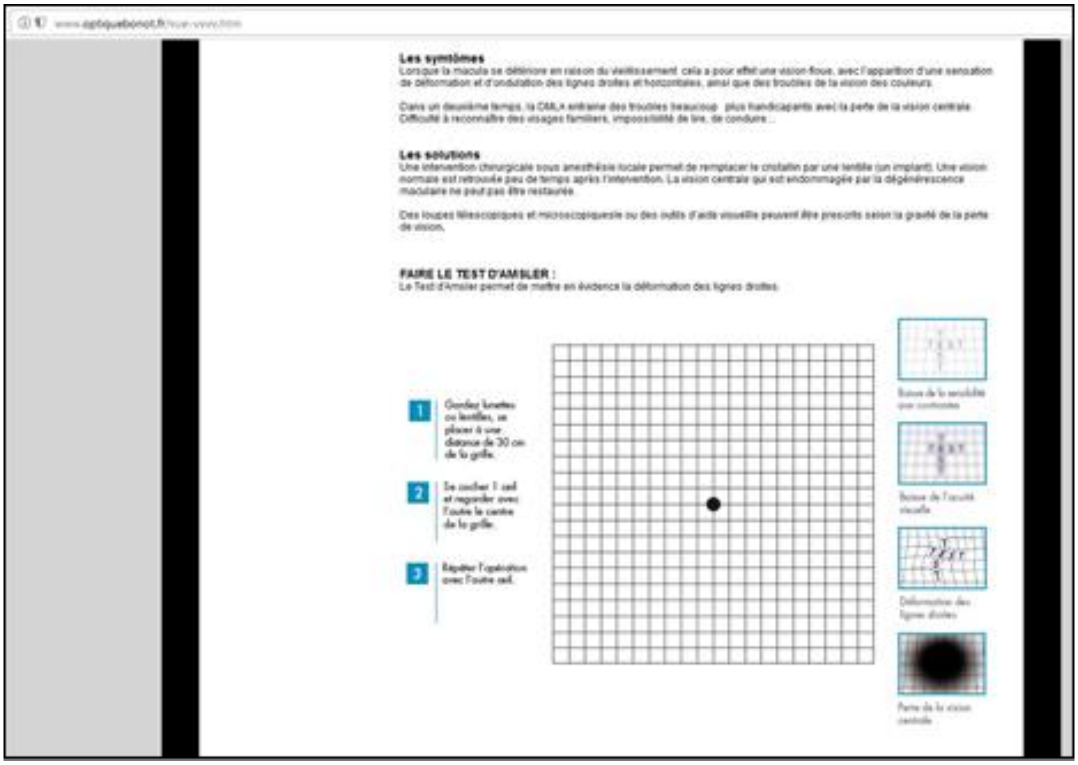


Figure 13: Screenshot, the Amsler test, deformed straight lines, Optiquebonot 2018.

‘Although the Amsler grid is a useful screening test, it also has inherent limitations. For instance, the test result is qualitative. It is difficult for some patients to describe what they see’ (Wang et al., 2002. p.1)

And

‘With the Amsler charts, however, it is difficult to quantify the severity of metamorphopsia because the patients have to self-describe the degree of image distortion’ (Okamoto et al., 2012. p.1)

And

‘Amsler grids do not provide precise, quantifiable measures of visual field defects, and are therefore not useful as monitoring tools for disease progression.' (Schwartz & Loewenstein, 2015. p.4)

Optiquebonot (2018) in presenting the Amsler Chart on their webpage encourages viewers to conduct the monocular visual field test, with the instructions alongside. Using images on the right-hand side of the page Optiquebonot (2018) demonstrate in this order, a normal scene of print, a blurred scene of print, a distorted scene of print, and finally a scotoma obscuring print. Their instructions of usage of the Amsler chart corresponded with the charts origins in 1947 by Swiss ophthalmologist Marc Amsler. Interestingly in comparison with Marmor & Marmor's simulations of metamorphopsia depicting 10 degrees of monocular visual field, this equates to approximately 'three quarters' of spatial coverage of that of the Amsler grid i.e. 15° 48' 0.86" of angular vision, when viewed at a distance of 36 cm.

Importantly the Amsler grid is freely available on worldwide online eye health resources. As such, Luk et al., (2013) indicate that over two million of these charts frequent the Google search engine database; some plain and others illustrating distortion. With the Amsler Chart being a gold standard ophthalmic practice, over the years of testing its effectiveness has come into question, see references;

'The Amsler grid is an especially challenging test for patients because it requires the patient to delineate, on the chart, the perception of their vision defects, while fixating elsewhere' (Trevino, 2008. p.2)

And,

‘With the Amsler charts, however, it is difficult to quantify the severity of metamorphopsia because the patients have to self-describe the degree of image distortion’ (Okamoto et al., 2012. p.1)

In the reference below, Okamoto et al., (2012) convey the principle limitation of the Amsler Chart in attempting to judge accurately the degree of distortion a patient is experiencing;

‘With the Amsler charts, however, it is difficult to quantify the severity of metamorphopsia because the patients have to self-describe the degree of image distortion’ (Okamoto et al., 2012. p.1)

5 Visualisations Accompanying Quantified Metamorphopsia

Having explored the qualitative depictions of metamorphopsia featuring print sampled from worldwide online eye heath information, this section of the study searches for evidence of quantification applied within the imagery. Of note no imagery sampled featured numerical expression of the severity of distortion displayed. Having identified this crucial omission in terms of directly linking quantification being applied to the images, a different approach sought to identify underlying processes of quantification. The process by which quantification information could inform qualitative expression in the drawings, is explored here. The selection of the metamorphopsia quantification tools was based on those tools capable of outputting a visualisation of the patients' view of distortion in conducting a test. The sampled tools range from, M-charts thought advantageous in clinical settings (Manabe et al, 2016; Kinoshita, 2015),Modified Amsler Grid bridging qualitative reporting of metamorphopsia (Shinoda et al., 2000), the Metastat Test, a free online interactive Grid for general public usage (Frisén, 2018) and finally a Metamorphopsia questionnaire previously utilised to evaluate M-Charts performance.

M-CHARTS

Note M- Charts have been included into the sample tools even though in practice no visualisation of distortion accompanies the scoring. However, this is not to say that patients could draw their distortions between the gaps of the dots, thus producing a visualisation.

The M-CHART technique:

Principally these M-CHARTS are a series of charts featuring nineteen doted lines which are presented to patients, with progressively widening gaps between the dots forming a line. On patients initially perceiving distortion amidst the finely pitched doted lines, the patient proceeds with viewing the ever coarser pitched dotted lines, while fixating on a central dot within the lines, until the perception of distortion disappears. The corresponding lines' assigned visual angle, on which the distortion disappears is utilised as the metamorphopsia score. This is for both vertical and horizontal orientations of chart usage in this monocular eye test (Nowomiejska et.al., 2013. p. 2).

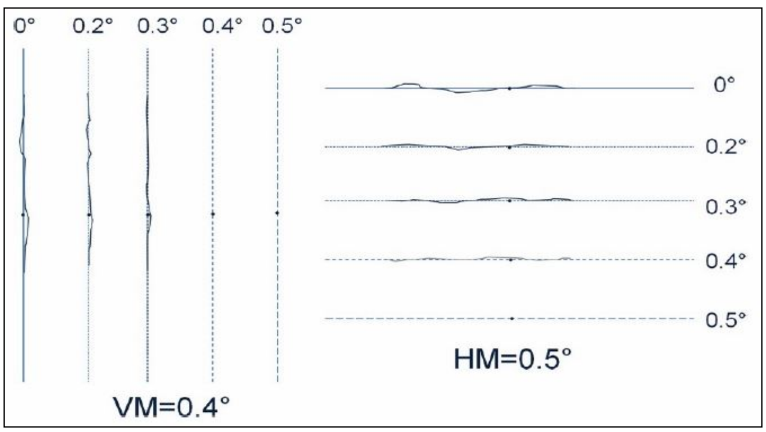


Figure 13: Metamorphopsia vertical (VM = 0.4°) (left) and horizontal (HM = 0.5°) (right) Nowomiejska et.al. 2013.

The M-CHARTS metamorphopsia sores and accompanying visualisations:

Interestingly in Figure 13, freehand lines illustrate a patient's view of the test. However, in practice as previously stated, only the original undistorted doted lines infer the severity of patient's metamorphopsia. Thus, an explicit view of the patient's actual perceived distortion remains hidden from the clinicians. Hence the distorted lines present in Figure 13 are an approximation of the patient's view, and only shown for illustration purposes. However, M-CHARTS in accuracy terms are clinically regarded as being effective at detecting and quantifying metamorphopsia (Matsumoto, 2013; Kinoshita, 2015; Bae et al, 2015; Kinoshita, 2015; Manabe et al,2016).

Modified Amsler chart

Modified Amsler chart technique:

The usage of a modified Amsler Chart, see Figure 14; involves patients perceiving distortion while viewing a chart, who are instructed to trace their perceived distortion of the chart, on the chart itself (Shinoda et al., 2000). Crucially this involves the usage of good vision in the other eye. Overall this technique involves fixating on the central dot of the chart, and delineating the distortion from memory. Subsequent comparison of the original modified Amsler Chart's total 'lineage' length, to that of the lineage drawn on the chart by the patient is the basis for the metamorphopsia score.

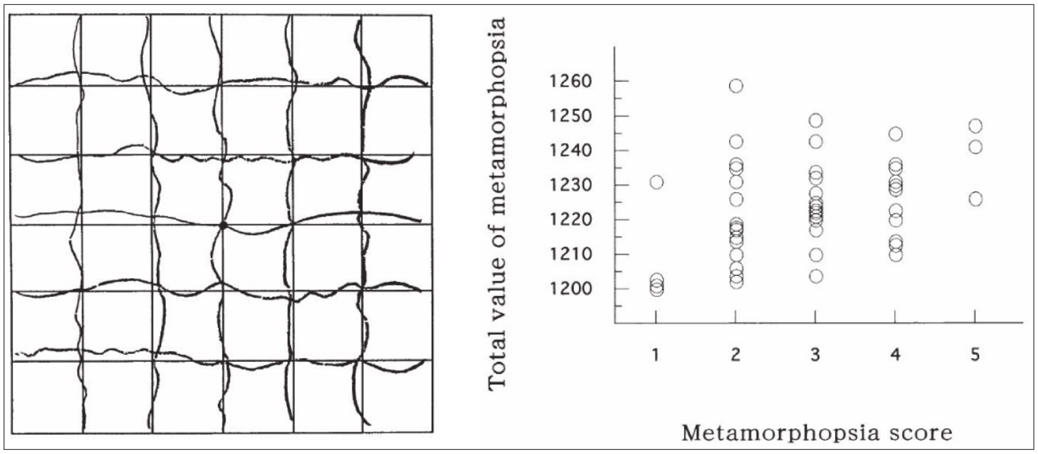


Figure 14: Calculation of metamorphopsia value (left)… score (Right) Shinoda et al., 2000

A modified Amsler Chart metamorphopsia sores and accompanying visualisations:

It is evident that a metamorphopsia scores of between one to five is used in this instance. The lineage drawn on a chart (left hand image) demonstrates a good level of qualitative detail. However, Shinoda et al., (2000) indicates that patients may encounter difficulties in drawing accurately. Also fundamentally, this technique relies on not having binocular vision distortion.

Metastat Test (online browser based)

Metastat Test technique:

On Lars Frisén's website Neuro-Ophthalmology Nuggets, a webpage entitled On Critical Testing of Central, provides a link to open Lars Frisén's Metastat Test in a web browser, see Figure 15. Here individuals are presented with a keyboard interactive grid consisting of black lines on a white background, with a centralised fixation point. On patients encountering distortion when viewing this grid, by pressing the keyboard arrows manipulation of selected grid vertices can be straightened. On straightening the grid elements and pressing an assigned results key, the mean and max deviation scores for distortion are produced across the grid

Metastat Test metamorphopsia sores and accompanying visualisations:

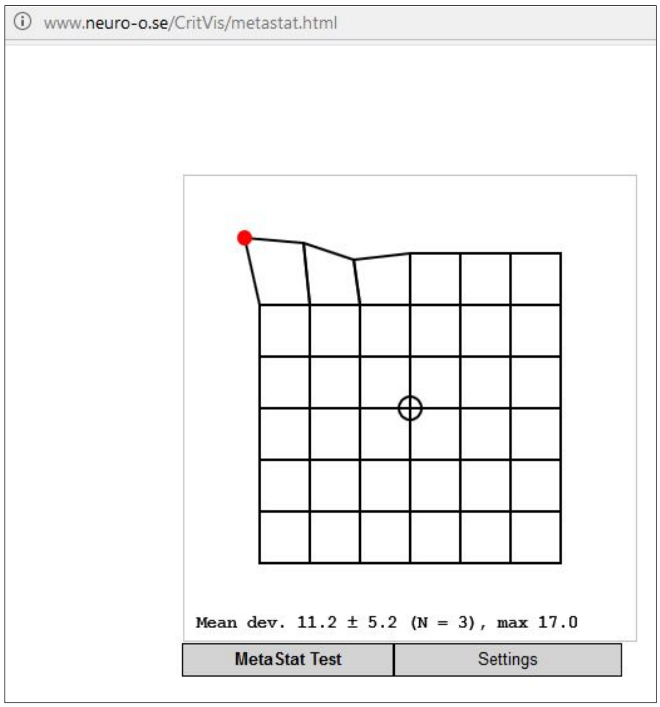


Figure 15: Metastat Test, Frisén 2018.

Interestingly, as shown in Figure 15, the Metastat Test produces not only a mean/max score, but the accompany visualisation is a clinicians view, of patient nullified distortion. This a significant limitation when seeking a patients view of distortion.

Metamorphopsia Questionnaire

The Metamorphopsia questionnaire described here was utilised to examine the performance of M-CHARTS etc. (Arimura et al., 2011).

Metamorphopsia Questionnaire technique:

Within the context of this research it was noted that aside the author's intended use of the metamorphopsia questionnaire, seeking the severity of distortion from past memories of objects distorted, the printed questions are test visual stimuli in themselves.

Metamorphopsia Questionnaire scores and accompanying visualisations:

In figure 16, it is evident that patients gauge their vision loss on a scale from zero to four, by recalling their past memories of visual distortion.

10) When reading a book, newspaper or display on a computer screen, do the lines of words appear distorted to you ?
0) Not at all 1) A little 2) Moderately 3) A great deal
4) None of the above

Figure 16: Question Ten, Metamorphopsia Questionnaire, myvisiontest.com 2018

On reviewing the metamorphopsia quantification tools sampled, it is apparent that there is a trade off between the reported high accuracy of the M-CHART and the limitations of having no output other than a metamorphopsia score. The modified Amsler Grid was identified as limited due to the necessity of possessing drawing skills, accompanied by one good eye. The MetastatTest while easy to conduct, has a resulting visual output not reflective of the original patient's distorted view of the grid. The metamorphopsia questionnaire has only rudimentary scoring and no visual output.

Metamorphopsia quantification tools	Distortion signifiers					
	Print	Dots	Lines	Grids	Faces	Scenes
M-CHARTS		*				
Modified Amsler chart			*	*		
MetaStat Test				**		
Metamorphopsia questionnaire	*					

Table 7: Metamorphopsia quantification tools test stimuli * and output stimuli *

5.1 Correlations Within Quantification Tools And Sampled Depictions

Having previously identified metamorphopsia quantification tools/techniques, the comparison of what elements coexist with the depictions sampled is explored here.

Metamorphopsia quantification tools with score visualisation	Sampled online depictions					
	NHS Choices.2018	Mivision, 2014	Macular Society 2018	Heidelberg Engineering, 2018	Singhealth, 2018	Optiquebonot 2018.
M-CHARTS						
Modified Amsler Chart				G	G	G
Metastat Test				G	G	G
Metamorphopsia Questionnaire	P	P	P	P	P	P

Table 8: Score and visualisation correlations

(S) Scores; (P) print; (G) Grid via quantification tools an online depictions.

In Table 8, the visual stimuli of Print is intrinsically linked to the selection of sampled online depictions. On comparison with the metamorphopsia quantification tools with score visualisation, only the Metamorphopsia Questionnaire surfaced as using print as a possible visual stimulus. Importantly overall the comparisons made in Table 7 demonstrated the following information:

- No scoring of metamorphopsia severity accompanies the depiction sampled
- Grids correlated in visualisation terms

Importantly, the use of grids in the quantification techniques of the Modified Amsler Chart and Metastat Test also correlate in visualisation terms only, with grids also presented in Singhealth, Optiquebonot 2018 and Heidelberg Engineering, 2018 depictions. Of note, Heidelberg Engineering, 2018 image being a crossword was regarded as closely resembling a grid in this exercise.

5.2 Nullification Of Metamorphopsia Principle

In this part of the literature review, the theory of metamorphopsia nullification is explored, having seen this evident in the Metastat Test. The concept of nullifying patients' visual distortions was examined by the late Professor Walter Kohn, and James Klingshirm, with their findings presented in a paper entitled 'Characterisation and correction of Macular distortion' (Kohn & Klingshirm, 2011). In this paper the authors discuss the mapping of the retina, in order to identify and attempt to nullify visual distortion, like that encountered by his wife, who developed AMD, see reference;

'I asked myself as a theoretical physicist, is there something I can contribute to this issue?' (Di Christina, 2012. p.1)

Professor Walter Kohn and James Klingshirm's research culminated in a patent being granted in April 2014, originally filed in 2011. Kohn & Klingshirm (2011) illustrated the complexity of interpretation of nullified distortion between patients and clinicians/technicians, see Figure 17. Here a grid of 16 squares first conveys no perceptual distortion observed while fixating on the central point, this is indicated in (a), a patient perceives distortion, this is indicated by (b), and in normal vision no distortion is evident. In nullifying the patient's perceptual grid distortions, indicated by (d), in normal vision the grid appears distorted, indicated by (c). Importantly on comparing (c) to (b) it is evident that an inverse of distortion characteristics emerges.

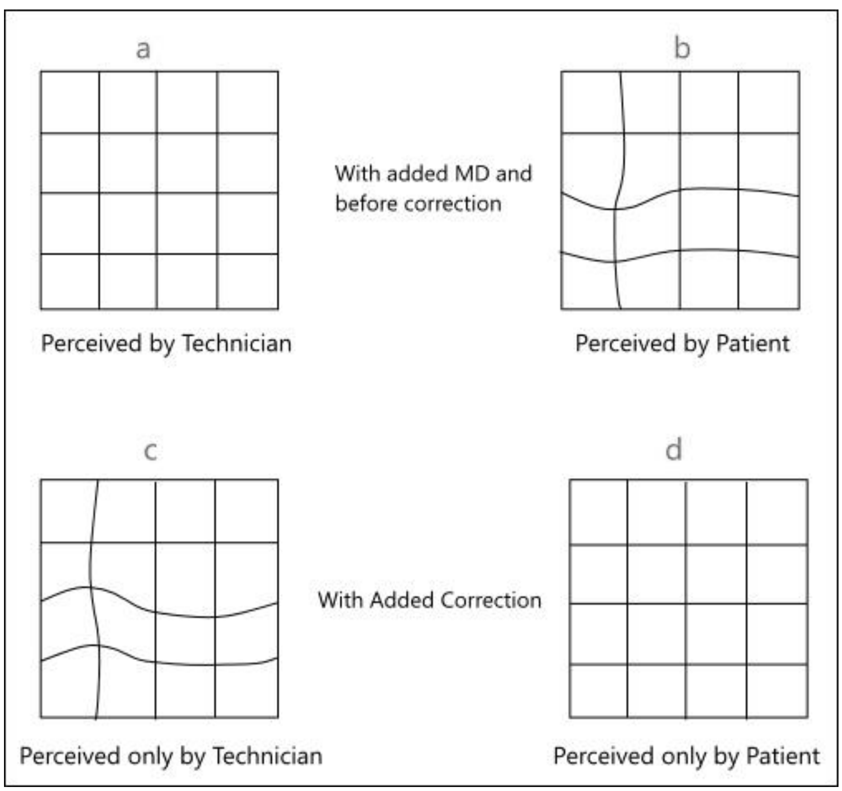


Figure 17: Time line of perceptions. Kohn. & Klingshirm

Kohn & Klingshirm's (2011) research culminated with the patent being granted from which they presented their research in colloquium, staged at the Kavli Institute of Theoretical Physics in 2014. At this event Kohn & Klingshirm (2014) presented their findings via a presentation demonstrating the nullification theory utilising print. However in subsequent years, authors like Wiecek et al., (2015) have expressed doubts as to whether accurate metamorphopsia correction is feasible via nullification. This is due to the accuracy required in the diagnostic tool determining the displacement calculations necessary.

5.3 Amsler Tool For Processing Metamorphopsia Correction In Practice

In a similar vein to Professor Walter Kohn initiating his research due to a family member experiencing symptoms of AMD, similarly Dr Markus Selmke relates how concerns about a relatives' vision problems initiated his interest in this area of research, see quote below;

'I was interested in that topic since I thought my grandma had this disease .... I wonder why the brain doesn't dimorph the image itself '(Selmke, 2016)

The above quote from Dr Markus Selmke, who champions the visualisation of theoretical physics, through his website at http://photonicsdesign.jimdo.com/software/, utilised knowledge previously revealed at Walter Kohns's colloquium at the 62nd Lindau Nobel Laureate meeting in the year 2012.

Amsler Tool for processing technique:

The above wording of ‘Processing’ refers to the underlying programming language of software which drives a ‘sketchbook’ displaying an Amsler grid. In functionality terms the Amsler Tool for Processing has a high feature set, incorporating two image layers; one for a grid, with the second a layer designated to image input via the file format of Joint Photographic Experts Group (jpg). Fundamental to the design of the Amsler Tool for Processing is the manipulation of the black line grid which in turn, similarly manipulates the image. Thus when a patient manipulates the grid vertices to remove their perceived distortion, the resulting background is their view of an undistorted grid Figure 18, image (A). Subsequently suppressing the grid layer reveals the clinicians view of what the patient perceives as being straight. See Figure 18, image (B). This is the same scenario as the Metastat test, whereby nullified distortion is only perceived by the patient and the clinician is left seeing the distortion.

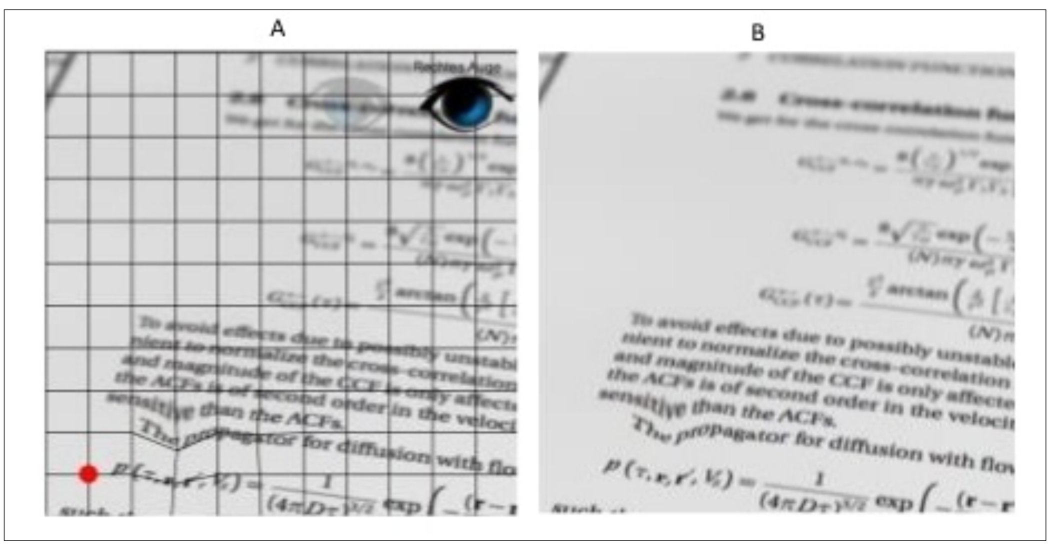


Figure 18 : Amsler Tool for Processing, (A) Clinicians view of Patients nullified distortion.

5.21 Updated Amsler Tool For Processing, A Patient's View Of Distortion

On contacting Dr Markus Selmke via email on the 19th of May 2016 regarding interrogating additional functionality of a patient's view of metamorphopsia, Dr Selmke provided an experimental Amsler Tool for processing script. This is entitled the Updated Amsler Tool for Processing, Figure 19

Update to Amsler Tool for processing technique:

On running the updated Amsler Tool for Processing script, the standard operational features remain the same. However using the keyboard input of 'p', results in an image which is inverse to that of the clinician's view previously discussed. In effect this is the patient's view of the distortion prior to nullification, hence a significant advantage in interpreting what a patient experiencing metamorphopsia observes. In Figure 19 (B) the image is that of the patient's nullified distortion seen in normal vision, as previously indicated. However in Figure 19 (C) reports the patient's original distortion.

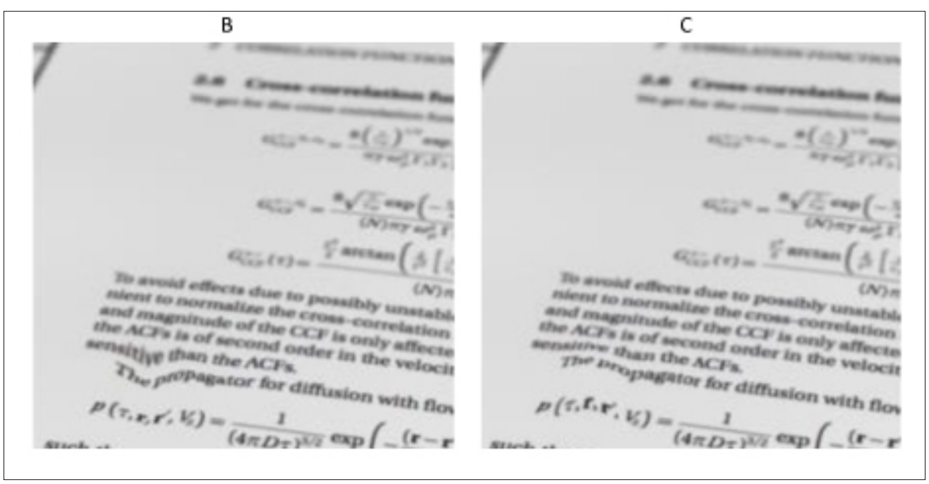


Figure 19: (B) Clinicians view of Patients nullified distortion, (C) Clinicians view of Patient's distortion,

On reviewing the Update to Amsler Tool for processing functionality, it is wise to consider this a new ‘concept’ in qualitative reporting of patient’s vision.The accuracy to such a process is unknown, as no literature is available detailing the accuracy of the tool at is present state.

5.4 Qualitative And Quantitative Measures May Coexist In Future Depictions

In reviewing the Updated Amsler Tool for processing, the extended functionality offering a patient’s view of metamorphopsia via an interactive grid, the principle of the interactive grid correlates with the interactive grid found in the Metastat Test. However, crucially, the Updated Amsler Tool for processing’ is limited to qualitative reporting of patient’s vision, whereas the interactive grid of the Metastat Test is currently limited to quantitative scoring of metamorphopsia, see Table 9.

Metamorphopsia reporting tools		Distortion signifies					Quantification
	Print	Dots	Lines	Interactive Grids	Faces	Scenes	
Updated Amsler Tool for Processing	*	*	*	* *	*	*	
MetaStat Test				**			*

Table 9: Metamorphopsia tools test stimuli * and output stimuli * and quantification.

On inspection of Table 9, it is evident that interactive grids while having commonality, currently neither of the tools in 'practice' has a means combining a patient's view and that of quantitative reporting of a patient's severity of metamorphopsia.

Fundamentally if either the Updated Amsler Tool for Processing or the MetaStat Test were to adopt each other's functionality this would result in bringing qualitative and quantitative measures of metamorphopsia together within distortion depiction. Such a union is the basis of emergent theory grounded theory propositioning that qualitative and quantitative measure can coexist in depictions of metamorphopsia. In order to test the principle of this proposition, the following bulleted steps demonstrate a means by which the imagery featured in Figure 20 was created.

1. Image (A) represents a patient's nullified distortion curve; a resulting quantitative metamorphopsia score is recorded via the Metastat test.
2. The patient's nullified distortion curve is then replicated in the Updated Amsler Tool for Processing, with the addition of a print layer in the background, this resulting in image (B)
3. On applying the Updated Amsler Tool for Processing, 'patient view', an image is created on which to superimpose the corresponding Metastat metamorphopsia quantitative sore, as displayed on image (D)

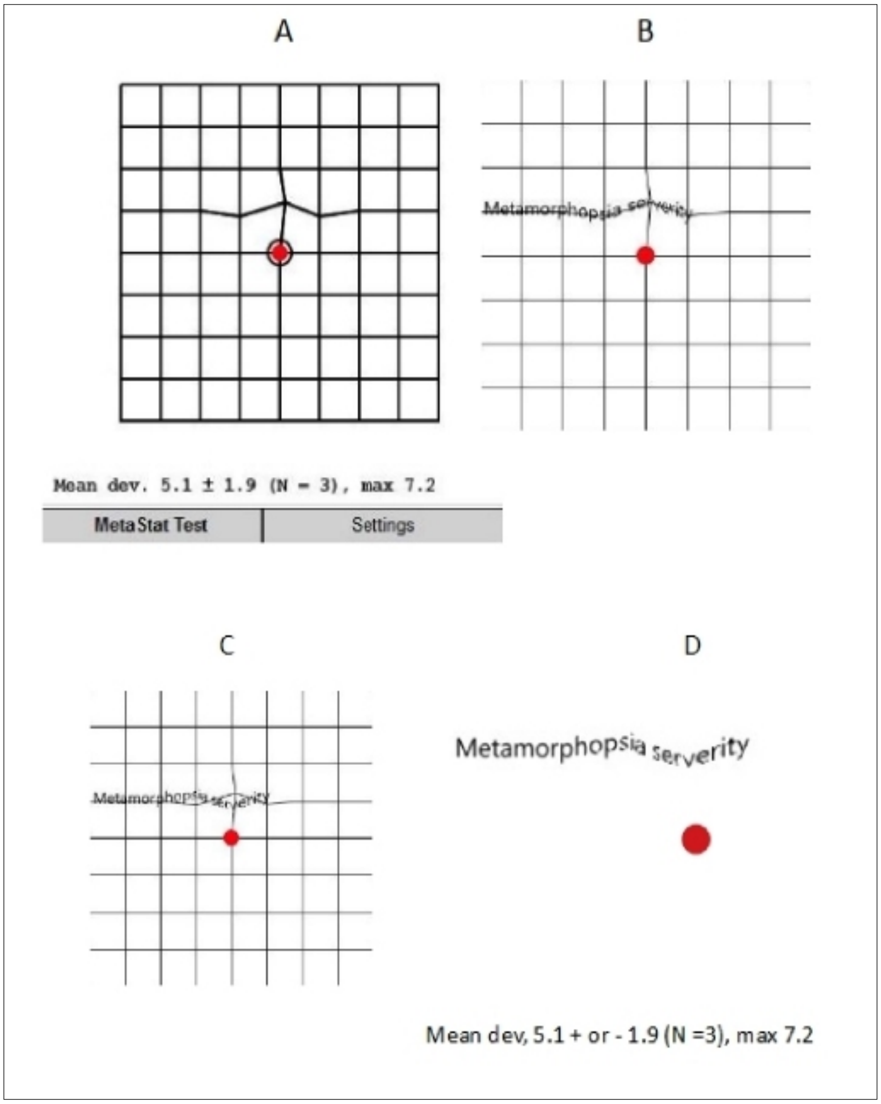


Figure 20: Metamorphopsia qualitative and quantitative measures coexisting in an image.

In examining the concept of merging qualitative and quantitative measures together, image (D) in Figure 20 demonstrates a patient's binocular, rather than the monocular view currently facilitated in the tests. In this instance the binocular view was instigated by fixating binocularly on the fixation point similarly to standard reading practice. Of note it must be emphasised that this experimentation demonstrates that qualitative and quantitative measures can co exist in the creation and viewing of images. Hence as will be discussed below, the research question in inquiring “is metamorphopsia captured in print, quantified?” has a basis in reality now.

6 Discussion

With Saigal et al., (2011) indicating that metamorphopsia is regarded as the hallmark of wet AMD and amidst the alarming AMD prevalence rates indicated by Shanahan (2017), the few online depictions available reporting ‘reading problems’ appear disproportionate to the scale of the problem. With clinical research focusing on lines and grids for quantitative measurement of metamorphopsia as seen in Table 7, qualitatively this correlates with UK online eye health information describing distortion with similar signifiers as seen in Tables 2 and 3. Edvard Munch’s drawing depicting his vision impairment demonstrates that personal accounts of metamorphopsia are possible using an artist’s skillset. Mamor and Mamor (2010) in demonstrating the simulation of metamorphopsia, revealed the importance of the ratio of size of image to viewing distance in the creation and viewing process of depiction. Similarly Legge & Bigelow, (2011) stressed the importance of these vision metrics, with Kroyer et al., (2005) indicating that metamorphopsia is commonly localised within retinal projections. The division between the Art and Science of depiction of metamorphopsia becomes apparent through lack of clarity within online worldwide imagery, as to whether even monocular versus binocular vision is portrayed, as indicated in Table 6. Winther (2016) highlights that patient to clinician communications are often problematic in matters of vision related reading problems. However, reading problems emerge in depictions alongside instances of Amsler Grid usage. Okamoto et al., (2012), state that the qualitative nature of Amsler Charts are inadequate quantifying metamorphopsia severity. This is the archetypical tool for metamorphopsia portrayal even in the context of reading problems, as indicated by

Optiquebonot’s 2018 webpage.

Notably, in terms of the research question, an absence of any quantified metamorphopsia scores within the images, weighs in favour of the argument that metamorphopsia captured in print, is not currently quantified. Furthermore as mentioned by Holz et al.,(2012), visual acuity scoring is not adept at relating reading problems. Intriguingly in correlating the visualisation aspects of metamorphopsia quantification tools, as seen in Table 7, interactive grids seemingly bridge qualitative and quantitative measures together, via the principle of metamorphopsia nullification as described by Kohn & Klingshirm (2011). In practice Lars Frisén’s Metastat Test in producing distortion scores, combined with Dr Markus Selmke’s Updated Amsler Tool for processing, gives insight into the ‘creation’ of pictorial depictions accompanied by a factual metamorphopsia score. While such a concept of merging qualitative and quantitative measures together is untested in one application, ‘principally’ an emergent theory now exists by which to make a reasoned response to the research question ‘is metamorphopsia captured in print quantified’. The response being ‘it is doubtful’, for past and recent depictions of this nature as no empirical evidence surfaced in the course of this study. However, it could be propositioned that the answer ‘yes’ could be construed as principally valid given the existence of image (D) in Figure 20, here in the study.

6.1 Conclusion

The research question, in asking ‘is metamorphopsia captured in print, quantified ?’ dared to challenge the division that is apparent between qualitative and quantitative reporting of metamorphopsia. To date no empirical evidence suggests such metamorphopsia depictions are informed or expressed through quantitative measures. However an emergent grounded theory identified in this study suggests such measures can co-exist in principle.

6.2 Future Potential Lines Of Inquiry

Having identified an ’emergent’ grounded theory through this research, developing it into a grounded theory requires thorough testing. Such testing within the context of general metamorphopsia depiction practice could not only add credability to the theory if valid, but add significant value to future metamorphopsia depiction practice.

6.3 Consideration Of The Limitation Of The Present Work

This study has been conducted from an author’s personal perspective of suffering metamorphopsia, and that of having an Art and Design, rather than a clinical background. The rarity of online pictorial depictions of metamorphopsia captured in print, results in few images being critiqued. No contact was made with the hosts of the images sampled. This prevented possible removal of images, which could jeopardise both this research and the current value of these existing depictions published within the public domain.

7 References

Ali, M, (2014) Personal communication, Contact Centre Team, Health and Social Care

Information Centre, Email: enquiries@hscic.gov.ukhttp, 2014, 29th April

Amsler, M. (1953) Earliest symptoms of diseases of the macula, The British Journal of Ophthalmology, 37(9) 521. (Internet). Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1324189/pdf/brjopthal01145-0011.pdf/ (Accessed 20th Nov 2016)

Arimura, E., Matsumoto, C., Nomoto, H., Hashimoto, S., Takada, S., Okuyama, S., & Shimomura, Y. (2011). Correlations between M-CHARTS and PHP findings and subjective perception of metamorphopsia in patients with macular diseases. Investigative ophthalmology & visual science, 52(1), 128-135 (Internet). Available from http://iovs.arvojournals.org/article.aspx?articleid=2126245 (Accessed 7th June 2016)

Arstila, V. & Pihlainen, K.(2009) The Causal Theory of Perception revisited Erkenntis, 70L3) 397-417. (Internet). Available from https://link.springer.com/article/10.1007/s10670-008-9153-7(Accessed 19th April 2015)

Atchison, D. A., Smith, G., & Smith, G. (2000). Optics of the human eye. (Internet). Available from https://pdfs.semanticscholar.org/c6a6/1968a25c1236024213cf30a240593a2db589.pdf. (Accessed 03th Aug 2015)

Audre Lorde (2012)   Sister Outsider (Web image) Available at https://books.google.co.uk/books?id=kE3ek (Accessed 07th Feb 2018)

Axel, E.S., Levent, (2003) N.S., eds.: Art Beyond Sight: A Resource Guide to Art, Creativity, and Visual   Impairment. AFB Press..(Internet). Available from https://books.google.co.uk/books?hl=en&lr=&id=B4ioCFic7m0C&oi=fnd&pg=PA11&dq=Axel,+E.S.,+Levent,+(2003 (Accessed 15th Feb 2018)

Bae, S. & Chae, J. (2013) Assessment of metamorphopsia in patients with central serous chorioretinopathy. Indian journal of ophthalmology, 61(4), 172.ebook. (Internet) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3714955/ (Accessed 20th Aug 2015)

Bae S, Jin K, Kim H, Bae SH. (2015) Clinical parameters related to metamorphopsia outcome in patients with resolved central serous chorioretinopathy using M-CHARTS: retrospective cohort study. BMC Ophthalmol 2015;15:180. (Internet). Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4683969/ (Accessed 3rd Dec 2015)

Bennett, M. D, (2011) RETINA: Refractive Eye-care, Advances in Epiretinal Membrane Treatment. (Internet) Available from http://epubs.democratprinting.com/article/RETINA%3A+Advances+in+Epiretinal+Membrane+Treatment/765211/72752/article.htm (Accessed 11th Jun 2016)

Birks, M. & Mills, J.(2011).Grounded theory: A practical guide. London, UK: SAGE.(Internet) Available from https://books.google.co.uk/books?hl=en&lr=&id=YsGICwAAQBAJ&oi=fnd&pg=PP1&dq=Birks,+M.+%26+Mills,+J.(2011).Grounded+theory:+A+practical+guide.+London,+UK:+SAGE&ots=-N- (Accessed 2nd April 2017)

Blom, J. D. (2010) A dictionary of hallucinations. New York, NY: Springer. (Internet) Available from https://www.springer.com/us/book/9781441912220 (Accessed on 15th

April 2018)

Boots WebMed.(Internet) Available from https://www.webmd.boots.com/a-to-z-guides/conditions-a-to-z/default.htm (Accessed 1st April 2018)

Burt J, Abel G, Elmore N, et al.(2016). Rating communication in GP consultations: the association between ratings made by patients and trained clinical raters. Med Care Res Rev;1–18 (Internet) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5858640/ (Accessed 9th Jan 2018)

Chaplin, P. K. N., & Bradford, G. E. (2011). A Historical Review of Distance Vision Screening EyeCharts What to Toss, What to Keep, and What to Replace. NASN School Nurse, 26(4), 221-228. (Internet) Available from http://journals.sagepub.com/doi/abs/10.1177/1942602X11411094 (Accessed 3rd Nov 2014)

Cohen, L., Gray, F., Meyrignac, C., Dehaene, S., & Degos, J. D. (1994). Selective deficit of visual size perception: two cases of hemimicropsia. Journal of Neurology, Neurosurgery & Psychiatry, 57(1), 73-78. (Internet) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC485042/ (Accessed 19th Mar 2017)

Creswell, J.W. (2009). Research Design: Qualitative, Quantitative, and Mixed Approaches. Thousand Oaks, CA: Sage. (Internet) Available from https://scholar.google.co.uk/scholar?q=Creswell,+J.W.+(2009).+Research+Design:+Qualitative,+Quantitative,+and+Mixed+Approaches.+Thousand+Oaks,+CA:+Sage.&hl=en&as_sdt=0&as_vis=1&oi=scholart&sa=X&ved=0ahUKEwj228Ocu7raAhWFJsAKHW7lA

YUQgQMILDAA. (Accessed 23rd Jun 2017)

Daily Express. (2012) Blindness epidemic, (Internet), Available from: http://www.express.co.uk/news/uk/302018/Blindness-epidemic-fear.(Accessed 10th August 2016)

Davies A. J, Borschmann R, Kelly S. P, et al, (2016). The prevalence of visual symptoms in poppers users: a global survey. BMJ OpenOphth2016;1:1–6.doi:10.1136/bmjophth-2016 (Internet) Available from http://bmjophth.bmj.com/content/bmjophth/1/1/1.full.pdf (Accessed 24th April 2017)

Déruaz, A., Safran, A. B., Sutter, M., & Müri, R. M. (2008). Alterations of the visual perception in advanced age-related macular degeneration. Clinical Medicine Insights. Geriatrics, 2, 21.(Internet) Available from http://docplayer.net/43128751-Alterations-of-the-visual-perception-in-advanced-age-related-macular-degeneration.html. (Accessed 16th Mar 2017)

DiChristina, M, (2012) Scientific America: How Physics Can Help Patients with Macular Degeneration, [Online], Available: (Internet) Available from https://blogs.scientificamerican.com/observations/how-physics-can-help-patients-with-macular-degeneration, (Accessed 3rd June 2016)

Du Toit, N. (2013) The gradual loss of vision. South African Family Practice, 55(6), 493-500. (Internet) Available from https://medpharm.tandfonline.com/doi/abs/10.1080/20786204.2013.10874404 (Accessed 10th Feb 2017)

Enacademic.com. (2014), Metamorphopsia, (Internet), Available from http://hallucinations.enacademic.com/1147/metamorphopsia, 2014, 14th (Accessed 11th Jul 2014)

Foley G, Timonen V. (2015). Using grounded theory method to capture and analyze health care experiences. Health Services Research. 2015;50:1195–1210 (Internet) Available fromhttps://www.ncbi.nlm.nih.gov/pmc/articles/PMC4545354/ (26th Mar 2018)

Frisén, L. (2012) Metastat test (Internet) Available from http://www.oft.gu.se/webdiagnos/CritVis/Cvis1.html, (Accessed 18th August 2016)

Gray, D. E. (2013). Doing research in the real world. Sage. (Internet) Available from

https://pdfs.semanticscholar.org/4511/52a94c97687ac0c42238cb4b1481dbe1d8cd.pdf Accessed 24th Jun 2016)

Haes,P,D, (2013) UK's NICE Final Appraisal Determination (FAD) Confirms Positive Recommendation for ThromboGenics' JETREA® for Treatment of Vitreomacular Traction and Macular Hole. ThromboGenics. (Internet) Available from http://www.thrombogenics.com/sites/default/files/upload/news. (Accessed 14th April 2016)

Healey, C. G., & Sawant, A. P (2012) On the limits of resolution and visual angle in visualization. ACM Transactions on Applied Perception (TAP), 9(4), 20. (Internet) Available from https://www.csc2.ncsu.edu/faculty/healey/download/tap.12.pdf (Accessed 2rd Mar 2016)

Heidelburg Engineering. 2018. Screenshot. AMD. https://www.spectralis-eyehealthcheck.co.uk/eye-disorders/age-related-macular-degeneration-amd/ (Accessed 23rd Feb 2018)

Jensen OM & Larsen M (1998): Objective assessment of photoreceptor displacement and metamorphopsia. Arch Ophthalmol 116: 1303–1306. (Internet) Available from https://jamanetwork.com/journals/jamaophthalmology/fullarticle/263799 (Accessed 4th Feb 2017)

Katz, M., & Kruger, P. (2009) The human eye as an optical system. Duane's clinical ophthalmology, 1, 49-50. (Internet) Available from https://entokey.com/the-human-eye-as-an-optical-system/ (Accessed 14th Jan 2017)

Kell, M. (2014) Macular degeneration: Navigating the Patient Pathway. (Internet) Available from https://www.mivision.com.au/macular-degeneration-navigating-the-patient-pathway, (Accessed 4th Jun 2016)

Kinoshita T, Imaizumi H, Miyamoto H, Okushiba U, Hayashi Y, Katome T, et al.(2015) Changes in metamorphopsia in daily life after successful epiretinal membrane surgery and correlation with M-CHARTS score. Clin Ophthalmol. 2015;9:225–33. Epub 2015/02/14. opth-9-225 [pii]. pmid:25678770; PubMed Central PMCID: PMC4322879 (Internet) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4322879/ (Accessed 2nd Aug 2017)

Kohn, W, & Klingshirn, J. (2011) Characterisation and correction of Macular distortion (Internet) Available from http://www.google.com/patents/US20110285960, (Accessed

16th Aug 2015)

Kohn, W, & Klingshirn, J. (2014) Visual Distortions in Macular Degeneration: Quantitative Diagnosis and Correction (Internet) Available from http://online.kitp ucsb.edu/online/colloq/kohn3/pdf/Kohn3_Colloquium_KITP pdf) (Accessed 7th Aug 2016)

Krøyer, Kristian, Ole Mark Jensen, and Michael Larsen. (2005) "Objective signs of photoreceptor displacement by binocular correspondence perimetry: a study of epiretinal membranes." Investigative ophthalmology & visual science 46.3 (2005): 1017-1022. (Internet) Available from http://iovs.arvojournals.org/article.aspx?articleid=2124526 (Accessed 11th Feb 2017)

Krøyer, K., Christensen, U., Larsen, M., & La Cour, M. (2008). Quantification of metamorphopsia in patients with macular hole. Investigative ophthalmology & visual science, 49(9), 3741-3746. (Internet) Available from http://iovs.arvojournals.org/article.aspx?articleid=2164372 (Accessed 23rd Feb 2016)

Legge, G, & Bigelow, C. (2011) Does print size matter for reading? A review of findings from vision science and typography. Journal of Vision, 11(5) (Internet) Available from http://jov.arvojournals.org/article.aspx?articleid=2191906 (Accessed 23rd Feb 2016)

Liu H, Wong D, Yow A, Xu Y, Yin F, Laude A, Lim T. (2016). "Determining the difference in eyegaze measurements in individuals with Age related Macular Degeneration", 2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), pp. 1348-1351, 2016. (Internet) Available from http://ieeexplore.ieee.org/abstract/document/759095(Accessed 7th Feb 2017)

Macular Society. (Internet) Available from https://www.macularsociety.org (Accessed 23rd Mar 2018)

Macular Society. 2018. Screenshot. Age Related Macular Degeneration-AMD symptoms https://www.macularsociety.org/age-related-macular-degeneration-0 (Accessed 23rd Feb 2018)

Maheshwari, A., & Williams, D. R. (2001) Learning optics using vision. Biomedical Engineering Center for Visual Science University of Rochester Rochester, NY. (Internet) Available from http://www.cfao.ucolick.org/EO/Resources/Learn_optics_AO.pdf (Accessed 5th March 2014)

Manabe, K., Tsujikawa, A., Osaka, R., Nakano, Y., Fujita, T., Shiragami, C., & Muraoka, Y. (2016) Metamorphopsia Associated with Branch Retinal Vein Occlusion. PloS one, 11(4), e0153817. (Internet) Available from http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0153817 (Accessed 1st Feb 2018)

Marmor, M. (2000) A brief history of macular grids: from Thomas Reis to Edvard Munch and Marc Amsler. Surv.Ophthalmol. 44, 343-353. (Internet) Available from http://www.surveyophthalmol.com/article/s0039-6257(99)00113-7/abstract (Accessed 12th Jun 2016)

Marmor, D, & Marmor, M. (2010) Simulating vision with and without macular disease. Archives of ophthalmology, 128(1), 117. (Internet) Available from http://www.myvisiontest.com/img/sim_txt.jpg, (Accessed 18th August 2016)

Marshall, M. (2012) Oldest confirmed cave ar is a single red dot. New Scientist, 214(2870), 10-11.(Internet) Available from https://www.newscientist.com/article/dn21925-oldest-confirmed-cave-art-is-a-single-red-dot/ (Accessed 19th Jun 2016)

Matsumoto,C. Arimura, E. Okuyama, S. Takada, S. Hashimoto, Y. Shimomura.(2003) Quantification of metamorphopsia in patients with epiretinal membranes. Invest. Ophthalmol. Vis. Sci., 44 (2003), pp. 4012-4016 ((Internet) Available from http://iovs.arvojournals.org/article.aspx?articleid=2124317 ((Accessed 5th March 2017)

McBride S. (2015).Patients with severe sight loss Emotional support and counselling. Eyecare NHS. (Internet) Available from http://www.eyecare.nhs.uk/uploads/Emotionalsupport.PDF. (Accessed 8th March 2017)

McGowan G; Ivanova T; Yorston D; Strang N; Manahilov V. (2013) ARVO Annual Meeting Abstract JUNE 2013, Volume 54, Issue 15. (Internet) Available from http://iovs.arvojournals.org/article.aspx?articleid=2148661 (Accessed 15th Apr 2017)

McGowan, Gerard & Yorston, David & Strang, Niall & Manahilov, Velitchko. (2015). D-CHART: A Novel Method of Measuring Metamorphopsia in Epiretinal Membrane and Macular Hole. Retina (Philadelphia, Pa.). 36. 10.1097/IAE.0000000000000778. (Internet) Available from https://journals.lww.com/retinajournal/Abstract/2016/04000/D_CHART__A_Novel_Method_of_Measuring.6.aspx (Accessed 26th Oct 2017)

Metamorphopsia. (n.d.) Collins Dictionary of Medicine. (Internet) Available from http://medical-dictionary.thefreedictionary.com/metamorphopsia, (Accessed 29th June 2016)

Midena E, Vujosevic S. (2016) Metamorphopsia: An Overlooked Visual Symptom. Ophthalmic Res. 2015;55(1):26–36. Epub 2015/11/12. [pii]. pmid:26554918. (Internet) Available from https://www.karger.com/Article/Abstract/441033 (Accessed 19th Sept 2017)

Mintel Group Limited. (2017). Optical Goods Retailing – UK, February 2015.London: Mintel Group Ltd. (Internet) Available from http://reports.mintel.com. (Accessed 5th March 2017)

Montori VM. Ebbert JO. (2002) TRIP database.BMJ Evidence-Based Medicine 2002;7:104.(Internet) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1852635/ (Accessed 3rd Feb 2018)

Myvision (2014). Macular degeneration. Screenshot-Macular degeneration- navigating the patient pathway. (Internet) Available from https://www.mivision.com.au/macular-degeneration-navigating-the-patient-pathway/(Accessed 10th May 2017)

Myvisiontest.com (2018). Question ten, Metamorphopsia questionnaire, (Internet) Available from http://www.myvisiontest.com/img/arimura_1.jpg/(Accessed 10th Feb 2016)

Nassar M.K., Badawi,N.M., & Diab,M.M.M.(2015). Resurrection of the Amsler chart in macular diseases.Menoufia Medical Journal, 28(1) 174. (Internet) Available from https://www.researchgate.net/publication/276431177_Resurrection_of_the_Amsler_chart_in_macular_diseases (Accessed 5th Sept 2017)

NHS Choices (2018) Screenshot. Age Related Macular Degeneration(AMD) (Internet) https://www.nhs.uk/conditions/age-related-macular-degeneration-amd/symptoms/ (Accessed 23rd Mar 2018)

Nowomiejska, K., Oleszczuk, A., Brzozowska, A., Grzybowski, A., Ksiazek, K., Maciejewski, R., ... & Rejdak, R. (2013). M-charts as a tool for quantifying metamorphopsia in age-related macular degeneration treated with the bevacizumab injections. BMC ophthalmology, 13(1), 1. (Internet) Available from https://bmcophthalmol.biomedcentral.com/articles/10.1186/1471-2415-13-13 Accessed 2nd Feb 2018)

Opticalexpress. (2018) Available from https://www.opticalexpress.co.uk (Accessed 23rd Feb 2018)

Optiquebonot (2018) Screenshot, (Internet) Available from http://www.optiquebonot.fr/vue-vvvv.htm (Accessed 23rd Marl 2018)

Owen, C. G., Fletcher, A. E., Donoghue, M., & Rudnicka, A. R. (2003). How big is the burden of visual loss caused by age related macular degeneration in the United Kingdom?. British Journal of Ophthalmology, 87(3), 312-317. (Internet) Available from http://bjo.bmj.com/content/87/3/312.short (Accessed 18th Jun 2016)

Oxforddictionaries.com, (2018a), Quantification definition (Internet) Available from https://en.oxforddictionaries.com/definition/quantification. (Accessed 11th April 2018)

Oxforddictionaries.com, (2018b), Qualitative definition (Internet) Available from https://en.oxforddictionaries.com/definition/qualitative (Accessed 11th April 2018)

Oxforddictionaries.com, (2018c), Delineation definition (Internet) Available from https://en.oxforddictionaries.com/definition/delineation. (Accessed 11th April 2018)

Patient info. (Internet) Available from https://patient.info/health/eye-problems (Accessed 23rd Mar 2018)

Popov D (2018) Shutterstock.com. Young businessman reading newspaper, https://www.google.co.uk/search?safe=strict&client=safari&rls=en&dcr=0&q=andrey+popov+stock+id+young+businessman+reading+breaking+news&spell=1&sa=X&ved=0ahUKEwjI_fmTzLzaAhVkDcAKHTSADnEQBQgkKAA&biw=1126&bih=706 (Accessed 12th Feb 2018

Precision vision, (2016) Snellen Eye Test Charts Interpretation; Visual Ability (Internet) Available from http://precision-vision.com/snellen-eye-test-charts-interpretation/ (Accessed 15th Augl 2016)

Radner W, (2016).Near vision examination in presbyopia patients: Do we need good homologated near vision charts (Internet) Available from https://eandv.biomedcentral.com/track/pdf/10.1186/s40662-016-0061-7 (Accessed 23rd May 2017)

Ricci, F., Cedrone, C., & Cerulli, L. (1998). Standardized measurement of visual acuity. Ophthalmic epidemiology, 5(1), 41-53. (Internet) Available from https://www.tandfonline.com/doi/abs/10.1076/opep.5.1.41.1499 (Accessed 27th April

2017)

RNIB. (2018) (Internet) Available from https://www.nhs.uk/conditions/Pages/BodyMap.aspx?Index=S (Accessed 23rd Mar 2018)

Rose S, Spinks N, and Canhoto I. (2014) .Management Research: Applying the Principles.Routledge, New York, NY, Chapter Supplement:Quantitative Content Analysis, 117–12 (Internet) Available from https://scholar.google.co.uk/scholar?hl=en&as_sdt=0%2C5&q=Rose+S%2C+Spinks+N%2C+and+Canhoto+I.+%282014%29+.Management+Research%3A+Applying+the+Principles.Routledge%2C+New+York%2C+NY%2C+Chapter+Supplement%3AQuantitative+Content+Analysis%2C+117–12&btnG= (Accessed 14th Oct 2017)

Schwartz, R., & Loewenstein, A. (2015). Early detection of age related macular degeneration: current status. International Journal of Retina and Vitreous, 1(1), 1. (Internet) Available from https://journalretinavitreous.biomedcentral.com/articles/10.1186/s40942-015-0022-7 (Accessed 12th Jun 2016)

Scrivens Opticians. (2018)(Internet) Available from https://scrivens.com/opticians/ (Accessed 23rd Mar 2018)

Selmke, M, (2016). Personal email. Macular Degeneration Analyzer and Reverse Distortion, (Internet) www photonicsdesign.jimdo.com/software, (personal communication 19/05/2016

Shields and Twycross A. (2003). The difference between incidence and prevalence, Paediatric Nursing vol 15 no 7 (Internet) Available from http://russwilson.coffeecup.com/Incidence_prevalence.pdf (Accessed 16th Sept 2016)

Shinoda, K., Ishida, S., Kawashima, S., Matsuzaki, T., Yamada, K., & Katsura, H. (2000). A new method for quantification of metamorphopsia in patients with epiretinal membrane. Japanese journal of ophthalmology, 44(4), 424-427. (Internet) Available from https://www.sciencedirect.com/science/article/pii/S0021515500001738. (Accessed 19th Aug 2016)

Shutterstock (2018a) Man completing crossword. Paul Maguire. Available from https://www.google.co.uk/search?q=shutterstock.com%5Cimage-+photo%5Cman-completing+crossword-1817063+Paul+Maguire&safe=strict&client=safari&rls=en&dcr=0&tbm=isch&source=iu&ictx=1&fir=xLPHF8d4cYO0XM%253A%252CI-wanRs3kxewUM%252C_&usg=__UuUeQewHzZyN_5tLytiWutHN1cE%3D&sa=X&ved=0ahUKEwjw1bD_3LzaAhWiJ8AKHdDjA9IQ9QEIQDAA#imgrc=xLPHF8d4cYO0XM: (Accessed 20th Jan 2018)

Singhealth.(2018).Screenshot. Age related macular degeneration symptoms. Available from https://www.singhealth.com.sg/PatientCare/Overseas-Referral/vt/Conditions/Pages/Age-Related-Macular-Degeneration.aspx (Accessed 23rd Mar 2018)

Specsavers.(2018) (Internet) Available from https://www.specsavers.co.uk (Accessed 23rd Mar 2018)

Strauss, A., & Corbin, J. (1998). Basics of qualitative research: Grounded theory procedures and techniques (2nd ed.). Newbury Park, CA: Sage. (Accessed 15th Oct 2017)

Tesco opticians.(2018) (Internet) Available from https://www.tescoopticians.com/help-and-advice/eye-health/ (Accessed 23rd Mar 2018)

Trevino, R. (2008) Recent progress in macular function self-assessment. Ophthal. Physiol. Opt, 28(3), 183-192. (Internet) Available from https://onlinelibrary.wiley.com/doi/full/10.1111/j.1475-1313.2008.00561.x (Accessed 26th th Sept 2017)

Ugarte, M., Shunmugam, M., Laidlaw, D. A. H., & Williamson, T. H. (2013) Morphision: A method for subjective evaluation of metamorphopsia in patients with unilateral macular pathology (ie, full thickness macular hole and epiretinal membrane) Indian journal of ophthalmology, 61(11), 653. (Internet) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3959082/ (Accessed 14 th Aug 2017)

Varano M, Eter N, Winyard S, Wittrup-Jensen KU, Navarro R, Heraghty J.(2016) The emotional and physical impact of wet age-related macular degeneration: findings from the wAMD Patient and Caregiver Survey. Clin Ophthalmol;10:257–267 (Internet) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5328297 (Accessed 23rd Sept 2017)

Vision Express. (Internet) Available from https://www.visionexpress.com/eye-health/eye-conditions/macular-degeneration/ (Accessed 23rd Mar 2018)

Wang, Y. Z., Wilson, E., Locke, K. G., & Edwards, A. O. (2002) Shape discrimination in age-related macular degeneration. Investigative ophthalmology & visual science, 43(6), 2055-2062. (Internet) Available from http://iovs.arvojournals.org/article.aspx?articleid=2123562 (Accessed 16th Aug 2017)

Wiecek, E., Lashkari, K., Dakin, S. C., & Bex, P (2015) Prevalence, Patterns and Repeatability of Metamorphopsia in Macular Disease: A Statistical Analysis of 7,106 Amsler Grids. Ophthalmology, 122(2), 431. (Internet) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4339289/ (Accessed 19th Jan 2018)

Wiecek, E., Dakin, S. C., & Bex, P (2014) Metamorphopsia and letter recognition. Journal of vision, 14(14), 1-1. (Internet) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4249589/ Accessed 2nd Feb 2016)

Wiecek, E., Lashkari, K., Dakin, S. C., & Bex, P (2015) Novel Quantitative Assessment of Metamorphopsia in Maculopathy. Investigative ophthalmology & visual science, 56(1), 494-504. (Internet) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4299468/ (Accessed 7th Nov 2017)

Winther, C. (2016) Aspects on Function in Age-Related Macular Degeneration. (Internet) Available from https://gupea.ub.gu.se/handle/2077/40885 (Accessed 12th Jun 2017)

Wong, W. L., Su, X., Li, X., Cheung, C. M. G., Klein, R., Cheng, C. Y., & Wong, T. Y. (2014) Global prevalence of age-related macular degeneration and disease burden projection for 2020 and 2040: a systematic review and meta-analysis. The lancet global health, 2(2), (Internet) Available from https://www.sciencedirect.com/science/article/pii/S2214109X13701451 (Accessed 11th

Mar 2017)

Zekite, A. (2014), personal commination, Study Research Assistant, Research & Development, Moorfields 25th April 2014