An exploration of students' perceptions regarding medical illustrations as a learning tool

by

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Summary

Modern medical students are exposed to a variety of anatomical and physiology textbooks and atlases as part of their medical training. Although little has been written on how these students interact with medical illustrations during learning, several scholars allude to the importance of combining visual and textual information in the learning process. Medical illustrators have the ability to proficiently organise visual and textual elements in such a fashion to communicate a certain message. However, medical illustrators should be aware of students' needs when designing visual material for learning purposes. The gap that this study aimed to address is one often experienced in South Africa, where illustrators know very little about the user, in this case medical students' use of illustrations as a learning tool. The importance of this study derives from the development of user-centred knowledge to improve the quality of work produced by medical illustrators.

The aim of the study was to explore how design elements and principles influence the use, comprehension and preference of medical illustrations as part of the learning experience. Two other aspects selected for this study are the relevance of labelling techniques in medical illustration as well as the quality of the reproduction of images, especially for learning purposes.

This study was conducted through exploratory qualitative research in order to develop a deeper understanding of the way medical illustrations are used during learning. Constructivism was selected as the epistemological approach for this study as it focuses on new knowledge constructed by students from previous experiences.

Data was collected by means of semi-structured in-depth interviews and open-ended questions. Six second year and six fifth year medical students of the School of Medicine, Faculty of Health Sciences at the University of Pretoria were purposively selected and interviewed. The discussion guide used for interviews consisted of 15 sets of medical illustrations with three or four images per set. Each illustration contained a different application of the same design characteristic, but similar in content or nature of information. The largest part of the interview was an adaptation of the repertory grid method to compare and analyse rich data.

Data were transcribed verbatim and organised following the principles of grounded theory. Data sheets were listed, compared and analysed through the application of open and axial coding to determine the relationship between students' learning styles, and the attributes of the design characteristics selected for this study.

This study shows that design elements in medical illustrations influences second- and fifth-year medical students' comprehension and learning of anatomy when illustrations are used as teaching material. Deeper understanding regarding their learning styles, drawing abilities and preference for drawing styles were gained. Furthermore, second- and fifth-year medical students' preferences for media, labelling methods, as well as the quality of the reproduction of the illustrations for learning purposes were illustrated. This information is imperative when designing illustrations for learning and teaching purposes. This study accentuates the importance of collaboration with medical illustrators in South Africa and abroad, as well as with physicians and educators.

Key words: medical students, learning styles, user-centred design, design characteristics, qualitative research, constructivism, grounded theory, media, drawing abilities, collaboration.

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I declare that **An exploration of students' perceptions regarding medial illustrations as a learning tool** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references. I also understand what plagiarism entails and am aware of the University's policy in this regard. I did not make use of another student's previous work and submitted it as my own.

Mrs M Pretorius

Date

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LIST OF ABBREVIATIONS

AD:	*Anno Domini*
AMI:	The Association of Medical Illustrators
BC:	Before Christ
BMS:	Basic Medical Science
CNV:	5th Cranial nerve / Trigeminal nerve
CNVII:	7th Cranial nerve / Facial nerve
CT:	Computed Tomography
dpi:	dots per inch
EEG:	Electroencephalogram
ELT:	Experiential learning theory
IMI:	Institute of Medical Illustrators
MRI:	Magnetic resonance imaging
ppi:	pixels per inch
RGI:	Repertory Grid Interview
RBGE:	Royal Botanic Garden Edinburgh
SMFHS:	School of Medicine, Faculty of Health Sciences
swf:	shockwave flash
UP:	University of Pretoria
VARK:	Visual, Aural, Read/Write and Kinaesthetic model

1. INTRODUCTION

1.1 Background and problem statement

1.1.1 *Medical illustration – the quest to understand its impact on learning*

The work of renowned medical illustrators such as Leonardo da Vinci (1452-1519) and Andreas Vesalius (1514-1564) has been of immense value for providing decisive insight into the field of medicine. For years, students at medical educational institutions have used the illustrations of these masters to learn and understand the anatomy and physiology of the human body. Although little has been written on how modern students interact with medical illustrations during learning, several scholars allude to the importance of combining visual and textual information in the learning process.

The studies of Richard Mayer, Professor of Psychology, University of California, (2005:3) have shown people learn better from pictures and words than just from words alone. When exposed to new and complex information, learning from pictures and words combined, is essential. Students understand information more clearly if illustrations and text are presented in an interesting manner. As seminal information designer, Richard Saul Wurman (2001:249) states: "In order to acquire and remember new knowledge, it must stimulate your curiosity in some way." Although there is agreement regarding the importance of medical illustrations during learning, limited literature is available about the impact of medical illustrations on students' learning methods, specifically in a South African context. This study aims to address these limitations.

1.1.2 *Medical illustration and education*

The Free Dictionary by Farlex (2010:[sp]) defines illustrations as pictorial matter used to explain and demonstrate textual material. Medical illustrations are visual demonstrations which are artistically expressed in a perceptible or virtual medium to communicate medical or biological information (The Association of Medical Illustrators. Careers 2012:[sp]). Well-known medical illustrator Frank Netter (1957:358) refers to remarkable contributions that have been made throughout the history of medical illustration, especially in the fields of science, art and education. However, there is a need for educational designers[1] and medical illustrators to be aware of the type of illustrations students prefer as a learning device and what they find easier to comprehend.

Punyashloke Mishra (1999:179) is of the opinion that there is an absolute lack of research into how readers may understand illustrations during learning. Priti Pandey and Craig Zimitat (2006:8) state there are many anecdotal reports of how students approach anatomy, but little research is available about how students learn anatomy.

[1] Educational designers are professional practitioners who work in close collaboration with instructional designers, academic and technical staff to ensure educational rigour through the incorporation of appropriate learning theory into the learning material and events designed (O'Reilly 2004:724).

A study by Ardis Cheng, Gregor Kennedy and Edmund Kazmierczak (2010:174-178) has shown how biomedical students continuously tried to mentally recall images of a complex anatomical structure to which they had been previously exposed, when asked to create their own correct representation. Cheng *et al* (2010:178) conclude by emphasising the importance of the nature of medical or scientific illustrations, as it imposes an enormous impact on students' learning methods.

1.1.3 *Challenges within a South African educational and medical educational environment*

Education in South Africa was predicated on an outcomes-based education system until 2010, but is currently again in the process of change (Mahlangu 2010:[sp]). Trichard Malan (2000:26) explains that outcomes-based education promotes interaction between the learner and the curriculum as the learner consults sources, reconstructs knowledge and takes responsibility for his/her own learning outcomes with the lecturer only as a facilitator in the teaching and learning process. Apart from the fact that outcomes-based education in South Africa is currently in the process of change, the field of education is still facing serious challenges.

Shaheeda Jaffer, Dick Ng'ambi and Laura Czerniewicz (2007:132) are of the opinion that education in South Africa is confronted with problems such as increasing pressure from government to meet social transformation and skills needs, lack of academic preparedness, large classes and multilingualism. According to Jaffer *et al* (2007:136) the key is to know how to use the technological resources that are available in the most suitable situations. Large classes and multilingualism are endemic features of tertiary programmes in South Africa, and they pose additional challenges to lecturers and educational designers in an educational environment such as the University of Pretoria (UP).

A major transition in South African medical education enforced by government is the change from a specialist-based training of undergraduates towards a primary health care approach (Kent & De Villiers 2007:906-907). A transitional process towards primary health care requires dedicated medical practitioners who will serve the health needs of the population and prepare undergraduate medical students to a different mind-set based on a wide-ranging approach towards the patient and community (Kent *et al* 2007:906-907). Training according to the community-oriented approach requires embracing the paradigm of a horizontal rather than a vertical approach to health care where more focus is placed on the way medical students learn, what they learn and where the learning process takes place (Kent *et al* 2007:906-907). The challenge for educators and information designers is to develop learning materials which prepare undergraduate medical students to integrate educational and clinical knowledge within a primary health care system.

1.1.4 *Challenges specific to the School of Medicine, Faculty of Health Sciences, UP*

In order to establish an integrated system of content and clinical application, the School of Medicine in the Faculty of Health Sciences (SMFHS) at UP changed its curriculum from [2]problem-based learning to a problem-orientated system. The problem-orientated curriculum is implemented to ensure both horizontal and vertical incorporation of a community-orientated practice to medicine (Boon, Meiring & Richards 2002:46). This means integrating academic as well as clinical knowledge for complete understanding. It is a system in which students are confronted with a certain problem they need to address (Die Leerplan 1997:1). Once the problem has been identified and discussed, subject-based teaching sessions follow where the lecturer acts as the primary source of information, but encourages students to use additional medical resources (Die Leerplan 1997:1). The department of anatomy at UP remodelled their courses to become more relevant to the primary health care approach as students have to integrate basic scientific knowledge, such as anatomy for instance, into clinical contexts to develop skills for future clinical practice (Boon *et al* (2002:46). Within the problem-orientated system students are confronted with large amounts of prescribed and recommended material that should be integrated and learned.

1.1.5 *Importance of this study*

As a medical illustrator working in a department of SMFHS at UP, I am aware of the importance of being constantly cognisant of lecturers' needs when creating medical illustrations for their classroom presentations. According to Marks (in Ansary & El Nahas 2000:71), the role of medical illustrators has changed as they also need to acquire skills in the field of educational planning and technology. Recent new technologies for medical illustration are presented in the form of digital photography, digital communication, virtual reality, the Internet and interactive computer-aided learning (Ansary *et al* 2000:70).

This study focusses on the way students perceive[3] artistically created medical images for learning purposes. From this viewpoint, several questions emerge to determine medical students' perceptions of illustrations. How do medical students use illustrations to learn? What type of medical illustrations do they prefer to study from and what do they feel they comprehend best? Which illustrations reveal complex structures most efficiently?

The gap that this study aims to address is one often experienced in South Africa, where designers and illustrators know very little about the user, in this case students' preferences, comprehension and use of medical materials as a learning tool. The importance of this study derives from the development of user-centred knowledge to improve the quality of work produced by medical

[2] Problem-based learning is a technique where students have to evaluate problems, for instance medical history, in terms of predefined categories. The tutor acts only as a facilitator during the learning process (Die Leerplan 1997:1).
[3] Perception is the conclusion that is formulated when information is gathered through the stimulation of the senses and interpreted in the brain (Lester 2002:42).

illustrators. Such knowledge will also help the lecturers to make better-informed choices about which illustrations to use for South African students. This study is a mini-dissertation for coursework masters in information design with the focus on students' perceptions regarding medical illustrations as a learning tool, an area in which very little empirical research is available.

1.2 Aim and objectives

The aim of the study is to explore how design characteristics[4] influence the use, comprehension and appeal of medical illustrations as part of the learning experience. In this study, the focus falls on undergraduate medical students.

1.2.1 *Objectives*

The objectives of this study are to determine how design characteristics in medical illustrations influence:

- the way students use the illustrations as a learning tool;
- the way students comprehend the content of illustrations during learning; and
- students' preferences for certain illustrations over others.

1.3 Literature review

The review of literature touches on the following broad themes: the history of medical illustration, students' process of learning, the application of design characteristics in medical illustrations and qualitative research. Authors of the sources referenced are situated in various fields such as design, instructional design, psychology, medicine, information technology, education, art and techniques and research methods. To follow is a brief introduction into the expansion of subsequent points discussing various aspects pertinent to this study.

1.3.1 *The history of medical illustration*

The first selection of sources consulted for this study describes the history of medical illustration and the influence of renowned illustrators on medical knowledge, education and research since ancient times. These sources are used for context and are referred to again in Chapter two. Most literature provides a concise description of the development of medical illustration and how it is influenced by spiritual, technological and scientific factors. Jean-Charles Sournia (1992) discusses the history of medicine with beautiful illustrations and brings medical developments within the context of cultural, religious and social factors. Medical illustrators Mike De la Flor (2004:5), Netter (1957:358) and William Loechel (1960:169) accentuate the Renaissance period (approximately 1400-1700) as the 'rebirth' of medical illustration. The accuracy of anatomical detail detected in the work of artists from this period as stated by Leroy Vandam (1997:693), indicates close reciprocity

[4] Design characteristics is the term used to embrace design elements relevant to this study namely line, shape, colour, texture and depth and design principles namely unity, hierarchy, proximity and balance.

between medical science and art. Head of the Department of Anatomy and Histo- and Cytochemistry at the University of Münster, Reinhard Hildebrand (2004:295-296) supports this statement. He believes, however, that the rapid growth of medical scientific knowledge in the second half of the eighteenth century contributed to the transformation of medical art into depictions of "diagrammatic faceless figures". Recent literature demonstrates how the influence of late twentieth century medical technological developments, contributes to the advancement of medical illustration techniques. Experts in computer science namely Nicolai Svakhine, David Ebert and William Andrews (2009:77-86) introduce new medical illustration techniques combined with x-ray and MRIs for patient examination.

1.3.2 *Visual perception of students*

Of particular importance for this study is literature about visual perception; the way images are perceived and understood, especially during learning. The relevance of visual perception is discussed in more depth in Chapter two. Literature dealing with theories of picture perception such as gestalt (the field of psychology), visual literacy, and visual communication and science are examined.

Experts in the field of visual perception and instruction, Gary Anglin, Hossein Vaez and Kathryn Cunningham (2004:865-916) use primary theories of picture perception such as gestalt, constructivism and mentalistic approaches as a critical framework for the relevance of static and animated graphics in instructional design. These theories form the foundation to explain how viewers perceive and construct, for instance, line in a picture into identifiable shapes for understanding.

Doug DeCarlo and Matthew Stone (2010:175), specialists in cognitive science and visual interaction, reveal how different methods of abstraction such as the absence of line, enable the viewer to recognise the image in the same way as its original stance. Other literature exhibits the challenges designers face when applying visual cues in images for the enhancement of viewers' comprehension.

Head of Department of Education at the University of Pretoria Adelia Carstens (2004:459-487) demonstrates how the application of certain artistic conventions in pictorial representations may complicate low-literate people's understanding of the content. Furthermore, Robert Krull and Michael Sharp (2006:189-198) explain how the application of objects such as hands and two- and three-dimensional arrows in images to show certain actions, are interpreted. Their study shows the challenges designers face in constructing arrows in a comprehensible manner (Krull *et al* 2006:189-198).

1.3.3 *Learning styles of students*

Another aspect of particular importance to this study is the nature of learning styles of students which is discussed in more depth in Chapter two. Learning styles are mainly examined in articles regarding cognitive processing during learning that is relevant to instructional design, educational psychology and development.

Many authors recognise learning styles as a guideline for students' approach and interpretation of study material. Educational developer Neil Fleming (1995:308-309) introduces the Visual, Aural, Read/Write and Kinaesthetic (VARK) learning preferences questionnaire and considers this model as a basic framework to describe different learning styles, especially when learning from text and images.

Pandey *et al* (2007:8) refer to deep and surface learning, evident in the learning of anatomy. Diverse learning paradigms such as behaviourism, cognitivism and constructivism applicable to the field of instructional design in particular, are consulted as is the essence of the experiential learning theory (ELT). The latter forms the foundation of the current curriculum of the SMFHS at UP.

Authors such as David and Alice Kolb (2005:194) explain that the ELT focuses on the 'experience' as the main process of learning and encompasses different learning styles. ELT is portrayed as an idealised cycle including experiencing, reflecting, thinking and acting by learners (Kolb *et al* 2005:194). The integration of learners' experiences with new knowledge and meaning derived from previous experiences provide new insights with regard to the use of illustrations during learning.

1.3.4 *Design characteristics*

Another selection of sources consulted for this study describes different design elements and principles referred to as design characteristics. These are discussed in Chapter three. Literature of American artist, author and educator Mary Stewart (2002) is consulted, as well as of American writers and designers Poppy Evans and Mark Thomas (2008) who describe and discuss the essence of various design characteristics with reference to the works of well-known artists.

Corresponding to the work of Stewart (2002) and Evans *et al* (2008), Alex White (2002) focuses on features of various design elements and principles and provides vivid descriptions when discussing these characteristics. Seminal author and designer Edward Tufte (1997) provides valuable insight on the perceptual principles of various design characteristics in illustrations. Tufte (1997) explains how the application of design elements and principles by the illustrator may generate different interpretations and illusions amongst readers.

Recent articles by Paula Csillag (2009) and Willard Daggett, Jeffery Cobble and Steven Gertel (2008) discuss the relevance of colour on learners' spatial abilities and comprehension. Dagget *et al* (2008) and Csillag (2009) also provide brief discussions regarding the psychological, neurological and scientific aspects of colour.

William Andrews (2006) from the Medical Illustration Department, Georgia Health Science University provides valuable insight on the perceptual aspects of line in medical illustration. It should be noted that literature focussing on the relevance of design characteristics in illustrations, as well as the influences they may have on medical and other students' learning strategies are limited.

1.3.5 *Qualitative research*

The final selection of sources deals with basic considerations for research methods and is referred to again in Chapters four and five. Most of the literature consulted is from recent articles and books relevant to different aspects of qualitative research.

While Kobus Maree (2007) provides introductory steps with regard to qualitative and quantitative research, Anselm Strauss and Juliet Corbin (1998) explain the fundamental role and principles of grounded theory in qualitative research. On the other hand, author in the constructivist grounded theory convention Kathy Charmaz (2006) examines grounded theory in relation to other epistemological positions such as constructivism and objectivism and she brings new meaning to the principles of traditional grounded theory.

Procedures and applications regarding the repertory grid interview method (RGI) in qualitative research are drawn from recent articles by Keng Siau, Xin Tan and Hong Sheng (2010); Patricia Alexander, Johan van Loggerenberg, Hugo Lotriet and Jackie Phahlamohlaka (2010) and Carlos van Kan, Petra Ponte and Nico Verloop (2010). Both Alexander *et al* (2010) and Siau *et al* (2010) use similar applications of the RGI method for their research which provide valuable guidelines for this study.

1.4 Epistemological approach

Epistemology is defined in Luke Feast and Gavin Melles (2010:1) as "the theory of knowledge that defines what kind of knowledge is possible and legitimate"[5]. It is necessary to define the epistemological approach of this study as it steers the direction of the research methodology. Constructivism is the epistemological approach selected for this study. Within a constructivist framework, emphasis is placed on the role of the learner, in this case the medical student, in constructing rather than simply acquiring explicit knowledge (Lefoe 1998:454). It is unknown what

[5] Michael Crotty as quoted by Feast *et al* (2010:1-2).

new knowledge students acquire when learning from different medical illustrations. Learners construct new knowledge when visual stimuli unfamiliar or new to them are displayed. When encountering this new information, learners construct knowledge by comparing the latest input with existing mental models to formulate necessary changes.

The rapid development of digital technology makes it possible for students to gain knowledge and engage in new ways of thinking through collaborating with fellow students and educators. Attempts to memorise explicit knowledge and facts, according to Catherine McLoughlin and Mark Lee (2008:643), are dominated by the tendency to engage in the "know-how" or tacit knowledge. Students increasingly use internet sites and web-based educational systems developed for their institutions to share and engage with new knowledge for optimal understanding. These digital technological developments open up new opportunities for designers and illustrators when constructing multimedia for the stimulation of tacit and explicit knowledge. However, Ingo Eilks, Torsten Witteck and Verena Pietzner (2009:146) believe that students will construct new ideas from what is seen on screen, together with what they already know from previous experiences. These authors are unsure whether dynamic animations or illustrations demonstrating complex scientific processes will be understood by students. Designers and illustrators need to critically reflect on the communicative aspects of learning material presented to the reader, especially when formulated for learning purposes.

1.5 Research methods

This study is conducted through exploratory qualitative research in order to discover the way medical illustrations are perceived, comprehended and used by medical students. Strauss *et al* (1998:10-11) describe qualitative research as any type of research that produces findings not formulated by statistical procedures or any means of quantification, but research that focuses on persons' lives, experiences, behaviours, emotions and feelings as well as social, cultural movements and interactions.

Exploratory qualitative research also lends itself to the application of constructivism as the epistemological approach pertinent to this study. This study also adopts a constructivist approach to grounded theory as it examines how and sometimes why participants interpret and construct meanings and actions in specific situations (Charmaz 2006:130).

Grounded theory is a process of systematically gathering and analysing data through the research process in order to formulate the foundation for a theory (Strauss *et al* 1998:12). The research approach adopted in this study is described in more detail in Chapter four and comprises the following phases:

1.5.1 *Phase 1: Conceptual preparation*

A collection of selected sources was reviewed as background in order to outline the development and use of medical illustration in education. The outcome of the literature study is a conceptual model, summarising the most pertinent new thinking that address the research objectives (Chapter two). As part of the methodology for this study, this model then serves as guideline for the researcher to plan and design the discussion guide. The conceptual model is also used during data analysis.

1.5.2 *Phase 2: Data collection by means of in-depth interviews*

Data were collected by means of semi-structured in-depth interviews. According to Maree (2007:87) "an interview is a two-way conversation in which the interviewer asks the participant questions to collect data and to learn about ideas, beliefs, behaviours and opinions". Open-ended questions were asked to explore participants' opinions and views regarding medical illustrations as a learning tool.

The largest part of the interview was an adaptation of the RGI. The latter is a structural method to compare and analyse various examples with different characteristics (Hinkle 2009:1). Illustrations selected for the interviews were chosen from the disciplines of anatomy and physiology as they form the foundation of medicine. Medical illustrations with similar content projecting contrasting design characteristics were shown to each participant who was asked to select the illustration that would best aid learning. Students' preferences as well as their own descriptions from their discussions of the illustrations were captured on a data sheet which was formulated according to the RGI structure. The interview also included a section aimed at gaining an understanding of the current learning habits and preferences of participants. The discussion guide for the interview was designed after concluding the expanded literature review set out in Chapters two and three to ensure that all pertinent concepts were addressed.

1.5.3 *Sampling*

Six medical students in their second year and six in their fifth year of study at the SMFHS of UP were interviewed. Students from these two study years were selected to determine if the difference in their level of experience and medical knowledge would have an impact on their perception of medical illustrations. Purposive sampling was used as this enabled the researcher to select participants who met the inclusion criteria[6] and provided data relevant to the study. Participants were recruited through a short telephonic interview and met the necessary criteria to take part in the study.

[6] Inclusion criteria determine that second- and fifth-year medical students must be from the SMFHS at UP, willing and available to participate in this study.

1.5.4 *Recording and transcribing*

Audio recordings were made of the interviews. This allowed the researcher to be fully observant during the interview and enhanced rapport with the participant while capturing the content of the discussion for future reference. Participants were asked permission to make a recording. Interviews were transcribed verbatim by the researcher and transferred to a data sheet for analysis and interpretation. Data sheets were analysed and organised following the principles of grounded theory which include the identification of categories, asking stimulating questions, making comparisons to extract an integrated and organised scheme from masses of raw data (Strauss *et al* 1998:13).

1.5.5 *Phase 3: Interpretation*

Data were analysed with the conceptual model as general framework to ensure that the current study tested the relevance of the latest developments in literature for the South African context. The analysis remained loosely structured and open in order to allow new factors to emerge specific to the context of this study. The outcome of the interpretation process was formulated with a new model which incorporated new findings significant to learning strategies of medical students in South Africa.

1.6 Overview of chapters

Chapter two provides a brief description of the history of medical illustration and its influences on medical technological developments, education and research. The role of the medical illustrator within an educational environment is explored in the context of user-centred design and collaboration. This chapter also introduces different learning styles with the particular focus on study methods using illustrations. A conceptual model is drawn up as a summary of findings from the literature, addressing new thoughts valuable for the present study's research objectives.

Chapter three proposes the role of design characteristics in medical illustrations selected for this study, based on their relevance within the context of learning. This chapter aims to demonstrate how different applications of design characteristics in comparable medical illustrations may impose different meanings and interpretations. This chapter attempts to demonstrate the challenges designers and illustrators face when presenting students with illustrations for learning purposes.

Chapter four discusses constructivism as an epistemological approach that serve as framework for the methodology of this study. This chapter details various aspects of the research method including the discussion guide, in-depth interviews, the analysis and process of data structuring (adapted from the RGI) and principles for grounded theory.

Chapter five focuses on the discussion and interpretation of analysed data for each set of illustrations. Findings from analysed data are presented with summarised colour charts to demonstrate the category of preferences of illustrations used for learning among second- and fifth-year medical students. This chapter concludes with a tabulated comparison between findings from this study and the most pertinent literature set out in Table 2 of Chapter three. This table summarises similarities and differences between findings from literature and those of this study to demonstrate the influence of design characteristics' in illustrations on South African second- and fifth-year medical students' learning strategies.

The concluding chapter provides a new model that is the synthesis of literature, as well as the interpretation of the latest findings discussed in Chapter five and brought into context of second- and fifth-year medical students' learning styles within the learning environment of a South African academic institution. The conceptual model set out in Chapter two is used as backdrop for the new model to demonstrate the latest findings regarding the use, preference and comprehension of illustrations as a learning tool. This study concludes with a reflection on the research methods used in the study in order to determine the levels of validity and reliability necessary for the requirements of rigour within qualitative research. Finally, limitations and contributions of this study are discussed.

2. CHAPTER TWO

2.1 Medical illustration and education

This chapter provides a concise description of the history of medical illustration and its influence on current medical technological developments, education and research. The role of the medical illustrator within an educational environment is discussed, focusing on the collaboration between illustrator, educator and student.

Learning styles of higher education students, as well as aspects of visual perception such as spatial ability, visual literacy and the influence of colour blindness on perception are explored. These factors are essential for illustrators and designers to consider when visual material for learning purposes is planned. The chapter concludes with a conceptual model summarising literature that is most pertinent to the objectives of this study.

2.1.1 *The history of medical illustration*

Much controversy exists about which prehistoric pictures are regarded as the foundation of medical-related illustrations. Because of archaeological material not being documented, authors extrapolate about the origins of medical illustrations. Linda Nye (2002:123) and Rachel Hajar (1999:89) consider the legendary picture of a mammoth with a spot demonstrated in Figure 1 as prehistoric man’s first step towards scientific anatomical enquiry. However, many scholars regard Egyptian, Babylonian, Chinese and Indian civilizations as the first to showing awareness of medical knowledge approximately 2500 years before Christ (BC). Sournia (1992:42) explains that gynaecology is documented as one of the main preoccupations in Egyptian history during this period. In the example given in Figure 2, an Egyptian relief from a tomb at Saqqarah, mastaba of Ankhmahor demonstrates the performance of a circumcision, and is considered one of the first depictions of medical interest (Donald 1986:44; MacKinney 1953:1062).

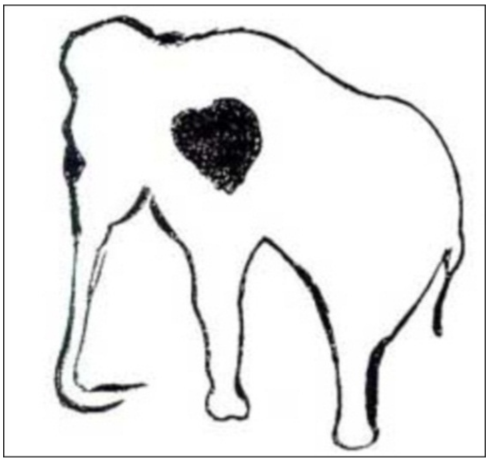


Figure 1: Illustrator unknown,
Palaeolithic drawing of a mammoth
with a dark spot.
(Hajar 1999:89).

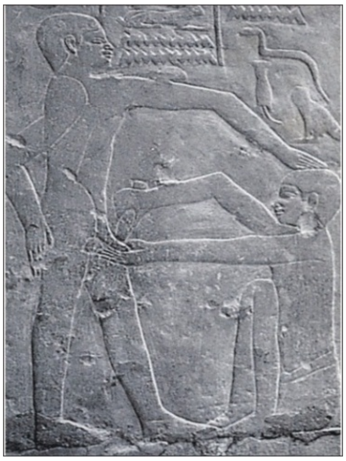


Figure 2: Egyptian relief from
a tomb at Saqqarah, mastaba
of Ankhmahor.
(Sournia 1992:49).

Due to Egyptian, Chinese and Indian spiritual and scientific influences on medical science, human bodies were considered sacred and dissections forbidden. Figures are therefore not drawn realistically. Examples of abstract figures in Chinese and Grecian art (Figures 3a-b) show the impact of religious law although vestiges of the illustrations are visible in images of Classical Greek. In Figure 3a an example of the Chinese figure drawings from the Han period is shown while a Greek figure drawing from the Hellenistic period is shown in Figure 3b. Camilla Matuk (2006:2) refers to the position of Chinese contoured figures as bodies lying supine as if on autopsy tables. The appearance of the frog positions of figures is still found in contemporary medical atlases and textbooks.

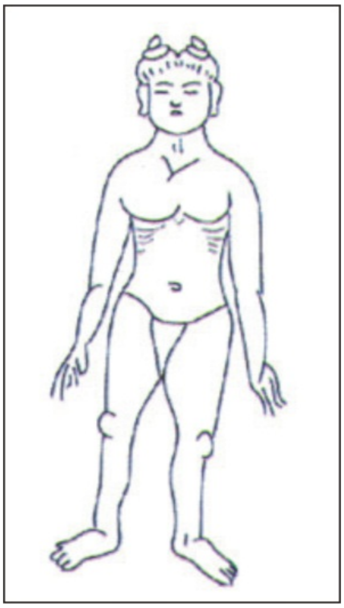


Figure 3a: Illustrator unknown, Chinese illustration from the the Han period. (Matuk 2006:2).

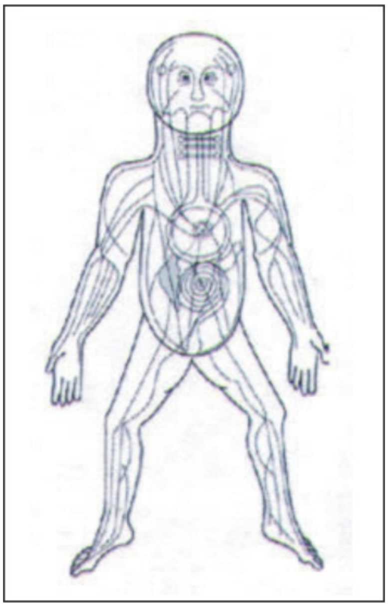


Figure 3b: Illustrator unknown, Greek illustration from the Hellenistic period. (Matuk 2006:2).

As is the case with their predecessors, ancient Greek illustrators also based their art on spiritual influences with depictions of Greek gods such as Aesculapius and Appollo evident on vase paintings and reliefs. Scientific and medical inquiry owes its foundations to the Classical Greek civilization (Donald 1949:44; De la Flor 2004:3). During the Classical Greek period scientific and medical investigations were based on direct observation of dissected bodies and animals. Hippocrates of Cos (460 – 375 BC) and Aristotle of Stagira (348 – 322 BC) are regarded as notable contributors of science and medicine as pragmatic disciplines during this period (De la Flor 2004:3).

With the Roman Empire's conquest of Alexandria (476 *Anno Domini*) (AD) a thousand years of superstition and anarchy ensued, also known as the Dark or Middle Ages (MacKinney 1953:1065). Greek scientific curiosity started to deteriorate without significant medical developments. Physicians such as Claudius Galen (131-201 AD) came to the forefront in the second century AD and dominated medicine with his erroneous interpretations of human anatomy and physiology, based on observations of animal dissections (Donald 1986:45; De la Flor 2004:4). Although Galen's work weakened the development of medical knowledge, education and illustration, it imposed a remarkable influence on medical knowledge and illustration until the end of the fourteenth century.

A marked difference between ancient and medieval illustrations can be detected with the creation of Byzantine medical manuscripts approximately five hundred AD (MacKinney 1953:1065). These manuscripts attest to beautiful illustrations originated from Muslim and Western Europe medicine and describe the preparation of plant and animal material for the development of drugs for patient treatments. One of the most famous of all medieval illustrated manuscripts of the sixth century is *De materia medica*, a Greek codex written by Pedanius Dioscorides (MacKinney 1953:1065). An example from Dioscorides's *De materia medica* is shown in Figure 4 and demonstrates the plant Pheasant's eye, commonly used as a sedative for patient treatments (Sournia 1992:100).

Although Muslim medical manuscripts are not thoroughly explored, it is evident that they contributed significantly to medical practice (MacKinney 1953:1066). A pioneer in the development of surgical instruments is Al Zehrawi (936-1013), also known as Albucasis (Annajjar 2010:857). Albucasis wrote an outstanding 30-volume encyclopaedia titled the Kitab al-Tasrif which contains more than 200 pictures showing surgical instruments covering fields such as anatomy, diseases, nutrition, surgery and ophthalmology (Annajjar 2010:857). One of the illustrations in the Kitab al-Tasrif is shown in Figure 5 which demonstrates surgical instruments with related descriptions and instructions.

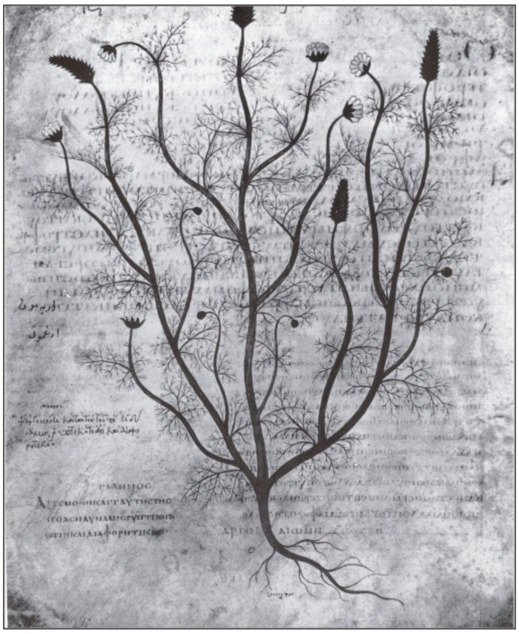


Figure 4: Illustrator unknown,
Pheasant's eye.
(Sournia 1992:100).

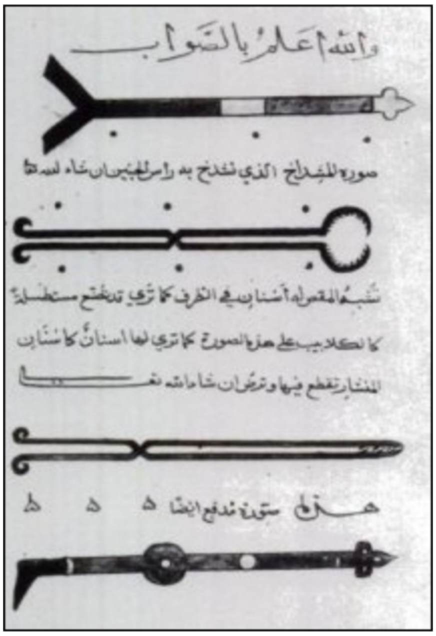


Figure 5: Illustrator unknown,
An illustration of medieval Muslim
surgical instruments in
Kitab al-Tasrif.
(Annajjar 2010:858).

The Renaissance period (approximately 1400 - 1700) is regarded as the resurrection of medical illustration with its renewed spirit of scientific thought and expression (De la Flor 2004:5-6; Netter 1957:358 & Matuk 2006:5). The work of artists, scientists and teachers such as Da Vinci and Vesalius are considered the epitome of accurate, beautiful detailed anatomical illustrations created from direct observation of dissected bodies.

Da Vinci is regarded as the first artist to develop cross sectional illustrations[7] still apparent in current anatomical atlases and textbooks (Elizondo-Omaña, Guzmán-López and Garcia-Rodriguez 2005:12). Louis Audette (1979:25-26) describes Da Vinci's work showing great attention to detail. Da Vinci can be regarded the first artist to portray great understanding for depth and perspective as he was able to depict figures from different angles during movement. With his figures displayed from different dimensions, the relations between various anatomical parts are clearly demonstrated. Although Choulant (in Matuk 2006:5) considers Da Vinci's work as often containing redundant text and ornamentation without explaining anatomical structure, his work remains the foundation of contemporary anatomical knowledge and detail. Da Vinci's *Studies of the head and shoulders of man* (Figure 6) attests to his knowledge of anatomical appearance and movement, for he often studied lean, living men (Wallace 1966:131).

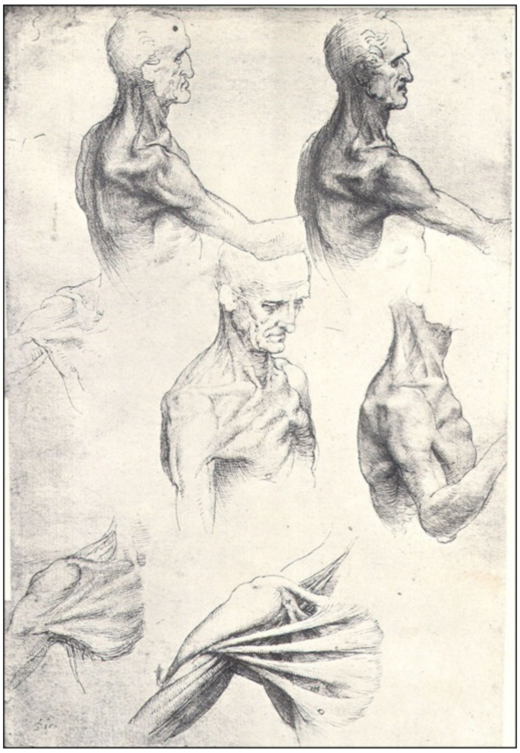


Figure 6: Leonardo da Vinci,
Studies of the head and shoulders of man, 1510.
(Wallace 1966:131).

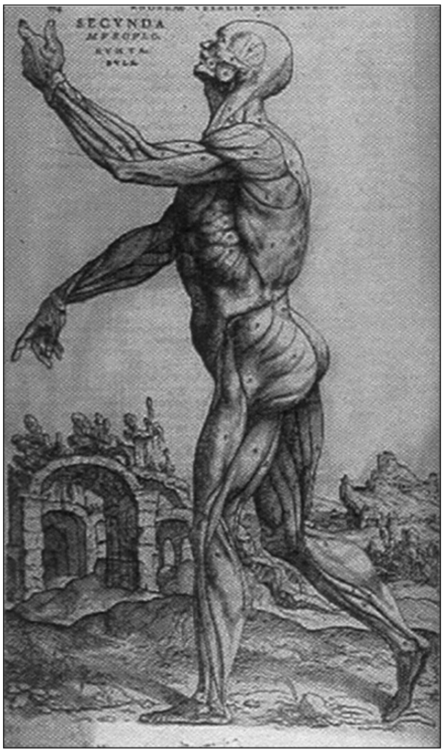


Figure 7: Andreas Vesalius,
De Humani Corpris Fabrica, 1543.
Woodblock engraving.
(Matuk 2006:1).

[7] Cross sections are slices of the body or its parts, cut at right angles to the longitudinal axis of the body or any of its parts (Moore & Dalley 2006:6).

Donald (1986:46) and De la Flor (2004:7), amongst other scholars, consider Vesalius as an extraordinary anatomist, artist and teacher who focused more than Da Vinci on the accuracy of medical illustrations. His work attests of graceful dissected figures with layers of muscles hanging down from the body to show underlying structures and functionality. Vesallius's *De Humani Corpris Fabrica* (Figure7) portrays remarkable understanding of the anatomical and physiological aspects of the body, as the functions of muscles are emphasised. De la Flor (2004:9), Donald (1986:46) and Vandam (1997:693) consider this book as an enormous leap forward in the field of medical illustration.

Hildebrand (2004:301), however, feels that Vesalius's attempts to present bodily structure and functionality are ineffectual as the dissected muscles hanging down do not create the illusion of action. Vesalius nevertheless succeeded in maintaining high standards of anatomical detail and functionality of muscles, especially for medical educational purposes. Imperfect lines and detail due to the effect of woodblock printing do not impose negatively on Vesalius's work (Audette 1979:26).

The rapid development of universities from the fourteenth century required mass production of books for which the woodblock printing technique becomes insufficient. According to Audette (1979:27) printing techniques such as copper engraving and etching became popular by the early sixteenth century. These techniques produced much finer lines providing more volume and detail in illustrations (Audette 1979:27). Copper engraving and etching were followed by lithography in the eighteenth century, a technique enabling the illustrator to draw directly on stone (Tsafrir & Ohry 2001:104). The artworks of Jules Cloquet (1970-1883), for instance, show remarkable clarity and detail with the application of lithography. Cloquet's *Optic chiasma* (Figure 8) from his book *Anatomie de 'l home* attests to beautiful delicate lines and gradation of tone. According to Netter (in Tsafrir *et al* 2001:104) further developments such as photo-engraving in 1868, the halftone screen in 1880 and the four-colour printing processes in 1893 further impacted on the development of medical illustration. All these printing techniques made the publishing of art books more affordable and enhanced the demonstration of complex and invisible points apparent in anatomical concepts (Nye 2004:125).

While the printing industry positively influenced the development of medical illustration, the invention of photography during the eighteenth century posed an enormous threat to the continuation of medical illustration. A greater demand for medical photography emerged as images detected through a microscope could easily be photographed and projected for teaching and research purposes (Donald 1986:47).

Physicians also better diagnose skin diseases from photographs, as they are difficult to identify in coloured engravings or lithographs (Donald 1986:47). The invention of the x-ray[8] in 1895 brought new dimensions to diagnostic radiology techniques, as functions of internal organs and morphological structures could be examined (Tsafrir *et al* 2001:105).

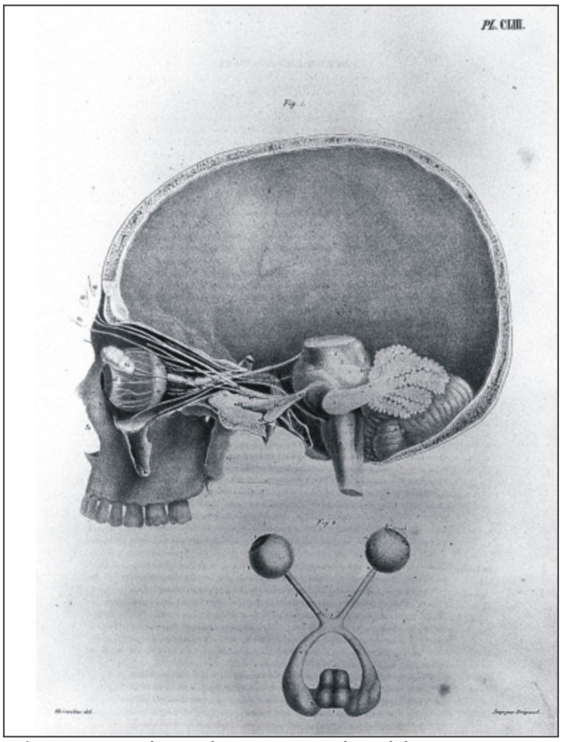


Figure 8: Jules Cloquet*, Optic Chiasma, 1825.*
(Wellcome images 2013 :[sp]).

Although the foundation of medical illustration was shaken by the invention of photography and diagnostic radiological techniques, several medical illustrators moved to the forefront during the nineteenth century to re-establish the value of illustrations in medicine. German-raised artist Max Brödel (1870-1941) is regarded as the "man who put art into medicine" (Johnson & Sainsbury 2009:88). Brödel is remarkable for his anatomical and surgical illustrations in the finest detail with various traditional media such as watercolour, oil, crayon and pencil. According to Pia Pace-Asciak (2006:[sp]), De la Flor (2004:13) and Vandam (1997:695), Brödel became famous for the development of another traditional medium called carbon dust and stipple board technique[9] or Ross-board. Pace-Asciak (2006:[sp]) considers this technique to convey the same authenticity of sparkling highlights on wet living tissue as demonstrated on black and white medical photographs. Brödel's *Sagittal section of hypophysectomy procedure showing the Killian incision* (Figure 9) is an excellent example of the Ross-board technique. Crosby and Cody (in Pace-Asciak 2006:[sp]) consider Brödel's carbon dust and stipple board technique as conveying more detail, accuracy and

[8] An x-ray is a diagnostic test where invisible electromagnetic energy beams are used to produce images of internal tissues, bones and organs onto film (De Miranda, Dogget & Evans 2005:6).
[9] Carbon dust and stipple board technique consists of dust layered in stages to create sense of depth, background and tonal gradation. An eraser is used to lift high-lights and soften edges, fine details are engraved with a scalpel tip and black water-colour or carbon pencil are used to darken lines (Pace-Asciak 2006:[sp]).

expression than can be shown in photographs. This technique has reinforced the need for medical illustration in education and research.

Netter (1906-1991) is renowned for his fine, accurate and beautiful hand-drawn illustrations, and is still eminent in contemporary medical education. Netter's *Nerves and vessels of neck* (Figure 10) is demonstrated with much clarity and anatomical detail. Hand-drawn and painted illustrations accompanying medical texts held their own throughout the nineteenth and twentieth centuries and are still evident in textbooks and medical journals such as Netter's eight-volume series of anatomical atlases published by the CIBA foundation (Tsafrir *et al* 2001:104-105). Netter's fifth edition anatomical atlas is currently available and used by many contemporary medical schools and health professionals globally.

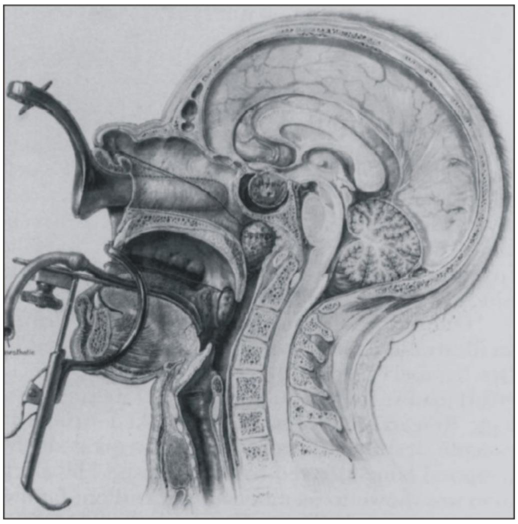


Figure 9: Max Brödel,
Sagittal section of hypophysectomy procedure showing the Killian incision.
(Pace-Asciak 2006:[sp]).

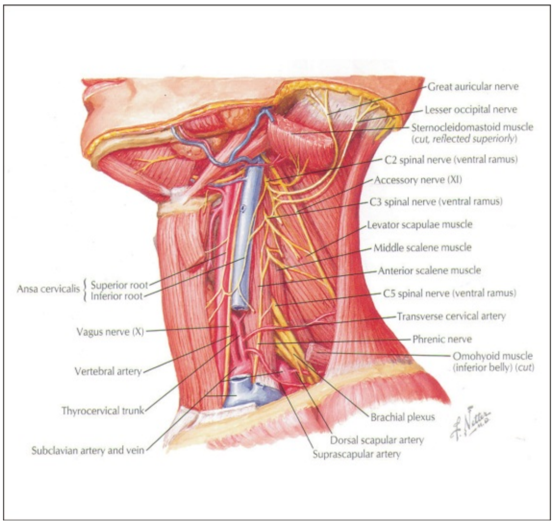


Figure 10: Frank Netter,
Nerves and vessels of neck.
(Netter 2011:31).

The development of computer graphic software programs accelerated during the twentieth century and provided new dynamic challenges and opportunities for medical illustrators. Diagnostic radiology techniques such as computed tomography (CT)[10] and magnetic resonance imaging (MRI)[11] created a new platform to graphically detect body functions and condition (De Miranda *et al* 2005:9). Computer-generated medical visualisation techniques, such as non-photorealistic rendering[12] and three-dimensional volume rendering,[13] became more evident during the late twentieth century. These techniques are especially applicable to the field of medicine, as images

[10] Computed tomography scanning (CT) is a cross sectional electronically created image using a very small beam or radiation (Gurley & Callaway 1996:377).
[11] Magnetic resonance imaging (MRI) is a cross sectional/three-dimensional imaging modality that creates digital images by the use of strong magnetic field and radio waves (Gurley *et al* 1996:380).
[12] Non-photorealistic rendering is the reproduction of traditional pen-and-ink techniques for the creation of visual effects in three-dimensional objects (Isenberg, Neumann, Carpendale, Costa Sousa & Jorge 2006:115).
[13] Three-dimensional volume rendering is generated clinically accurate and immediately available images from the full CT data set without extensive editing (Calhoun, Kuszyk, Heath, Carley & Fishman 1999:745).

are created realistically on computer and used in relation with other medical datasets to illuminate important medical patient information.

These developments provided new opportunities for medical illustrators to superimpose radiology images with the latest graphic software, generating three-dimensional graphic presentations of body functions and conditions. Computer software programs such as *Anatomic* were developed to open, produce, save and display medical images and anatomical structures to be observed from different angles (Heinonen, Dastidar, Frey & Eskola 1999:38). An example of an image created with *Anatomic* is demonstrated in Figure 11 and appears similar to a bitmap drawing program. With the use of *3DEEG* software, three-dimensional brain mapping is conducted to detect certain movements of the brain (Heinonen *et al* 1999:40). Electroencephalogram (EEG) [14] signals are designed with different spectrums of colour maps such as spectrums of Blue-White-Red (Heinonen *et al* 1999:40). The example in Figure 12 shows the movement of the colour spectrums to show certain functions of the brain important for patient treatment.

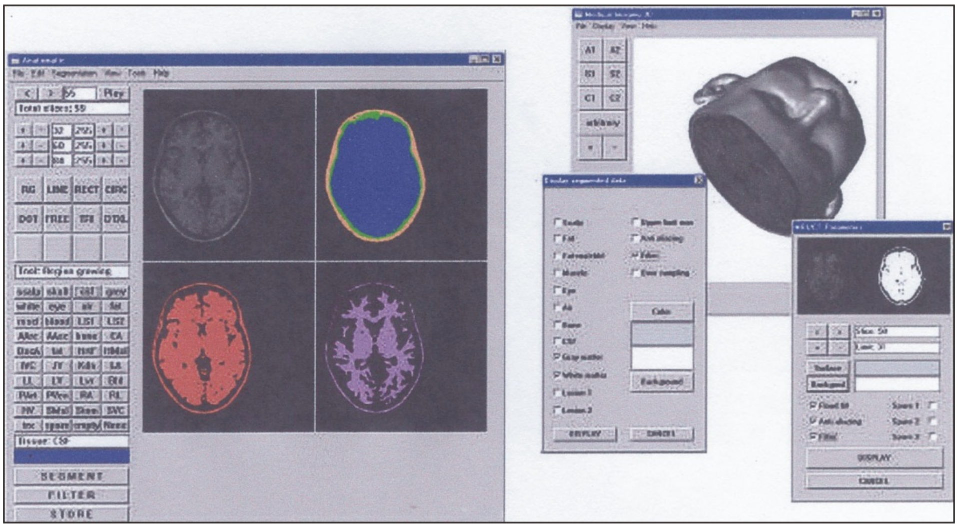


Figure 11: Illustrator unknown,
The user interface of *Anatomic* software.
(Heinonen *et al* 1999:38).

Experts in computer and information science, Costa Sousa, Ebert, Stredney and Svakhine (2005) developed an interactive illustrative volume visualisation system that uses principles from illustration and perception such as congruency and accuracy to emphasise or de-emphasise information valuable for clinical research and medical education. Furthermore, Svakhine *et al* (2009:81) demonstrate the latest dynamic techniques with the fusion of volume rendering and non-photorealistic rendering. With these techniques, details on MRI and CT scans are manipulated, enabling physicians to make accurate interpretations from MRI and CT patient data. The depiction in Figure 13a-e shows a range of different applications of volume rendering to illuminate depth

[14] Electroencephalogram (EEG) records electrical impulses produced by the activity of the brain cells (Sournia 1992:494).

perception effects. The vast development of computer software programs contributed to the dynamic appearance and functionality of current contemporary medical illustration.

Medical illustrators, whether famous or not, contributed to the progress of medicine and created the availability of visual stimuli necessary to understand the wonders of the human body. Medical illustrators can be regarded the visual communicators of complex medical information for educational, clinical and research purposes. The development of three-dimensional volume rendering and non-photorealistic rendering techniques created the platform for further research into medical and scientific illustrations, as well as the field of medicine and radiology.

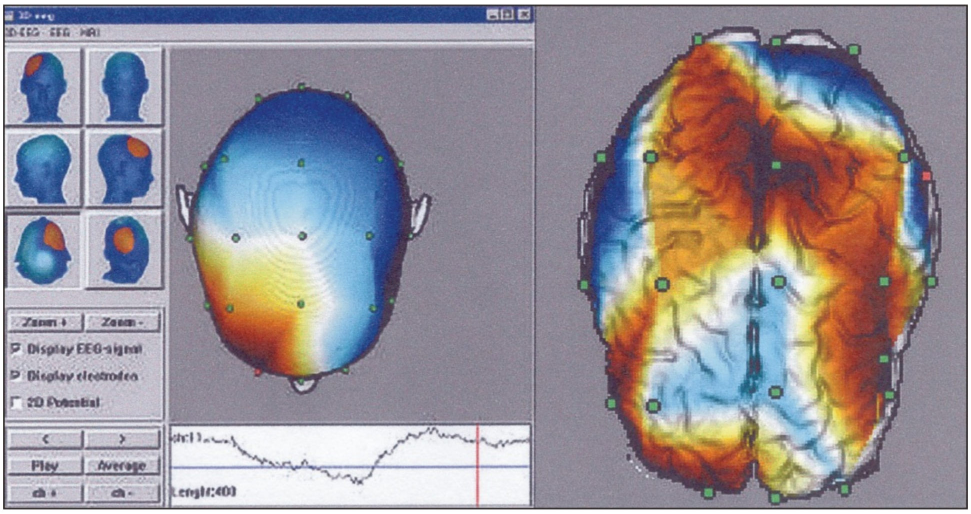


Figure 12: Illustrator unknown,
The user interface of *3DEEG* software.
(Heinonen *et al* 1999:40).

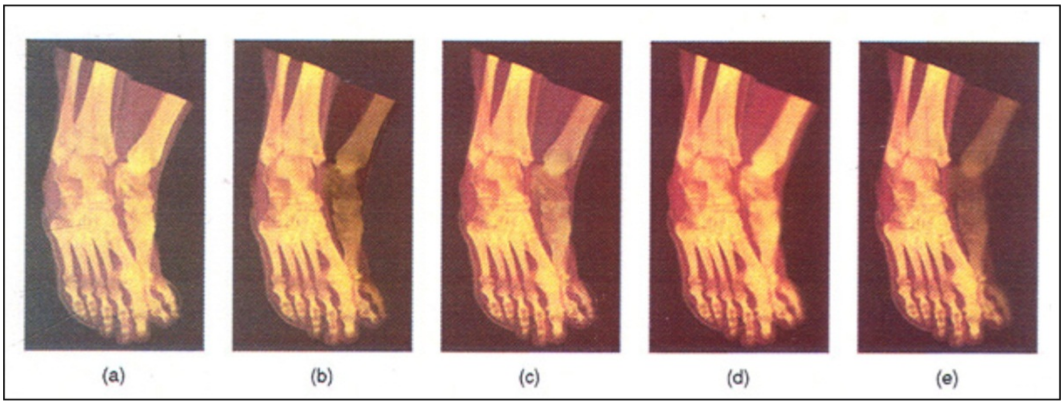


Figure 13 a-e: Illustrator unknown, Subtle application of depth perception enhancement effects. (Svakhine *et al* 2009:83).

2.1.2 *The start of medical illustration as a profession*

Spiritual and technological influences have affected the development of medical illustration in education and research over centuries and have led to close collaboration between illustrator and physician. Pace-Asciak (2006:[sp]) and Hildebrand (2004:295-296) consider the Renaissance as the time when medical illustration and science developed in close reciprocity. Hildebrand (2004:295-296) believes this reciprocity is evidenced through the remarkable development of anatomical atlases from the eighteenth century, which are considered transmitters of scientific knowledge and works of art.

The dedication that Brödel (see Point 2.1.1 p17) showed in his work, created the need to educate art students to become professional medical illustrators. This led to the establishment of the Department of Art as Applied to Medicine at the Johns Hopkins Medical School in 1911. A need for a professional society for medical illustrators emerged, leading to the launch of The Association of Medical Illustrators (AMI) in 1945 (History of the AMI [sp]). The Institute of Medical Illustrators (IMI) was founded in 1968 in the United Kingdom with the aim of bringing together different disciples of clinical photography, medical art, illustration, graphic design and video for healthcare (Institute of Medical Illustrators [sp]). Currently medical illustration is developing as a field of contemporary visual dynamics, education, communication and research, constituted by AMI. The Journal of Biocommunication, the academic journal of the AMI has become an authoritative source for research into medicine and illustration.

2.1.3 *Medical illustration and training*

Before the establishment of the Department of Art as Applied to Medicine at the Johns Hopkins Medical School, medical illustrators received no formal training in medical illustration. Brödel observed surgical procedures, autopsies and dissected cadavers to learn anatomy. At the University of Toronto illustrators sat with medical students during lectures, earning no degree or credited courses, as there were none to receive (Oglov 1983:1479).

At present the Johns Hopkins's Department of Art offers a two-year accredited Master of Arts programme in medical and biological illustration (Johns Hopkins Department of Art as Applied to Medicine 2011:[sp]). Their course includes a foundation of anatomical, biological and scientific knowledge combined with business policy and research. The University of Toronto presents a two-year MScBMC degree in biomedical communications, which is an interdisciplinary graduate programme in design and evaluation of visual media in medicine and science (Biomedical Communications University of Toronto 2011:[sp]).

Internationally medical illustration is regarded by some as a sub-discipline of medical and biological science. Illustration is also recognised in the field of botany, as a sub-discipline of plant biology. According to Jacqui Pestell (2010:4) the Royal Botanic Garden Edinburgh (RBGE) presents a two-year part-time diploma in botanical illustration. The course offers students fundamentals of plant botany, the essentials of different plant structures and the ability to produce and assess botanically accurate drawing and painting work (Pestell 2010:7).

Medical illustration as a profession in South Africa is still in its infancy. According to South African medical illustrator Pieter van der Bijl (2001:1030) no degree course is currently offered for medical artists and the majority of them are working at medical faculties of universities where knowledge and expertise are shared. Medical illustrators in South Africa depend on their own initiative and creativity and often attend courses at their own discretion (van der Bijl 2001:1030).

2.2 The role of the medical illustrator in education

The relevance of visual elements in the current learning environment is increasing with expanding integration of images and visual presentations with text in textbooks, instructional manuals, classroom presentations, and computer interfaces (Benson; Branton in Stokes 2002:10). Medical illustrators are now equipped with audio-visual technological abilities to design and manipulate complex medical processes for students to comprehend.

According to Ansary *et al* (2000:70) medical illustration departments in the United Kingdom, for instance, offer a wide range of photographic, graphic and audio-visual services for a mixture of clinical recording and medical education. With the rapid development of new media, medical illustrators and instructional designers have the ability to create images compatible to various media practices used in particular by students in order to enhance their learning. Richard Morton, Joe Nicholls and Robin Williams (2000:65) emphasise that medical illustrators can also help to improve communication and understanding amongst educators and students as well as specialists. The role of the medical illustrator is evolving to the field of educational planning and educational technology. Because medical illustrators have the advantage of being familiar with various computer software programs, their position in the formulation of teaching and educational strategies is becoming more prominent. (Ansary *et al* 2000:70).

2.2.1 *Education in South Africa*

Outcomes-based education was introduced in South Africa to improve the rationality and quality of education and training after the legacy of apartheid, although this educational system is still in the process of change. As explained in Chapter one, outcomes-based education is the process where the learner is primarily responsible for his/her own construction of knowledge with the educator only acting as facilitator or tutor during this learning phase (Malan 2000:26). This system focuses primarily on what learners actually learn and how well it is learned rather than focusing on what they are supposed to learn (Botha 2002:364). This form of learning allows students to study individually and use different forms of media to obtain new information and stimulate their creative thinking.

According to Melih Kirlidog and Malie Zeeman (2011:48) education in the post-apartheid era still reflects skills shortages amongst educators and learners, especially in the field of information technology and communication, due to vestiges of inequities apparent during the apartheid regime. Over and above the need to improve teachers' and learners' skills, other current factors within the South African educational system remain serious problems. These include increasing pressure from government to meet social transformation, the lack of academic preparedness, the rapid expansion of the number of students in classes and multilingualism. These remain endemic challenges that need to be addressed within this educational system (Jaffer *et al* 2007:132).

Another serious challenge facing tertiary institutions is the unremitting decline in budgets which force educators, designers and illustrators to use limited dynamic technological resources effectively at times for the enhancement of learning. Due to the high costs of reproduction, for instance, study guides used at the SMFHS at UP are generally printed in black and white. Illustrators and educators therefore have to carefully plan the structure and layout of these sources to make them understandable to students.

2.2.2 *Medical education at the SMFHS at UP*

As explained in Chapter one, SMFHS at UP changed its curriculum from a system grounded on specialist-based training to a system focusing on primary health care due to government enforcement. Therefore, the structure of the new curriculum has to embrace horizontal, as well as vertical thinking for students to enhance clinical and practical medical knowledge.

Horizontal thinking promotes the integration amongst different disciplines such as anatomy, histology and physiology within themselves or amongst each year of the curriculum, while vertical thinking includes the integration of disciplines that are taught in different phases or years of the course, such as early introduction and development of clinical skills alongside the basic principles of ethics and psychology in medicine (AlSaggaf, Ali, Ayuob, Eldeek & El-haggagy 2010:373).

The SMFHS at UP is currently using a problem-orientated curriculum which is outcomes-based with the content structured around body organs and systems (University of Pretoria. Faculty of Health Sciences, 2011:[sp]). The vision of the SMFHS at UP is to educate medical doctors and to integrate appropriate knowledge across interdisciplinary boundaries. It also aims to supply students with clinical knowledge and skills for the improvement of patient interaction, and to become life-long learners (Krüger, Schurink, Bergh, Joubert, Roos, Van Staden, Pickworth, Du Preez, Grey & Lindeque 2006:12). This curriculum is an educational system, dividing medical sub-disciplines into blocks to be presented over a certain number of weeks. Each sub-discipline has its own textbooks, atlases and study guides for study purposes.

First-year medical training consists of scientific subjects such as chemistry in the first semester and from the second semester students are exposed to cell biology and histology in the first block. It involves learning anatomical structures on microscopic level. During the second year of medical training, students are exposed to disciplines such as physiology and anatomy where they dissect cadavers for the first time. From the second year onwards, medical students also make use of the Study Resource Centre at the SMFHS at UP which contains a wide selection of dissected and labelled specimens of cadavers for study purposes. From the second semester of the second year, students start with introductory clinical training in the Skills Laboratory at the SMFHS at UP. The Skills Laboratory offers medical students the opportunity to acquire clinical, communication and ethical skills required for patient treatment (University of Pretoria. Skills Laboratory, 2013:[sp]). This laboratory is also equipped with a wide spectrum of resources such as dummy arms, backs and baby heads to teach skills such as inserting intravenous drips or sutures (University of Pretoria. Skills Laboratory 2013:[sp]). From the second year onwards, medical students also use the two libraries of the SMFHS at UP on a regular basis; the Basic Medical Science (BMS)/Dentistry library and the Medical library.

In the third year of medical training students continue to visit the Skills Laboratory and are exposed to surgical, anatomical, clinical and pathological conditions of different aspects of the body and are also introduced to paediatrics. Exposure to hospital rotations form part of fourth-year medical training, where students are exposed to clinical, anatomical, pathological and surgical case studies. Other disciplines during fourth-year training such as neurology, internal medicine, urology and ophthalmology are also examined, as well the start of government hospital rotations. During fifth-year medical training students continue with hospital rotations in disciplines such as surgery, psychiatry, trauma and pharmacology. Exposure to the Skills Laboratory continues until the end of medical training. Problem-orientated learning within the SMFHS at UP provides an integrated and practical approach to medicine. The role of the medical illustrator within this learning system is challenging, as the creation of visual material needs to assist students in the interpretation and comprehension of integrated complex medical information.

2.2.3 *The role of the medical illustrator within the SMFHS at UP*

Medical illustrators and designers at the SMFHS at UP are actively involved in designing visual stimuli for course material to be displayed on ClickUP[15]. This web-based educational environment allows illustrators to construct rich visual materials for web-based courses that are accessible to students. Due to budget constrains medical illustrators are challenged to use creative and strategic methods when designing visual material for educational purposes. Study guides are photocopied for cost effectiveness and this challenges illustrators to create simplistic, though aesthetically appealing illustrations for medical students to use during learning. Under these circumstances medical illustrators need to maintain accuracy of content, and select appropriate styles when

[15] ClickUP is a web-based environment where students have access to course material, communicate with lecturers or tutors and perform academic, administrative and financial activities (Lazenby 1998:446).

designing medical illustrations for learning. It is also important to work in close collaboration with educators in order to design and create accurate visual material appropriate for medical students' needs and knowledge.

2.3 The medical illustrator and user-centred design

Medical illustrators should be aware of students' needs when designing visual material for study purposes in order to enhance their learning and their comprehension of complex medical material. Effective liaison with educators enables illustrators to construct illustrations that meet the criteria for teaching and educational strategies while making them understandable for students. The opinions of students offered to lecturers should also be considered when designing illustrations, as they are the active users of the images during learning.

Ian Newell and Peter Gregor (2000:2) state that user-centred design enables designers to focus on the user as the "heart" during the design process. Patrizia Marti and Liam Bannon (2009:14) believe user participation should always be aimed at the knowledge and the abilities of people involved in the design process in order to participate in the definition, comparison and evaluation of concepts. The evaluation of the designed product is important in order to gain deeper knowledge regarding the design process, as well as the needs of the user. Cross (in Feast *et al* 2010:3) emphasises designers' intellectual reflection upon their designed activities, developed by Donald Schön in order to generate better knowledge regarding designed artefacts, the design process and users' needs.

Medical illustrators need to have sufficient knowledge when constructing visual material for learning purposes. According to Usha Reddy, Bhaskar Sripada and Roshni Kulkarni (2006:1778) the development of educational multimedia software for healthcare professionals for instance, includes many challenges such as the facilitation of accurate content and the depiction of pictures to explain text in the most comprehensible manner. It is important for medical illustrators to understand the colour, structure, shape and background of a medical structure to be illustrated, as the difference in the colour of a structure, for instance, can carry a different meaning (Reddy *et al* 2006:1779).

Working with other role players is crucial to communicate these factors clearly and complete a project on time (Reddy *et al* 2006:1778). For example, in the South African medical educational environment, the medical illustrator liaises with the physician or educator to determine the nature of the illustration necessary to be created; whether it is for publication or educational purposes. Both the physician or educator, as well as the illustrator are actively involved during the process of design planning as the physician or educator provides information from a medical perspective while the illustrator provides the practicality of the creation of the image, as well as the format, media and style of the drawing to be used.

Through this collaborative process the needs of the user are determined and information is communicated effectively. Medical illustrators are continuously facing new challenges to conform to the needs of students in terms of the way illustrations are perceived, comprehended and preferred during learning. Learning styles of students, for instance, are an importance factor to keep in mind when illustrations for learning purposes are created.

2.4 Learning styles of students

Learning styles focus on the way in which learners begin to concentrate on, process and retain new and complex information (Griggs & Dunn 1995:[sp]). Although students use different forms of learning styles, they can be used as guideline for illustrators and designers on how to construct visual material for educational purposes.

It is not known from literature what type of learning styles medical students adopt when learning medical subjects and how they would use illustrations to learn anatomy and physiology, for instance. Eizenberg (in Pandey *et al* 2006:8) finds that medical students memorise chunks of information and understand only selected aspects of anatomical information. The way students use illustrations during learning was not studied in depth by these authors.

Stokes (2002:12) believes that learners with predominantly right-hemisphere thought processes with visual, spatial abilities and non-verbal recognition activities may have difficulty in employing learning styles not compatible with their own abilities. Cheng *et al* (2010) conducted a study to determine how third-year biomedical science students created their own illustrations from an audio description about the functioning of the renal system of the body. According to Cheng *et al* (2010:176) students were able to draw key anatomical structures, although their attempt to demonstrate functionalities of structures was unsuccessful. Students might have experienced a lack of confidence to create new illustrations from own interpretations and rather spent time trying to recall previous material through continuous reasoning (Cheng *et al* 2010:176).

Many scholars argue that different factors tend to influence learning styles of students. Griggs *et al* (1995:[sp]) for instance, accentuate the influence of cultural, social and economic factors, while Jill Slater, Heidi Lujan and Stephen DiCarlo (2007:336) portray the impact of gender on the learning styles of students. According to Slater *et al* (2007:341) their study demonstrated that female students were more diverse than their male counterparts encompassing a broader range of sensory modalities of learning. Ioanna Vekiri (2002:304) is of the opinion that students' prior subject-matter knowledge, spatial abilities and learning strategies influence their learning from visual presentations. With reference to the structure of the current medical curriculum at the SMFHS at UP, as explained earlier in this chapter, fifth-year medical students gain more advanced clinical knowledge in relation to, for instance, second-year medical students. Difference in knowledge levels may cause both groups of medical students to use, perceive and comprehend a similar medical concept differently. This process is not yet fully understood.

The VARK learning preferences questionnaire introduced by Fleming (1995:308) in Chapter one is valuable for the development and reflection of teaching strategies tailored for individuals and accentuates four sensory modalities of learning namely visual, auditory, read-write, and kinaesthetic. Fleming (1995:309) explains that visual learners prefer the use of diagrams and symbolic devices such as graphs, flow charts, models and arrows that represent printed information. Auditory learners use speech which arrives at the learner's ear as a learning mode. This is the most common form of learning (Fleming 1995:308). Read-write learners prefer printed words and texts as a means of information intake (Fleming 1995:309). Kinaesthetic learners use all senses as part of the learning process and they can easily learn from abstract concepts, although they have to be accompanied by suitable analogies, real life examples or metaphors (Fleming 1995:309).

According to Fleming (1995:309) learners are not restricted to one mode of learning, although some dominant preferences are evident. These four sensory modalities are used in Chapter six as a foundation for this study to provide a better perspective regarding the nature of medical students' use, comprehension and preferences of illustrations during learning.

2.5 Visual perception

This study focuses on how students perceive medical illustrations as a learning tool. It is therefore necessary to discuss the concept of visual perception. Lester (2002:43) describes visual perception as the process when meaning is subscribed to visual stimuli originating from our visual senses regarding a certain aspect. Anglin *et al* (2004:867) are of the opinion that pictures will be interpreted differently depending on the attitudes of the reader and what is seen or thought to be seen which is filtered through a variety of mental sets and expectations. Lines, for instance, are used in illustrations to represent edges of objects, although this differs from what is seen in nature (Anglin *et al* 2004:867). Natural objects are not bound by lines, although due to convention, outline drawings are perceived as depicting shapes rather than an arrangement of wires (Anglin *et al* 2004:867).

Medical illustrations are enriched through variety of drawing styles, different intensities of colour, as well as various levels of detail and realism which may influence students' perceptions when learning from them. Realistic depictions of anatomical structures are important as students need to familiarise themselves with the reality of a patient's or human body. Abstract depictions of the human body, on the other hand, are also necessary, depending on the purpose of learning or teaching strategies. DeCarlo *et al* (2010:175) explain that when realistic structures are abstracted to clarify important features, the abstraction and its original detail depiction need to share a common visual explanation.

Other aspects that might influence visual perception of students are the selection of media and the application of illustration techniques when creating illustrations as a learning tool. A study by Isenberg *et al* (2006) shows how the application of computer-based illustrations, compared to the same concepts drawn by hand, influence participants' preferences. Isenberg *et al* (2006) conclude that illustrators need to know their audience in order to select appropriate media for the creation of illustrations. Three particular areas of visual perception, namely visual literacy, spatial visualisation and colour blindness require special attention and are introduced under the next three points.

2.5.1 *Visual literacy*

Wileman (in Stokes 2002:12) describes visual literacy as the "ability to read, interpret, and understand information presented in pictorial or graphic images". According to Siu-Kay Pun (2007:9;11) visual literacy involves functions of the right brain such as visualisation, intuition, creativity and imagination which enable students to analyse design elements and principles in an image in order to subtract meaning from it. Due to the rapid expansion of multimedia technology, visual communication has become an essential visual literacy skill needed to access and operate teaching and learning material effectively (Pun 2007:14).

The development of visual literacy is necessary as it encompasses divergent thinking and multidisciplinary knowledge which in turn nurture creativity (Pun 2007:10). Medical students face tremendous pressures coping with a demanding curriculum and are forced to focus on a diverse spectrum of medical subjects enriched with important visual representations in fields such as anatomy, physiology and histology. Medical training is based on the foundation of mathematics, science and biological subjects resulting in the left brain being better trained. The SMFHS at UP consists of a multicultural corps of students who might perceive and comprehend the nature of medical illustrations differently. Cultural conventions of medical students, as well as their exposure to various domains of information may influence the way illustrations are used, perceived and comprehended for learning purposes.

Several authors outline the importance of the application of design elements, principles and symbols in illustrations, as these factors may weaken visual literacy skills among readers. According to Carstens (2004:467) the application of visual conventions or symbols in pictures are often neglected and not carefully considered, as several cultural traditions are accustomed to specific artistic applications when viewing illustrations. For instance, in Western tradition highlights are used to show reflections on shiny surfaces. A white mark in an eye will be correctly understood by Western readers, while visually illiterate people or those from other cultural traditions may understand that the eye is damaged (Carstens 2004:476). Furthermore, Krull *et al* (2006:191) explain how readers may easily overlook important information when focusing on less important objects of illustrations. An example is cited where it was the intention of the illustrator to insert hands on an illustration that served as a general guide. Readers tended to duplicate the hand positions rather than focusing on the actual message conveyed by the image (Krull *et al* 2006:191).

The application of design elements such as line, colour, texture and shape as well as the selection of media are also important factors to consider when creating illustrations, especially for learning purposes. Tufte (1997:56) explains the complexities of understanding a medical illustration demonstrating two different surgical actions simultaneously. Elements such as attributes of line and direction of hands may influence the way the depiction is understood (Tufte 1997:56). It is therefore crucial for designers and illustrators to know different aspects of their audiences such as the difference in knowledge levels and cultural orientation which may influence their visual literacy skills.

Visual literacy skills also enable readers to find meaning in what is seen through the use of different visual examples and this skill provides them with better perspective of why designers or illustrators created a specific illustration in a certain manner (Pun 2007:11). Similar to visual literacy, spatial abilities of readers are also essential to acknowledge when illustrations are created for learning purposes.

2.5.2 *Spatial abilities*

Spatial abilities refer to the formulation, preservation, retrieval and transformation of visio-spatial information and consist of two spatial factors, namely spatial visualisation and spatial relations (Colom, Contreras, Botella & Santacreu 2001:903). Spatial visualisation is the ability to mentally manipulate visual patterns as indicated by the level of difficulty and complexity in visual representations, while spatial relations refers to the speed in mentally rotating or manipulating relatively simple visual patterns (Colom *et al* 2001:905).

Spatial abilities are essential for especially medical students in order to mentally visualise inner anatomical structures of cadavers or patients, as most of their learning material suggest two-dimensional appearances. According to Donald Risucci (2002:291;293) spatial abilities are also important when conducting surgical procedures and play a role in the development and manifestation of surgical thinking, for instance to understand two-dimensional imaging of three-dimensional anatomical structures in relation to others.

Objects depicted in from different angles to emphasise dimension and three-dimensional appearance, can also have an influence on the spatial visualisation of viewers. Csillag (2009:135) implies that the perception of an object shown from an angle to emphasise three-dimensionality, can easily be interpreted differently when the same object's angles are separated in another illustration. According to Csillag (2009:135) readers from various cultural groups may find it difficult to understand the dimensions of the object even when demonstrated separately.

The present study needs to explore to what extent a multicultural corps of medical students at the SMFHS at UP are able to mentally orientate themselves with two- and three-dimensional anatomical illustrations in order to comprehend underlying structures. Literature regarding spatial abilities of medical students within a South African context is limited. A need therefore exists to determine how two-dimensional illustrations are observed and understood by a multicultural audience of medical students during learning. Similar to spatial visualisation, colour blindness is another area that may influence viewers' perceptions of illustration, especially during learning.

2.5.3 *Colour blindness*

Normal vision occurs when short wavelengths lead to the perception of blue, medium wavelengths to the perception of green and longer wavelengths to the perception of red (Rubin, Lackey, Kennedy & Stephenson 2009:84). A lack of functionality in the sensing of one or more wavelength sensing cones is called colour blindness (Rubin *et al* 2009:84). Colour is an important design element in medical illustration, as it demonstrates, for instance, pathological conditions such as skin diseases and enables students to distinguish between different anatomical structures for learning purposes. Furthermore, colour in anatomical illustrations also enables students to determine clinical conditions. Literature regarding the influence of colour blindness on students' learning within a South African context is limited.

2.6 Conceptual framework for this study

The following model (Figure 14) summarises the most pertinent thinking that addresses the research objectives. It is a framework of existing literature that explains current students' learning styles and visual perceptions during learning against the background of the current curriculum structure of the SMFHS at UP. The role of the medical illustrator within this framework is also illustrated and demonstrates the importance of close collaboration with educators and physicians for the creation of illustrations valuable for learning purposes. This model is used as guiding framework throughout this study.

2.7 Conclusion

The founding of associations for medical illustrators, as well as the establishment of institutions presenting collective courses in science and illustration created the platform for continuous development of visual material within the fields of medical research and education. The Journal of Biocommunication, for instance, is a landmark for ongoing research developments. Continuous growth in volume rendering visualisation techniques enriches not only knowledge in diagnostic imaging and clinical anatomy endeavours, but also brings new understanding to other disciplines such as engineering, science and radiology. It is, however, evident that the medical illustrator should keep abreast of the latest developments in computer software and media technology in order to create visual material compatible and valuable especially for medical education.

Closer collaboration with educators and physicians is necessary to determine students' needs and what is understood and necessary to be learned. This form of collaboration will help illustrators and designers to create visual representations that facilitate better understanding among students, as educators and physicians work closely with a wide spectrum of learners from different cultural backgrounds.

Due to the current medical educational climate in South Africa, illustrators and designers are challenged to create dynamic visual educational material with limited resources due to budget constraints. Furthermore, medical illustrators are also becoming more involved in the process of educational planning. They have to pursue deeper knowledge of multimedia technology in order to develop dynamic visual educational material for teaching and educational purposes. Medical illustrators also need a thorough knowledge of the students in terms of their knowledge and experience levels, visual literacy skills, learning styles, as well as demographics. As explained by several scholars, these factors may serve as guideline when applying design elements and principles in the creation of illustrations for readers to comprehend.

Design elements and principles are generally applied in compositions to accentuate aspects such as form, structure, aesthetic qualities and order of objects. Due to the enormous scope of design characteristics in visual representations, only a limited group is selected that are relevant to this study and introduced in the following chapter. Attributes and functions of these design characteristics are discussed and interpreted at the hand of medical illustrations.

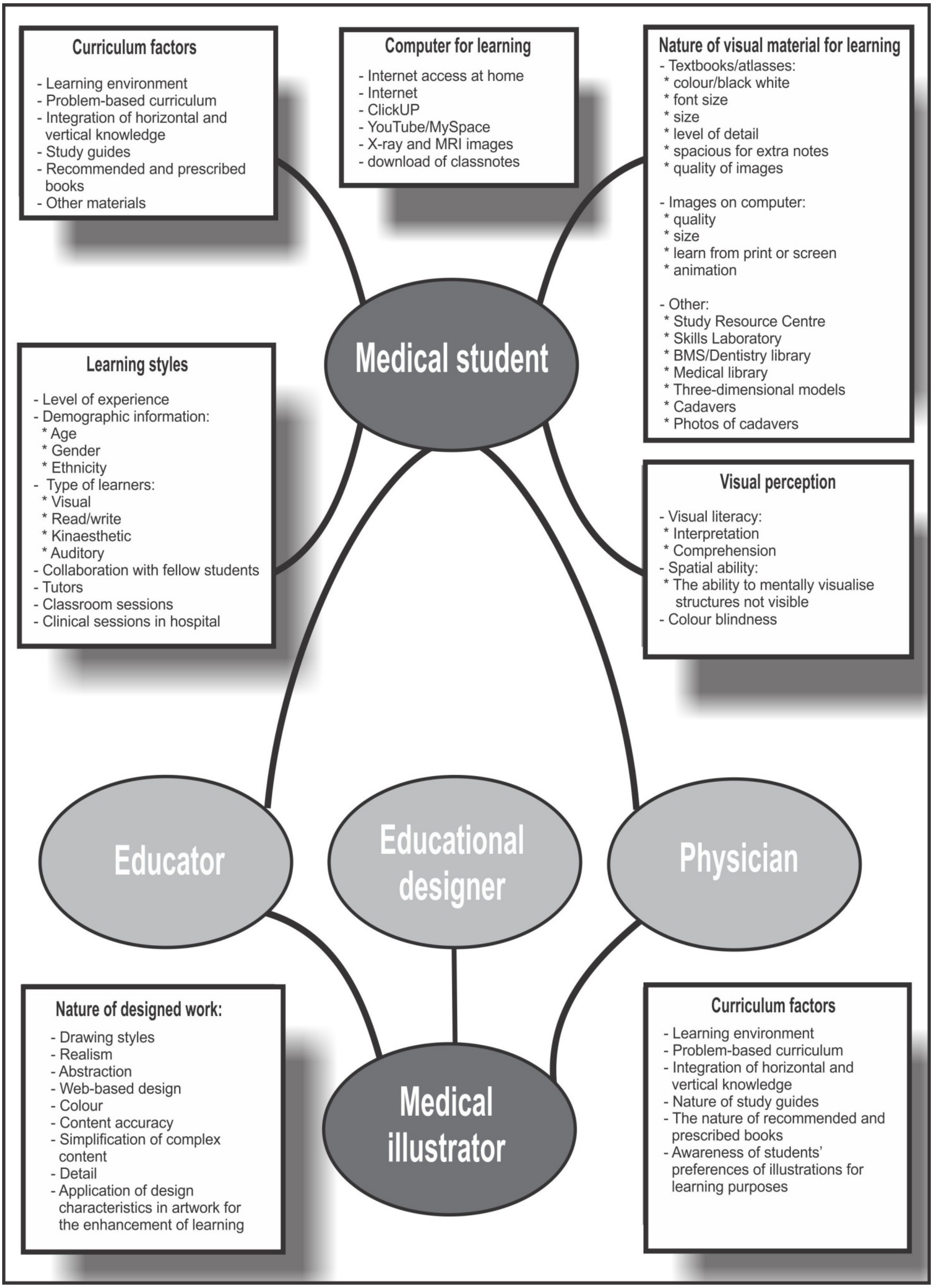


Figure 14: A conceptual model demonstrating factors for students' learning and the position of the medical illustrator within the medical curriculum of the SMFHS at UP, 2012. Created by the author.

3. CHAPTER THREE

3.1 Design characteristics in medical illustration

Chapter two not only accentuated the rapid growth of technology medical illustrators have to keep up with, but also highlighted the importance to gain deeper knowledge regarding the user when designing illustrations for learning purposes. Designers and illustrators have the ability to proficiently organise design and textual elements and principles in such a fashion that they visually communicate a certain message (Tufte 1997:55). Recognising the user enable illustrators to structure and organise design elements and principles in such a way that they can be more easily understood by the reader. A deeper understanding of the relevance of design elements and principles in illustrations created for learning purposes should be gained.

This chapter provides a brief introduction and overview of selected design elements and principles that are relevant to medical illustrations. Design elements chosen for this study are based on perspectives of Stewart (2002:1-6) who considers line as an element providing expression in a composition, while texture and shape as essential for the emphasis of dimension and structure in a composition, generating energy and flow (Stewart 2002:1-6).

Tufte (1990:55; 1997) accentuates the significance of colour in a composition, as it contrasts elements such as lines and shapes and contributes to a vibrant visual effect. Design principles selected for this study are based on the perspectives of White (2002) and Evans *et al* (2008) who consider unity and variety, proximity and repetition, as well as hierarchy and dominance essential for the structuring and ordering of a well-balanced composition to be understood by readers.

Two other aspects selected for this study are the relevance of labelling techniques in medical illustration as well as the quality of the reproduction of images, especially for learning purposes. These factors are considered essential to the essence of design characteristics as the application of labelling techniques in medical illustrations contribute to effective balance between text and images and direct readers' eyes to essential information.

Different qualities of reproduction in medical illustrations are referred to and discussed as they appear in study guides and textbooks. In some instances photocopied images result in poor quality and can be problematic for learning purposes. It is therefore necessary to determine to what extent methods of labelling, as well as quality of reproduction have an influence on viewers' learning.

Table 1 summarises the design characteristics discussed in this study. Design elements and principles grouped together are regarded to be of equal importance in medical illustrations. For the purpose of this study, the term design characteristics refers to this selection of design elements and principles.

Design characteristics					
Design elements - based on Stewart (2002) and Tufte (1990; 1997)	Line: actual and implied lines	Visual texture: combined texture and cross contour line textures	Colour	Shape and space	Size and depth
Design principles - based on White (2002)	Unity and variety	Hierarchy and dominance	Balance	Proximity and repetition	Movement
Additional factors	Labelling techniques		Quality of reproduction		

Table1: Design characteristics and two additional factors selected for this study, 2012. Created by the author.

3.2 *Design elements*

Design elements supply structure and definition to objects in a composition. Evans *et al* (2008:17) describe design elements as “the visual vocabulary providing voice to an image, allowing it to speak to the viewer”. The following design elements, namely line, visual texture, colour, shape and space, as well as size and depth are discussed and demonstrated with medical illustrations. This section provides essential background information for the fieldwork conducted in order to determine the influence these elements in medical illustrations may have on readers’ learning.

3.2.1 *Line*

Stewart (2002:1-1) and Evans *et al* (2008:20) provide a formal description of line as a moving path of a point or a series of adjacent connections between points for the viewer to combine. According to Teel Sale and Claudia Betti (2008:115) line for illustrations and other compositions is much more than a path between two points as they regard it as the purest form of drawing and the most direct means of generating style. Forrester Cole, Kevin Sanik and Doug DeCarlo (2009:28:1) regard line as a minimalist element as it helps to simplify objects for better understanding. Andrews (2006:1) however, considers the application of line in a composition to be the most difficult to attain, as line illustrations can easily be misinterpreted or misunderstood because of their abstracted or simplified manifestations. Except for the fact that line illustrations can cause ambiguity amongst readers, different attributes of line are used to express certain features, a message or a feeling in a composition. Stewart (2002:1-4) refers to the work of Gary Goldsmith who created an advertisement for an anti-drug campaign by only using one narrow white line on the left, followed by a big black line for the rest of the design. According to Stewart (2002:1-4) the narrow white line demonstrates the narrow strip of cocaine while the thick black line suggests death. Lines can therefore play an important role in a composition to express feeling or explain important information.

Besides the application of line variations in a composition, another aspect to consider is the selection of media[16] when creating lines (Evans *et al* 2008:20). The use of computer-generated lines in a composition, for instance, may generate a feeling of order and structure, while the application of lines with ink suggests a feeling of freedom and energy. Lines in a composition are vital as they suggest shape, convey various attributes and qualities, imply movement, show direction and enhance the texture of objects. All these characteristics of line are relevant when looking at medical illustrations. The use of actual and implied lines in medical illustrations also helps to accentuate anatomical contours or illuminates textures of muscle and bone.

3.2.2 *Actual lines*

Stewart (2002:1-1) describes actual lines as the demonstration of inner and outer edges or contours of an object. In medical illustration, actual lines are useful to outline important features of anatomical structures with the use of various line attributes. The illustrations below in Figures 15a-b use different attributes of actual lines to show the lymph drainage in the scalp and face. The various applications of media used in these illustrations provide different visual effects and expressions. The illustration in Figure 15a demonstrates lymph drainage depicted with soft contrast variation, tonal values and soft lines to provide a feeling of direction and order. In contrast, Terry Dolan's *Lymph drainage of the head and neck* (Figure 15b) shows dark lymph nodes against thinner black lines to demonstrate direction of lymph drainage which provides a feeling of energy and flow.

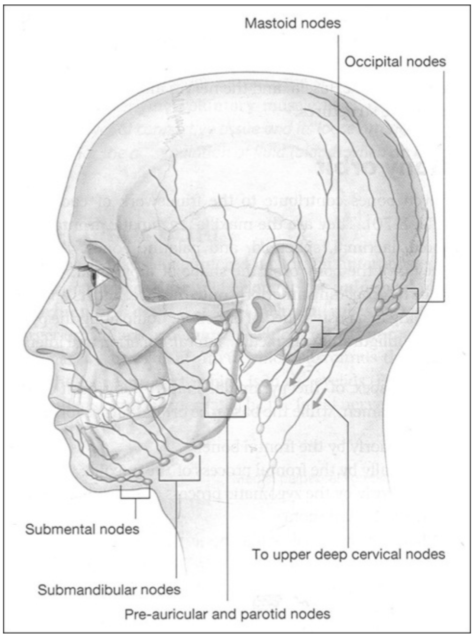


Figure 15a: Illustrator unknown,
Lymphatic drainage of the scalp.
Computer-generated. Adopted from
(Drake, Vogl & Mitchell 2005:829).

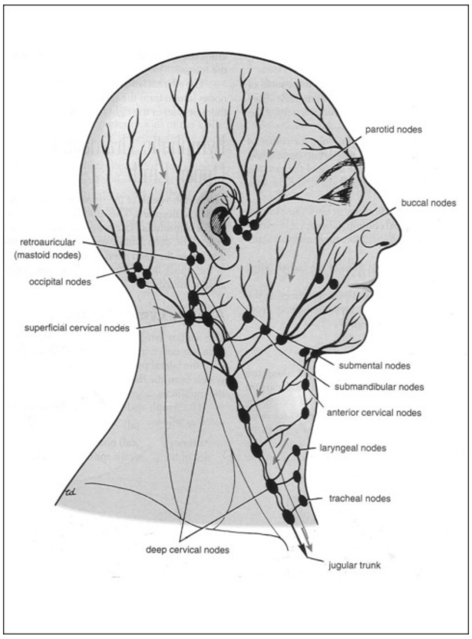


Figure 15b: Terry Dolan,
Lymph drainage of the head and neck.
Mixed media. Adopted from
(Snell 2007:273).

[16] The term media describes different tools that are used to create a composition such as pen, pencil, ink, watercolour, oil on paper and/or graphic software on computer.

3.2.3 *Implied lines*

Implied lines are also referred to as open lines consisting of unfilled areas for the human mind to complete (Stewart 2002:1-3). Tufte (1990:61) expresses a dislike of implied lines as he feels they do not reveal information effectively, but bring only noise to a design. There is a danger in using implied lines in compositions since they can be misinterpreted by viewers or distract them from important aspects.

Fisher and Smith-Gratto (in Chang, Dooley & Tuovinen 2001:6) state: “open shapes make the individual perceive that the visual pattern is incomplete” and the “sense of incompletion serves as a distraction to the learner”. The application of implied lines may cause the viewer not to see and comprehend a composition as a whole which is necessary especially during learning.

The relevance of implied lines in medical illustration can help the reader to focus on certain details or to demonstrate function. Implied lines are sufficient for the accentuation of important anatomical structures by showing features receding into the background as partial. Movement of anatomical structures can also be accentuated with the use of dashed lines. In the following illustrations demonstrated in Figures 16a-b the course of the optic nerve in the eyes are demonstrated. In both illustrations only vestiges of the skull is visible for the reader to focus on important areas. Dashed lines are used in both images to suggest movement of the optic nerve through the eye balls. In Myra Feldman’s *Optic nerve* (Figure 16a) readers are forced to mentally complete the essence of the background depiction which appears two-dimensional with only outer edges emphasised. In contrast, Figure 16b portrays more depth and dimension with the background depiction created with tonal values to suggest depth.

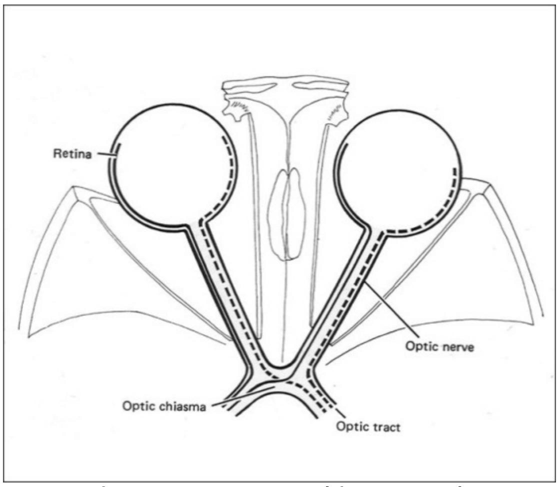


Figure 16a: Myra Feldman, *Optic nerve and its connections.* Computer-generated. Adopted from (Snell 2007:559).

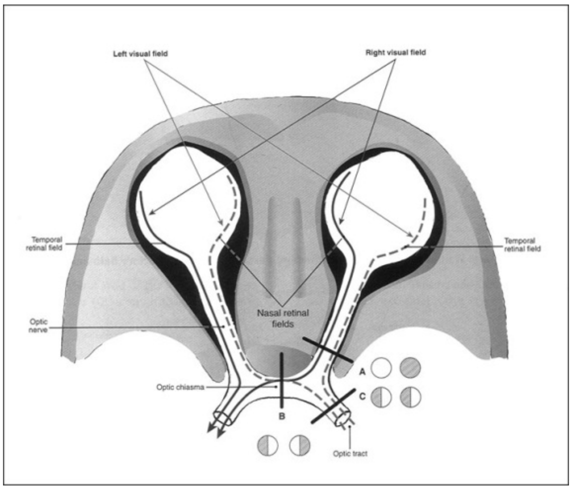


Figure 16b: Illustrator unknown, *Optic nerve*. Mixed media. Adopted from (Clemente 2011:673).

The application of dashed lines in each illustration provides a feeling of flow and movement. Line as design element is selected for this study as this element enhances structure, shape and function of anatomical structures, especially in black and white representations.

3.2.4 *Visual texture*

Stewart (2002:1-15) defines visual texture as the surface quality of two-dimensional or three-dimensional volume. Visual texture can be created using multiple shapes or line patterns on a two-dimensional surface while tactile texture refers to felt, feather or wood (Stewart 2002:1-15). Textures are created through a pattern to convey a realistic depiction of a surface.

The selection of media is essential to express the appropriate texture of a certain area. The study of Isenberg *et al* (2006) shows how an object created with different forms of media can influence the way the illustrations are perceived. Participants experienced hand-drawn images as expressing an organic feel, while the same objects created with computer were considered too clinical without any variation of line (Isenberg *et al* 2006:123). Different techniques of visual texture such as stippling, cross contours and cross hatch can be used to accentuate dimensions and surfaces of objects with the appropriate application of media. Stippling, for instance, is effective for the depiction of different gradients of shading on objects containing fine textures.

In medical illustrations combinations of different textures are used to help readers make a distinction between various areas. Textures in medical illustrations accentuate realistic appearances of anatomical structures by which readers can familiarise themselves. In other instances, anatomical structures are drawn with abstract patterns to distinguish between different areas or to illuminate important structures. The use of combined and cross-contour textures in medical illustrations helps to accentuate anatomical contours and/or illuminate textures of muscle and bone.

3.2.5 *Combined textures*

The examples demonstrated in Figures 17a-b show different applications of a combination of textures in different media to illustrate detail in the head and neck area. Netters' *Median section of the pharynx* (Figure 17a) is created with watercolour and ink, demonstrating smooth and contrasting areas of texture and tonal variations, resulting in a realistic appearance. In Dolan's *Sagittal section of the head and neck* (Figure 17b) computer techniques are used, providing a schematic, abstract and two-dimensional appearance to the illustration by showing each anatomical area with distinctive textures.

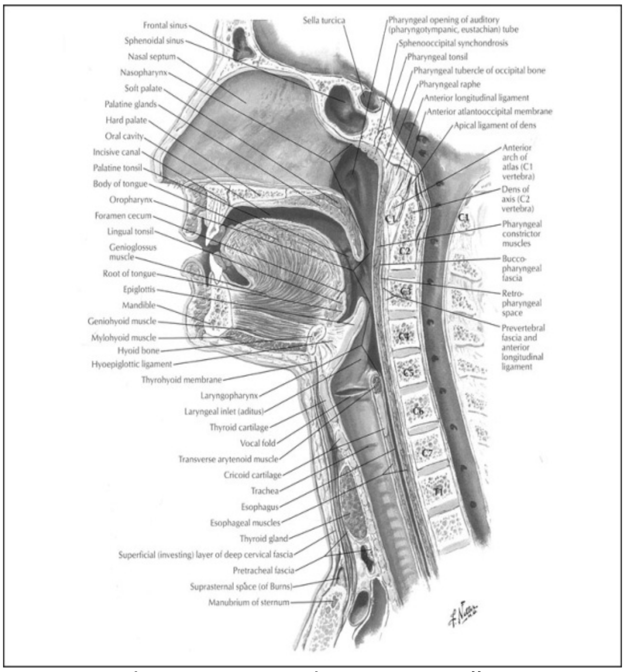


Figure 17a: Frank Netter, *Median section of the pharynx.* Mixed media. Adopted from (Netter 2011:63).

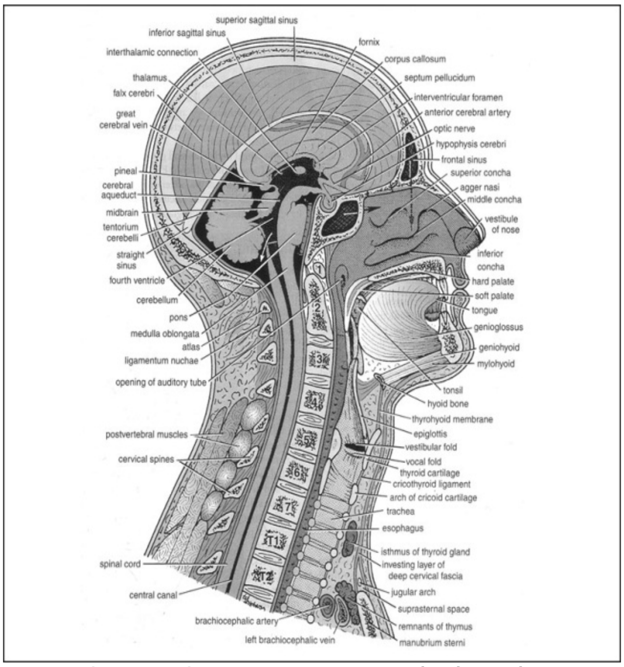


Figure 17b: Terry Dolan, *Sagittal section of the head and neck*. Computer-generated. Adopted from (Snell 2007:537).

3.2.6 *Cross-contour line textures*

Cross-contour lines are a form of texture to enhance dimension and structure of surfaces. According to Sale *et al* (2008:129) cross-contour line textures emphasise objects' horizontal contours rather than their vertical edges and enhance an object's transformation into space. The application of cross- contour lines in medical illustration provides dimension and structure in anatomical features in the form of dynamic patterns. Illustrations created with cross-contour lines need to be viewed in unison to reduce confusion. Andrews (2006:62) explains that the structuring of cross-contour lines in an illustration needs to be organised, otherwise "zebra stripes" are generated. Zebra stripes are lines spread too far apart not emphasising dimension and structure of anatomical structures.

The illustrations in Figures 18a-b demonstrate different applications of cross-contour line textures when showing the inferior base of the skull. Dolan's *Inferior surface of the base of the skull* (Figure 18a) is enriched with loose vibrant lines, showing structure, depth and energy. In contrast, the structured and organised patterns of the skull in Figure 18b create a form of order, realism and clarity. Visual texture is regarded an important design element selected for this study, as it provides energy, distinction and contrast in especially black-and-white representations.

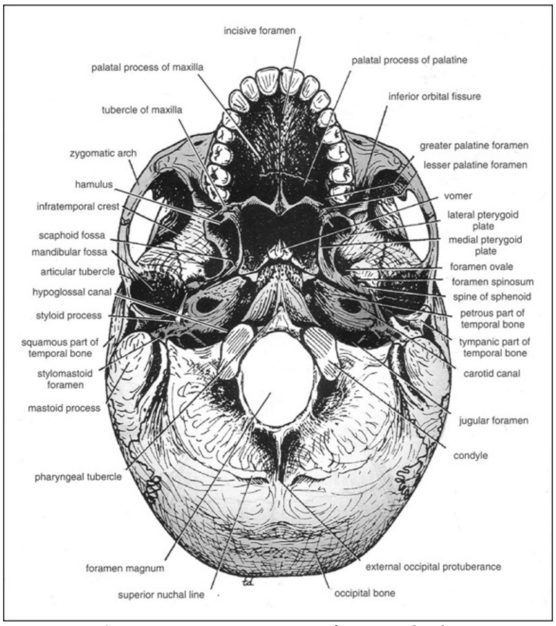


Figure 18a: Terry Dolan, *Inferior surface of the base of the skull*. Computer-generated. Adopted from (Snell 2007:298).

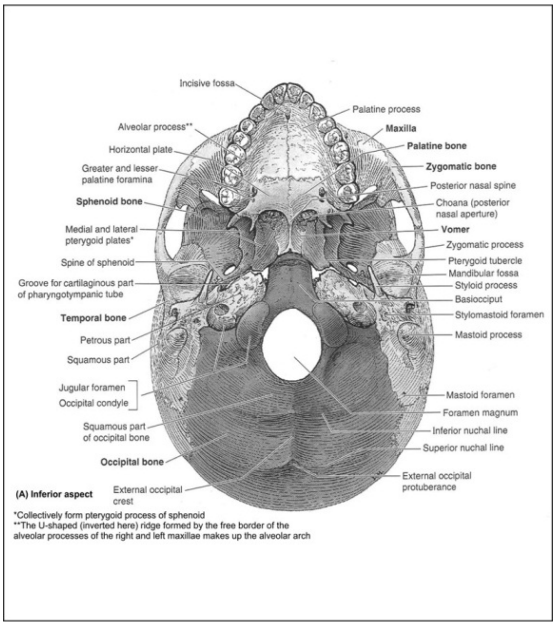


Figure 18b: Illustrator unknown, *Cranial base*. Mixed media. Adopted from (Moore *et al* 2006:879).

3.2.7 *Colour*

Colour is fundamental to illustrations as it illuminates important areas, helps to distinguish between different areas and provides energy and dimension to various objects. Other design elements such shape, line and texture are provided with much more depth, energy and dynamism when combined with colour in a composition. Daggett *et al* (2008:1) believe colour enriches a learning environment. According to Tufte (1990:81) colour in illustrations is essential to label or identify, represent and “imitate” real life objects as this design element reveals realistic appearances of structures and enhances aesthetical qualities.

These fundamental functions of colour illustrated by Tufte (1990:81) are also evident in medical illustrations. Colour enables viewers to distinguish between different anatomical areas and identify the realistic appearance of each body part. Although anatomical structures are coloured according to real body appearances, emphasis is also placed on the beauty and perfection of the human creation for readers to associate with. Different drawing styles and colour appearances are apparent in anatomical atlases and textbooks, although a standard form of colour coding of anatomical structures are used. When anatomical parts of the body are illustrated, each area is coded with a specific colour related to its realistic appearance and functionalities.

Anatomical structures are generally depicted with three primary codes of colours in textbooks and atlases. The colour blue is used to demonstrate veins, while red depicts arteries and yellow shows the nerves. Although this method of colour coding is generally applied in medical illustrations, these colours can also portray different colour intensities[17] (Schott 2010:511). Different intensities of colour can be used in medical illustrations to show a clinical condition or to illustrate a certain process. Saturated or bright colours such as saturated red for instance, is essential when demonstrating arteries filled with oxygen enriched blood while softer tones[18] of red demonstrate that the arteries contain blood with oxygen deficiency. According to Daggett *et al* (2008:5) saturated colours should be used sparingly especially when applied in illustrations for learning purposes. Saturated colours do not have any colour mixed with them and each saturated colour contains a different wavelength that needs to be focused on at different depths behind the eye lens. Therefore, the lens must change shape and refocus for every saturated colour and can thus cause eye fatigue (Daggett *et al* 2005:5).

Several medical textbooks show anatomical structures in colours other than the standard form of coding to explain physiological processes, for instance. It is not known whether readers need cognitive retrieval of memory when looking at different depictions of coloured anatomical structures other than their typical or original colours. A study by Thorsten Hansen, Maria Olkkonen, Sebastian Walter and Karl Gegenfurtner (2006:1367-1368) demonstrate that readers recognised digitised photographs of typical colours of natural fruit objects, even if the objects were manipulated to appear grey. However, unlike other studies where typical colours were separated from participants, observers in the study of Hansen *et al* (2006:1367-1368) were able to manipulate the colours of the fruit objects while exposed to their typical colours. The way readers perceive and understand coloured depictions of anatomical structures depicted in colours other than their typical or original representations is therefore not fully understood.

Another aspect also not fully known is the influence of colour on readers' spatial abilities when viewing objects depicted in different colour tones and demonstrated from at a certain angle. Different tones of colour are generally applied to accentuate the direction of light reflecting on the object, hence dimension and depth. Csillag (2009:135) explains that different tonal placements of colours on a cube to depict the dimensions of the object may be understood differently among various cultural groups, especially when the object's angles are divided in another illustration. The moment the cube's angles are separately displayed, the darkest tone receding on the side at first, suddenly appears more prominent and visually moves to the foreground (Csillag 2009:136). The placement of tones on an object has to be applied in such an instance for readers to understand and obtain the best spatial effects (Csillag (2009:136). Dagget *et al* (2008:7) also emphasise that colour creates different expectations amongst readers depending on their cultural background. Ambiguity can easily occur when colour is not used in a way contrary to their expectations.

[17] Colour intensity involves the brightness of colours and wavelength (Dagget *et al* 2008:5).
[18] A tone refers to colour tints (colours with white added) and shades (colours with black added) (Dagget *et al* 2008:5).

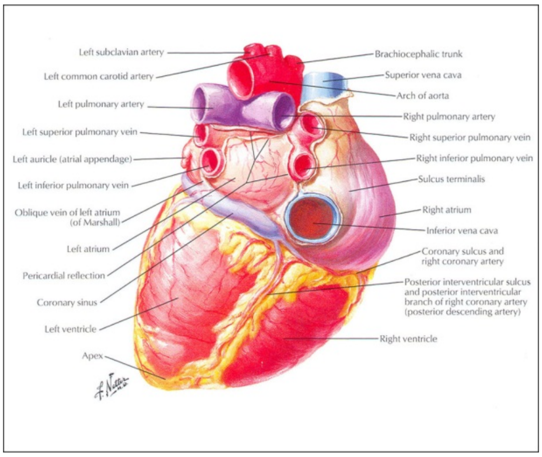


Figure 19a: Frank Netter, *Base and diaphragmatic surface:posteroinferior view.* Mixed media. (Netter 2011:208).

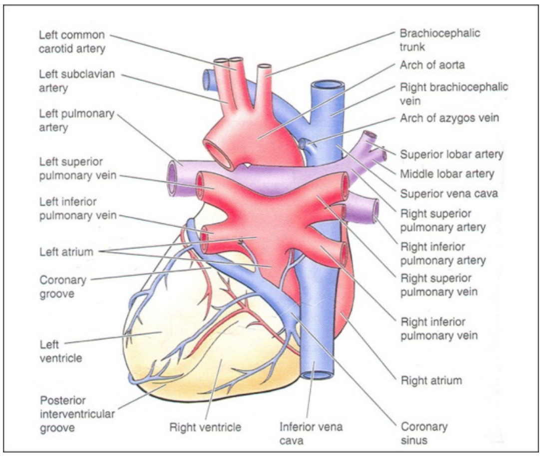


Figure 19b: Illustrator unknown, *The surfaces and base of the heart*. Computer-generated. (Moore *et al* 2006:146).

The illustrations in Figures 19a-b demonstrate the base and surface of the human heart and are depicted in different applications of colour and media. Netters' *Base and diaphragmatic surface: posteroinferior view* (Figure 19a) contains saturated colours, while softer tones and unsaturated colours are evident in Figure 19b. Colour is selected for this study due to its important role of providing realistic and aesthetic qualities of anatomical structures that are valuable to readers.

3.2.8 *Shape and space*

Shape and space are considered equally important elements in a composition, for space can suggest visual contrast and notable content in relation to the use of various shapes. Space in a composition is regarded as the background either filled or 'empty'. According to White (2002:13;15) space can be described as a context or physical environment which is created when a figure is placed on it. Objects are easily separated or combined with the application of space between or around them in a composition.

Spaces between objects on a white paper for instance, can function as an extra white colour to provide more dimension, structure and/or energy in a composition. In medical illustrations space between different anatomical structures helps viewers to distinguish between the objects. The amount of space available around an anatomical structure is important, especially when readers need to add additional information to the object as part of the learning process.

Shape is created when lines connect to enclose an area and is described as figure or form existing in a background or space (Stewart 2002:1-6; Evans *et al* 2008:18-19). The object being placed on a paper or space is referred to as shape. Stewart (2002:1-10) distinguishes between rectilinear shapes, dominated by straight lines and curvilinear shapes subjected to flowing lines. In medical illustrations curvilinear and rectilinear shapes function in correlation to each other in order to explain relations, function and structure of complex anatomical structures. In some instances, curvilinear shapes of anatomical structures are replaced with rectilinear shapes when a conceptual model of the structure is created to place more focus on the functionality of the structure. In other instances anatomical structures are depicted with simplistic curvilinear or rectilinear shapes to place focus on essential areas and remove visual clutter.

DeCarlo *et al* (2010:175) believe that a simplistic or abstracted version of a real object will be as recognisable as the original version. Simplistic illustrations of complex anatomical structures can help readers to immediately comprehend important content, although it can in some instances cause ambiguity especially for learning purposes. A study by Pourang Irani and Colin Ware (2000:1) shows that the creation of three-dimensional diagrams for engineering systems are visually analysed more rapidly and better remembered than two-dimensional diagrams.

The following illustrations in Figures 20a-b of the autonomic nervous system are created in various media and contain different levels of detail. Netter's *Sympathetic nervous system and parasympathetic nervous system* (Figure 20a) is a realistic illustration filled with curvilinear depictions of anatomical structures created in detail with mixed media. Due to the complexity and detail of this illustration, the degree of space available around the objects is limited.

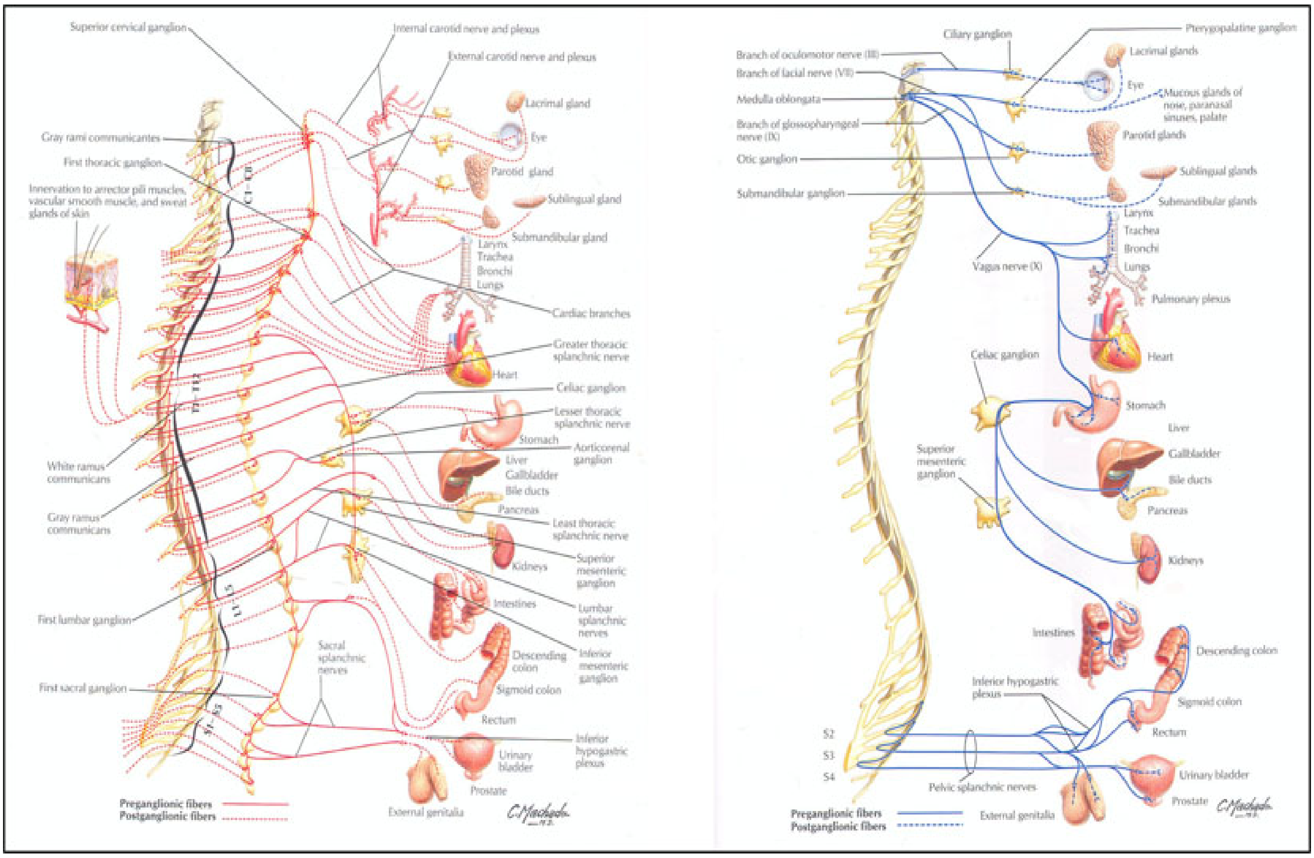


Figure 20a: Frank Netter, *Sympathetic nervous system and parasympathetic nervous system.* Mixed media.
(Netter 2011:160-161).

The second illustration of the autonomic nervous system in Figure 20b is schematically and simplistically drawn, showing rectilinear shapes created on a computer. This illustration focuses more on the functionality of the process than the appearance of anatomical structures. There are balance and harmony between the objects and white space. Shape and space are regarded important design elements selected for this study, as interaction between foreground and background objects is promoted so that readers can identify and understand the concept.

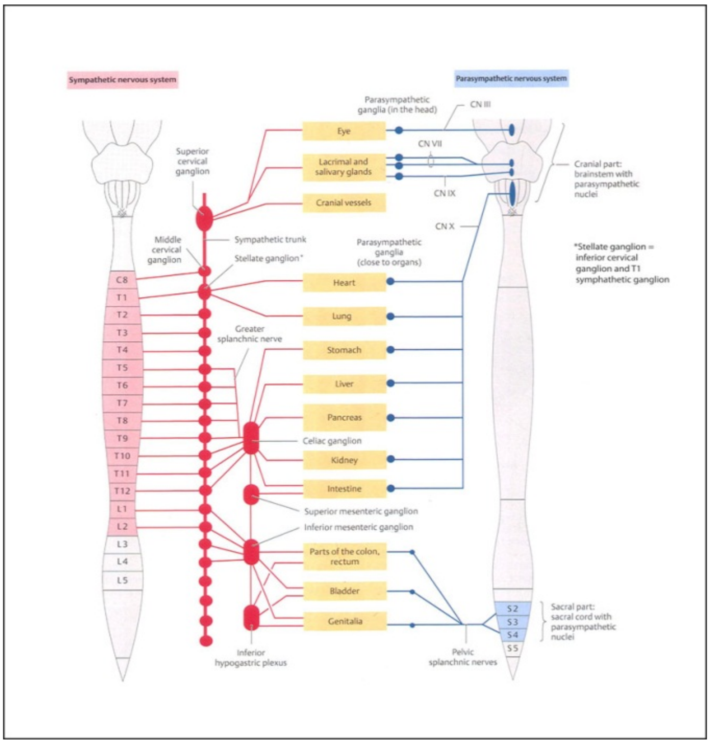


Figure 20b: Illustrator unknown, *Sympathetic and parasympathetic nervous systems, organisation.* Computer-generated.
(Schuenke, Schulte, Schumacher, Ross, Lamperti & Taub 2007:316).

3.2.9 *Size and depth*

Size and depth are considered equally important design elements in a composition, as the delineation of depth is determined by the placement and size of objects. The Free Dictionary by Farlex (2011:[sp]) describes the perception of depth as the ability to judge relative distances of objects in space and to orientate one's position in relation to them. According to Evans *et al* (2008:24) size refers to the physical dimensions of an object or format and the size of an object needs to be determined within the overall context of the design objective. Medical atlases, textbooks and study guides function as determinants of the overall size of illustrations. Therefore, planning the size of medical illustrations within the format boundaries is vital to communicate the appropriate message.

The organisation of anatomical structures in two-dimensional illustrations to show dimensions in different sizes and angles is important, because it influences the objects' perceived depth in relation to its size. During cadaver dissection, longitudinal[19] and cross sections[20] are made to view inner bodily structures on different levels. Medical students are able to physically rotate anatomical structures to view different angles and inner features. However, when cadaver dissections are demonstrated two-dimensionally, readers need to mentally rotate structures to visualise and understand various angles and features. The angles of cross sections of anatomical structures are important when trying to demonstrate inner features. Duff (in Krull *et al* 2006:194) believes angles or three-quarter views of objects may lead to distortion of dimensions. Demonstrating anatomical structures from various angles is important for readers to understand bodily appearance and functions in relation to each other.

The following two illustrations in Figures 21a-b show different applications of cross sections of the lower limb to explain relations between the sections and the actual size of the leg. Different drawing styles are applied in both examples, as well as various applications of media. The cross section of the thigh in Figure 21a is portrayed at an angle and is enlarged in relation to the smaller picture. The latter is used to show the location of the cross section in the leg. In Figure 21b the cross sections are placed in line with their approximate location in the leg. Size and depth are selected for this study as they play an important role to emphasise anatomical structures from various angles to enhance understanding and spatial visualisation.

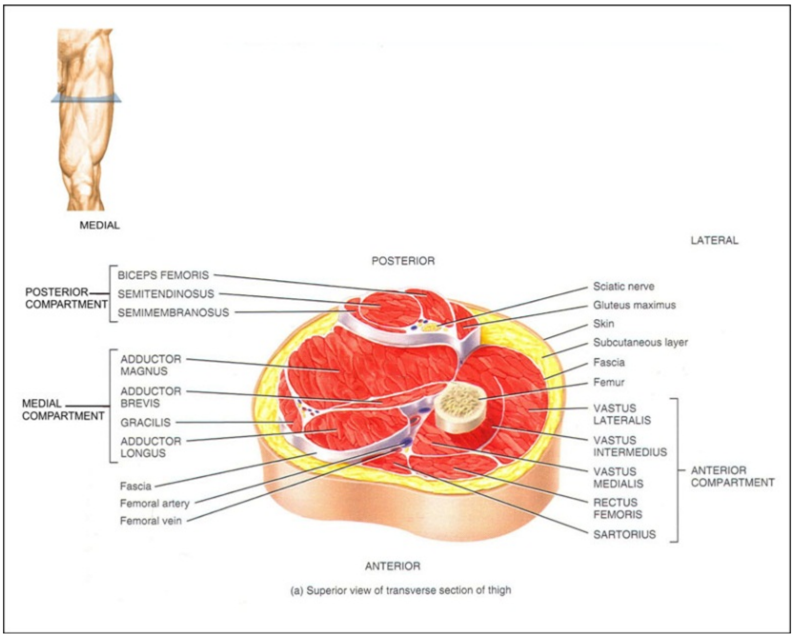


Figure 21a: Illustrator unknown,
Superior view of transverse section of thigh. Computer-generated.
Adopted from (Tortora & Nielsen 2009:307).

[19] Longitudinal sections run lengthwise or parallel to the long axis of the body or any form of its parts (Moore *et al* 2006:6).
[20] Cross sections are slices of the body or its parts, cut at right angles to the longitudinal axis of the body or any of its parts (Moore *et al* 2006:6).

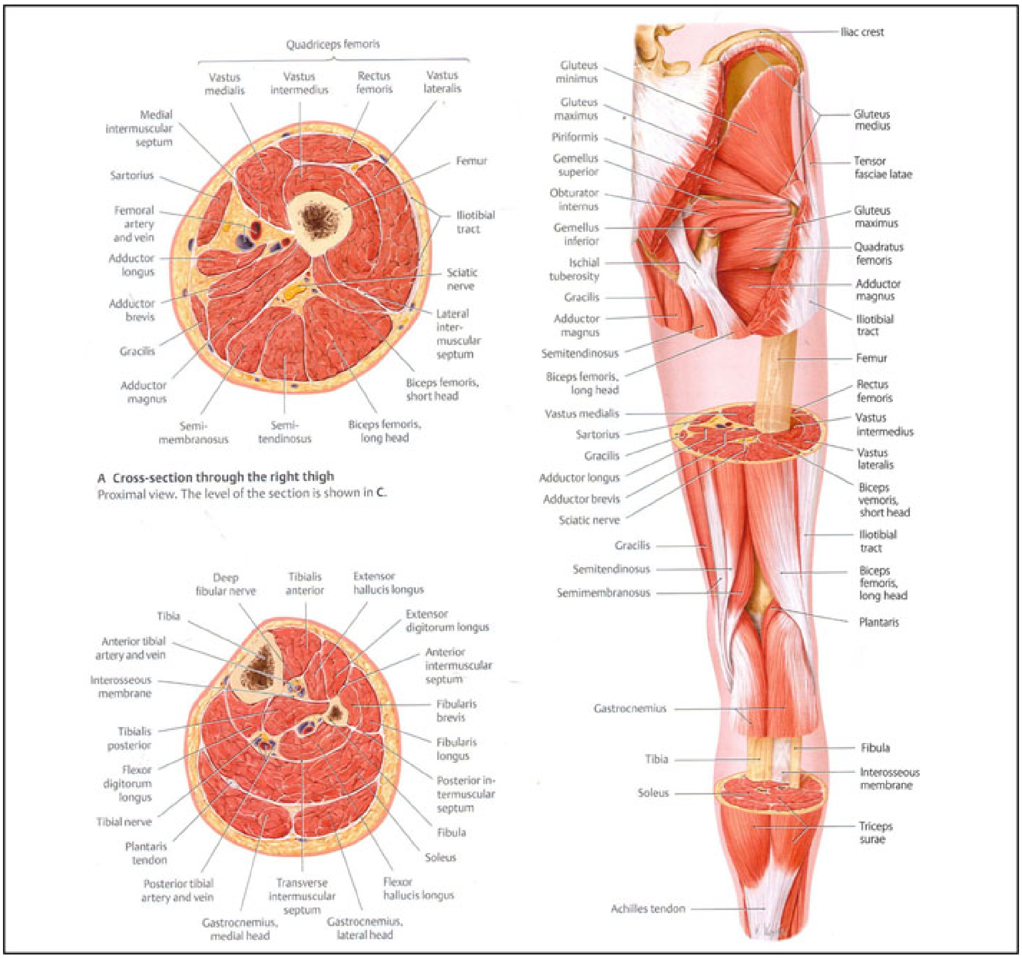


Figure 21b: Illustrator unknown,
Cross-sectional anatomy of the thigh and leg.
Computer-generated.
(Schuenke, Schulte, Schumacher, Ross & Lamperti 2006:462).

The application of design elements in medical illustrations enhances structure, dimension and shape of anatomical structures depicted, especially with the use of vibrant lines, textures and colour. These elements enhance realistic appearances of anatomical structures or contribute to the simplification of complex anatomical features and eliminate unimportant areas for better understanding. The way design elements are combined and structured in a composition is crucial for the enhancement and support of a message necessary to be communicated to readers, especially during learning.

3.3 Design principles

Design principles provide structure for the combination of design elements in a composition by serving as the affiliation between elements involved (Evans *et al* 2008:2). To ensure a balanced and structured composition, design principles are the foundation for the arrangement and combination of design elements to promote better understanding.

The following design principles are discussed and demonstrated with various medical illustrations: unity and variety, hierarchy and dominance, balance, proximity and repetition, and movement. One of the objectives of this study is to determine how the application of these principles in medical illustrations may have an influence on readers' learning.

3.3.1 *Unity and variety*

Unity and variety are discussed in relation to each other, as they provide dynamic balance in a composition. White (2002:57) considers unity to be the most important aspect of design. According to White (2002:51) and Evans *et al* (2008:3-4) unity contributes to the organisation of all visual parts into a unified whole for better understanding. Furthermore, Evans *et al* (2008:3-4) state that variety is essential to create visual interest and to balance contrasts. Stewart (2002:3-2) however, emphasises that the mind can absorb only a limited number of incongruent units within an illustration. Planning and construction of a variety of elements in a complex and detailed illustration are important, especially when it is created for learning purposes.

Medical illustrations often consist of complex and detailed illustrations to show a process or structure. The combination and organisation of the anatomical elements are necessary to form unity for better understanding. According to Stewart (2002:3-2) an image composed of units unrelated in size, style, orientation and colour will appear incomplete and unresolved. The following illustrations in Figures 22a-b demonstrate the course of the fifth cranial nerve in the face, namely the trigeminal nerve (CNV) and are shown with different, though related applications of shape and colour.

Similar tones of pink are shown in Figure 22a and applied in the four different faces to create unity. The depiction of the brain on the left is enlarged, although soft and dark tones of pink visible in the brain form a balanced composition in relation to the rest of the structures. The yellow lines represent the course of the trigeminal nerve by combining all the shapes to form a well-balanced composition.

Netter's *Trigeminal nerve* (Figure 22b) shows three different colours on the left of the illustration to demonstrate the different locations of the trigeminal nerve in the face. Although various colours are used in this illustration, soft tonal values are applied throughout the presentation to emphasise unity. The three colours on the left of the illustration flow around the face although created in a different colour to form a unified whole. Unity and variety are selected for this study as they play a vital role in the construction and organising of design elements such as colour, line and shape into a whole to create better understanding.

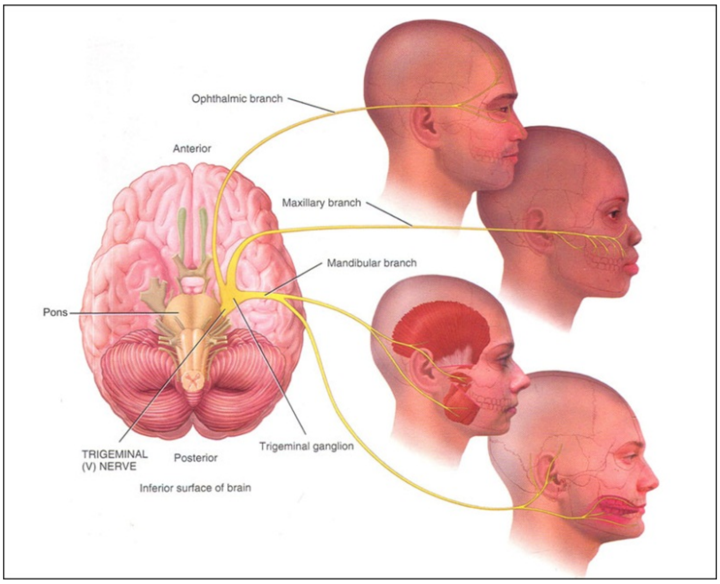


Figure 22a: Illustrator unknown, *Trigeminal nerve*
Computer-generated.
(Tortora *et al* 2009:643).

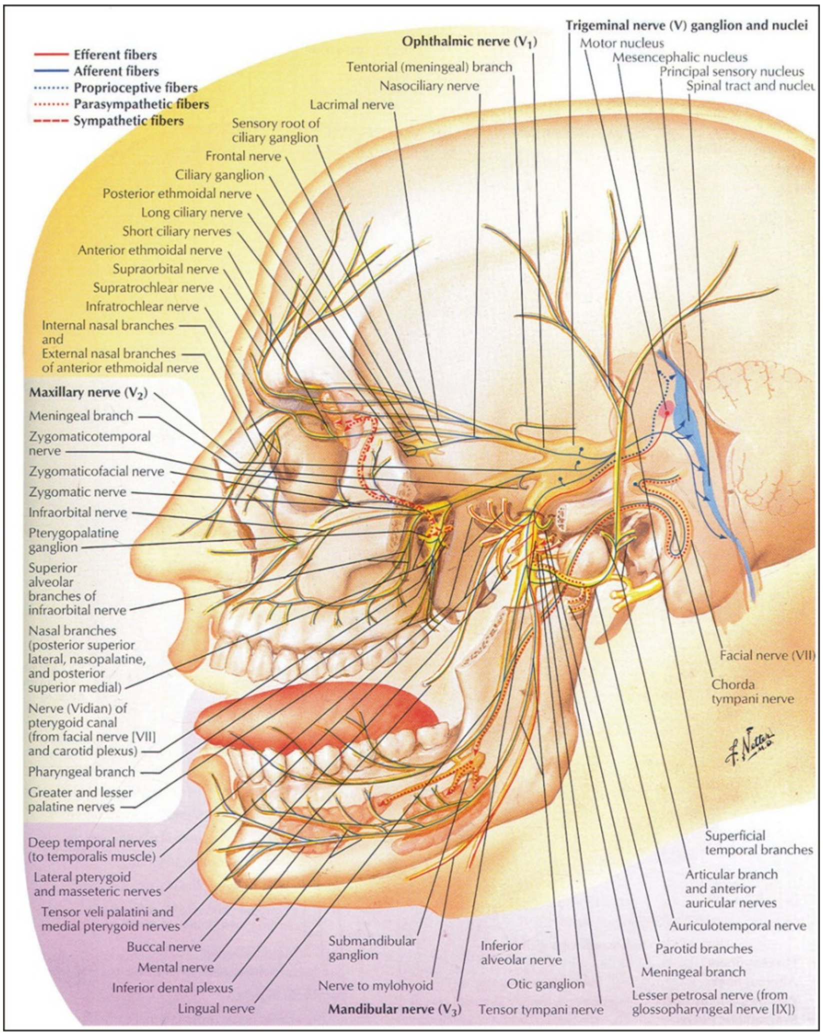


Figure 22b: Frank Netter, *Trigeminal nerve*
Mixed media.
(Netter 2011:121).

3.3.2 *Hierarchy and dominance*

Hierarchy refers to the level of emphasis ranging from dominant to subsidiary objects in an illustration. Dominance is the influence one element has over another to establish a function of hierarchy (Evans *et al* 2008:5). White (2002:63) explains that dominance in a composition is evident when there is contrast in the position, size, colour and style used in different elements. When a process or action is demonstrated, designers and illustrators need to place objects in a dominant order for readers to follow and subtract meaning, especially during learning. According to White (2002:2) the guidance of the reader in non-traditional directions requires greater accord between elements and the focal point of the illustration must be extremely clear.

In medical illustrations the application of hierarchy and dominance is vital when a complex process is demonstrated. When certain objects in medical illustrations are dominant, it enhances the direction and flow of a process or action. The hierarchy of objects in medical illustrations must be demonstrated clearly, especially when viewed for the first time. Evans *et al* (2008:5) believe that hierarchy determines readers' eye paths from the scanning of information at first to focusing on certain detail. Hierarchy and dominance are important for medical illustrations, as certain complex medical procedures are necessary to be structured in a specific order for readers to follow and comprehend.

The following two illustrations in Figures 23a-b demonstrate the course of the taste pathways in different drawing styles with different applications of hierarchy and dominance. Various media applications are also evident in these two examples. Netter's *Taste pathways* (Figure 23a) shows distended and illuminated depictions of the brain and tongue to accentuate the process of the taste pathway. The use of saturated colours is also notable in Figure 23a.

The second illustration in Figure 23b provides a detailed depiction of a horizontal section of the brainstem to show the path of the nerves and nuclei. Although the illustrator emphasises the brainstem (enlarged figure on the right) with much detail and size, soft tones of colour are used for a balanced and structured composition. Hierarchy and dominance are selected for this study as they play an important role in illustrations to arrange and organise design elements in a specific order when a certain action or process is displayed.

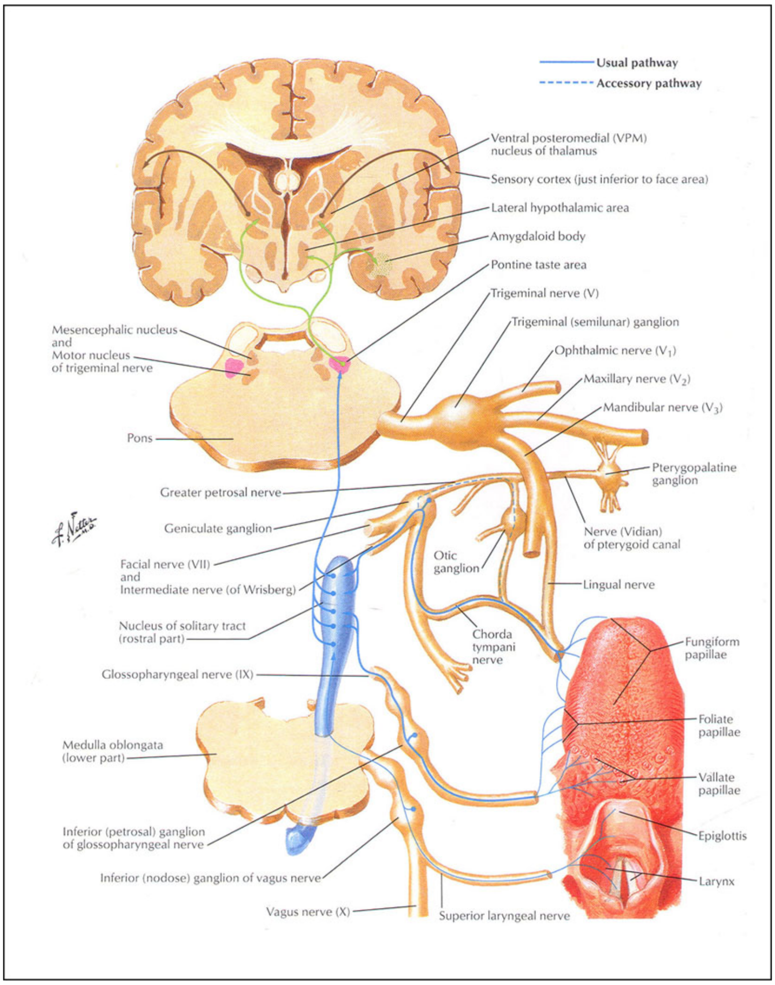


Figure 23a: Frank Netter, *Taste pathways*.
Mixed media.
(Netter 2011:134).

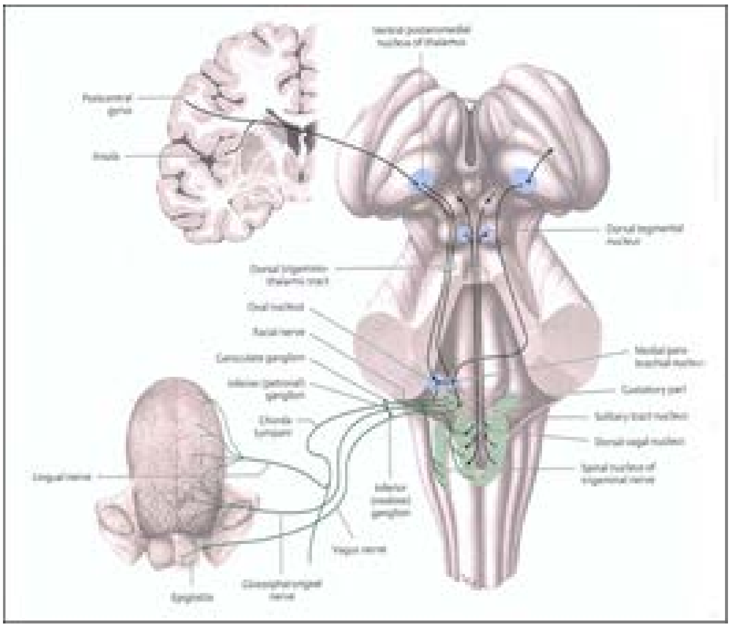


Figure 23b: Illustrator unknown,
Taste pathways. Computer-generated.
(Schuenke *et al* 2007:370).

3.3.3 *Balance*

Balance is the visual distribution of elements in an illustration (Evans *et al* 2008:8). The importance of balance is to provide unity (White 2002:65). Different forms of balance can be used in compositions such as symmetric, asymmetric and mosaic balance. The choice of balance depends on the nature of the atmosphere and expression designers and illustrators need to create. Symmetric balance is the arrangement of similar elements on either side of a central axis (Evans *et al* 2008:8). White (2002:65) considers symmetric balance as static, formal and constant.

Symmetric balance is usually applied in medical illustrations to show relations between different structures or to demonstrate various steps of a process. When symmetric balance is used in medical illustrations, the placement of structures on a page will form a straight line and the structures will be similar in size to show them all of equal importance.

Asymmetric balance on the other hand, refers to the dynamic process of balancing uneven elements (Evans *et al* 2008:8). White (2002:65) considers asymmetric balance as an evocation of feelings, forcefulness and vitality. When asymmetric balance is used in medical illustrations, different sizes of anatomical structures are shown on one page which are related in content. The enlarged structures can be regarded as an introduction to the rest of the structures.

Another form of balance mentioned by White (2002:65) is when too many elements are forced on a page which is called mosaic balance. This form of balance includes the structuring and overlapping of different elements on a page to which readers relate. Mosaic balance is not generally used in medical illustrations, as the overlapping of anatomical structures can cause important features to be obscured.

The illustrations in Figures 24a-b contain examples of asymmetrical and mosaic balance demonstrating the muscles of mastication in the head. These muscles are responsible for the movement of the jaw. The first illustration in Figure 24a is a depiction of asymmetrical balance with the top picture drawn larger to serve as introduction to the remaining images. Compositional balance between the figures and the amount of space is promoted. The following illustration in Figure 24b shows mosaic balance where as many elements as possible are forced onto one page to provide the reader with as much information as possible within limited space. Balance is selected for this study as this design principle plays an important role enabling viewers to focus on essential areas for better understanding.

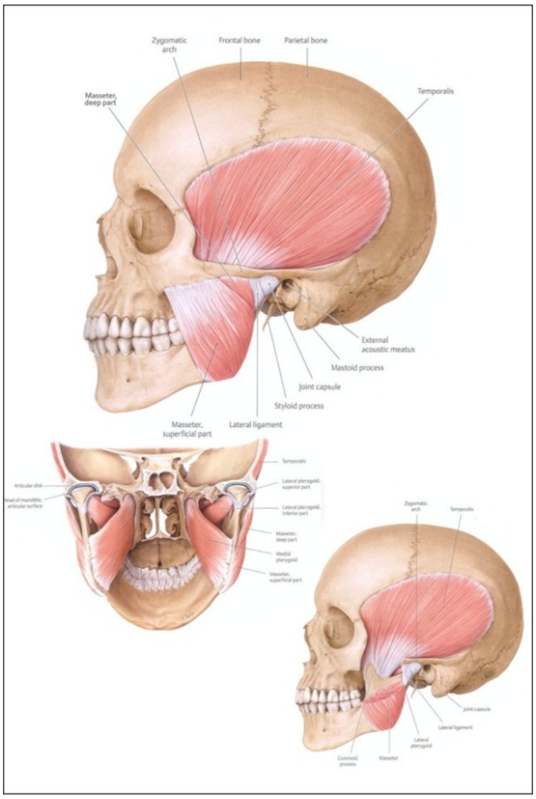


Figure 24a: Illustrator unknown, Muscles of mastication and superficial muscles demonstrating asymmetrical balance. Computer-generated. Adopted from (Schuenke *et al* 2006:49).

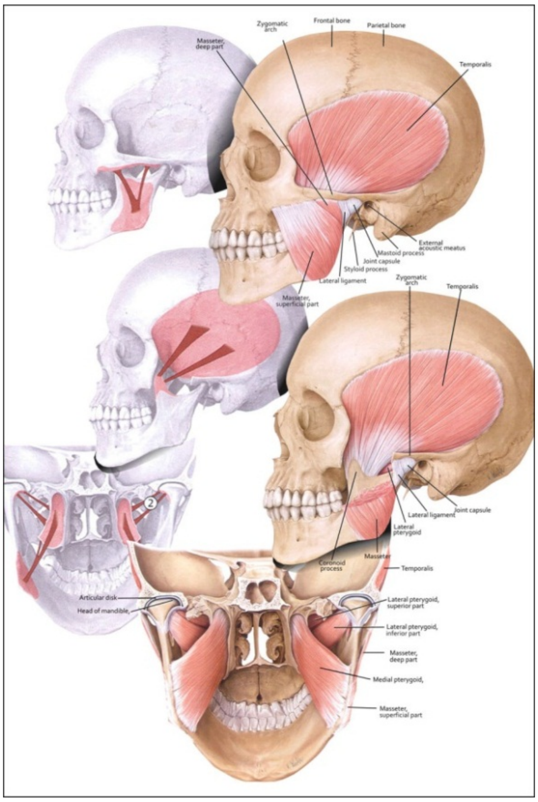


Figure 24b: Illustrator unknown, Muscles of mastication and superficial muscles demonstrating mosaic balance. Computer-generated. Adopted from (Schuenke *et al* 2006:49).

3.3.4 *Proximity and repetition*

Proximity and repetition are design principles that enable readers to focus on important aspects in a composition. Compositional rhythm, balance and flow are accentuated with the application of proximity and repetition, especially when a certain process or action is demonstrated. White (2002:59) describes proximity as relative nearness and considers it as the simplest way to achieve unity. Repetition on the other hand, is the similarity of elements such as position, colour, size or shapes. Proximity functions through either repetition (where related elements form a regular pattern or the placement of different elements in a certain pattern) (Evans *et al* 2008:14). Chang *et al* (2002:3) are of the opinion that readers automatically recognise objects closer together as related while no relation between objects further apart is evident.

In medical illustrations the closeness of objects in a pattern accentuated by proximity enables readers to view and understand objects as a whole, while repetition emphasises the flow and rhythm of the pattern, showing similar objects repeatedly in different positions. The illustrations in Figures 25a-b show the functions of the eye muscles in different patterns of movement. In the first depiction in Figure 25a each group of patterns contains objects that are similar in colour and size for the reader to make the relation.

Similar colours and pictures of eye and muscle movement are used to demonstrate various eye movements of a person's face. Netter's *Function of eye muscles* (Figure 25b) shows three different angles of the anatomy and function of the eye muscles, similar in colour and drawing style. Proximity and repetition are selected for this study as these design principles are important for readers to identify related and/or unrelated objects in a specific pattern to better understand a process or action.

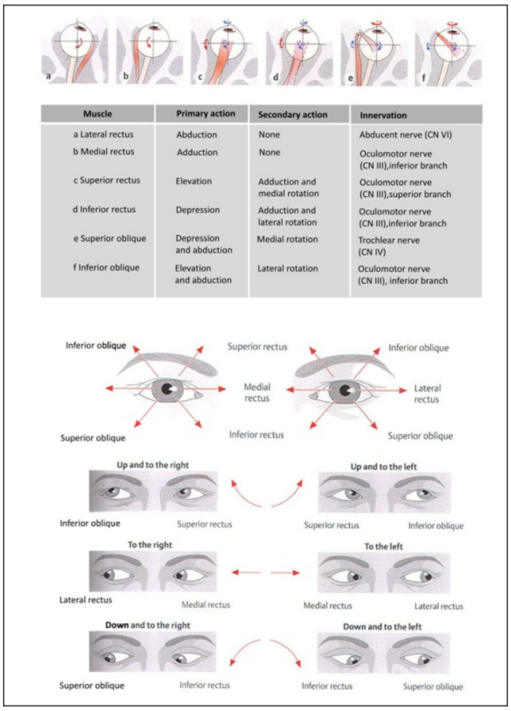


Figure 25a: Illustrator unknown,
Eye muscles.
Computer-generated.
(Schuenke *et al* 2007:135).

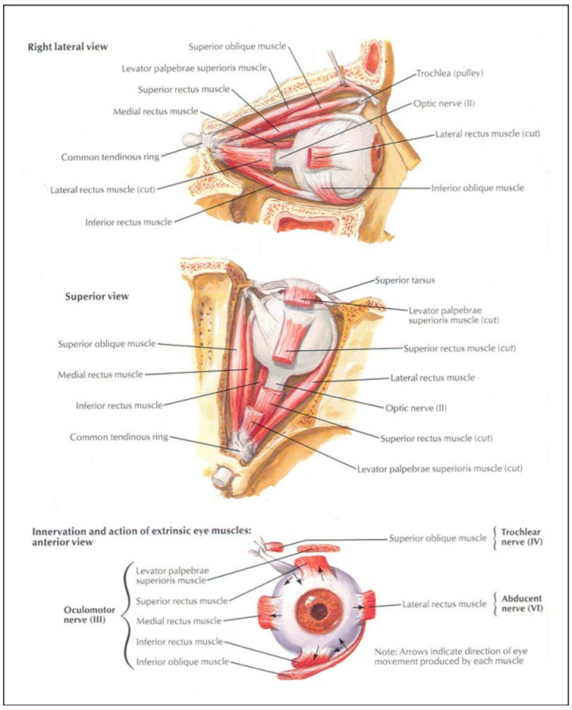


Figure 25b: Frank Netter,
Function of eye muscles.
Mixed media.
(Netter 2003:80).

3.3.5 *Movement*

Movement is a principle considered vital for use in different compositions, particularly where it is necessary to show the functionality of structures. In medical illustration movement is generally used to explain a complex process or action. Many studies have shown enhancement of readers' comprehension as well as their spatial abilities when they are exposed to three-dimensional animations demonstrating a certain procedure (Prinz, Bolz & Findl 2005). The study of Prinz *et al* (2005:1495-1499) shows that a three-dimensional animation demonstrating a surgical procedure of the eye, is better understood than a video of the similar procedure. Aspects such as arrows used in three-dimensional animations can help to enhance readers' comprehension when complex procedures are demonstrated. However, when showing such a complex surgical procedure two-dimensionally, the application of arrows might be understood incorrectly or they may even been ignored. According to Krull *et al* (2006:192) a straight horizontal arrow illustrated with a straight line and a shaft drawn against an object to suggest direction can easily be interpreted two-fold, either the action has not started or is already completed. In other instances, it is possible that readers do not recognise the application of arrows, as they rather focus on other cues for better understanding such as hand positions (Krull *et al* 2006:196). Readers understand illustrations demonstrating a certain action and supported by three-dimensional arrows better than illustrations containing two-dimensions or no arrows (Krull *et al* 2006:196).

The following illustrations in Figures 26a-b demonstrate the movement of the lateral rectus eye muscle shown with different attributes of two-dimensional arrows from various angles. The lateral rectus eye muscle is a structure that enables the eyes to move laterally (to the side). The arrow in Figure 26a is shown laterally (from the side) and is straight and enlarged to illustrate movement of the eye muscle. The following illustration in Figure 26b shows the movement of the eye muscle superior (from above) with finer and smaller, but bended arrows to demonstrate movement. Arrows play an important role in illustrations and are selected for this study to emphasise direction of movement of various anatomical actions or processes.

The application of design characteristics in medical illustrations is important, as they support the nature of the message being communicated. The combination and structuring of design characteristics in medical illustrations have to be planned with care, as they determine the nature of the message to be communicated. Fine attributes of design characteristics such as saturated or soft tones of colour, for instance, is important when creating anatomical structures, as they communicate important medical information. Tufte (1997:74) believes that the smallest effective differences applied to illustrations help to unveil the information necessary to be conveyed.

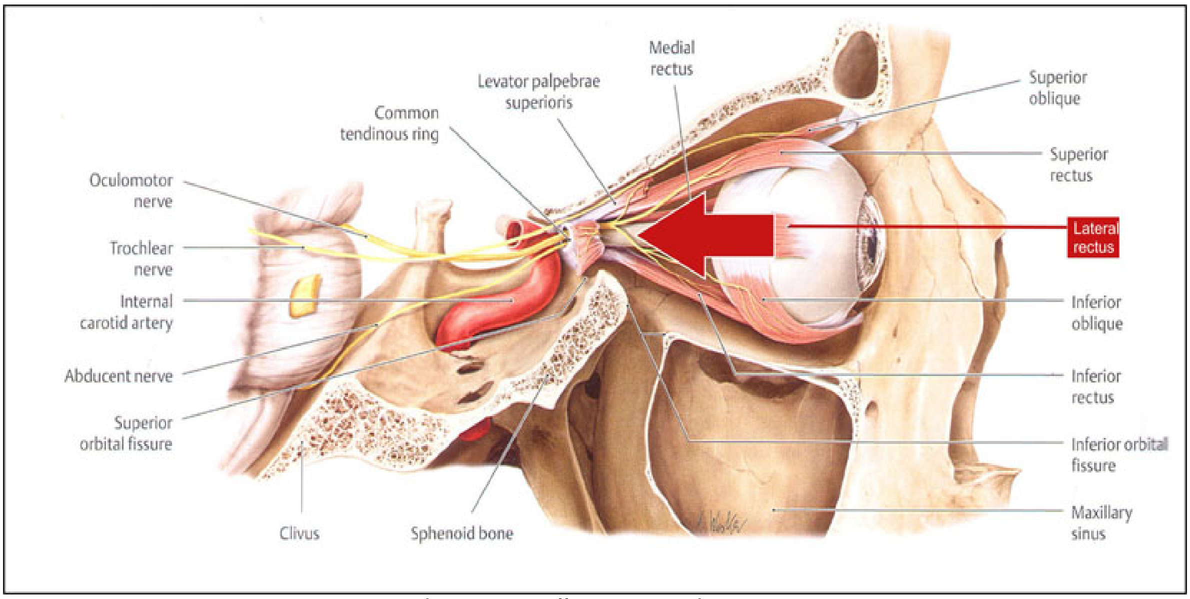


Figure 26a: Illustrator unknown,
Movement of the lateral rectus eye muscle accentuated with an arrow.
Computer-generated.
Adopted from (Schuenke *et al* 2007:134).

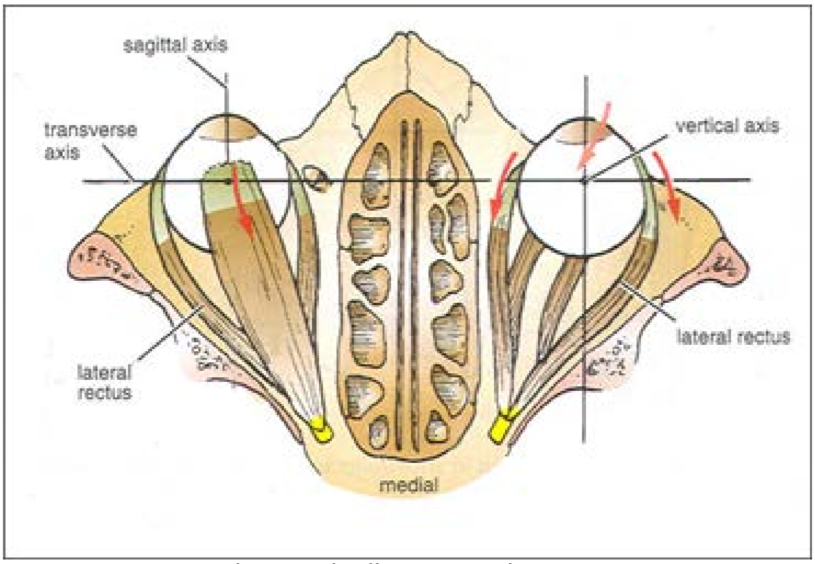


Figure 26b: Illustrator unknown,
Movement of the lateral rectus eye muscle.
Computer-generated.
(Snell 2007:667).

In Table 2 the list of the design characteristics explained above is provided, as well as their significance to readers' learning based on interpretations by selected scholars. This table illustrates the lack of research regarding the use of these design characteristics in medical illustrations and the influence they may have on readers' learning.

Design elements:	**Literature pertaining to how readers learn:**	**Sources consulted:**
Line:	***Actual line:*** Line illustrations can be misinterpreted because of abstraction of simplification. Line can simplify complex structures for better understanding. ***Implied line:*** Can easily be perceived as incomplete rather than visualised as a whole.	Andrews (2006) Cole *et al* (2009:28:1) Fisher et al (in Chang *et al* 2001:2)
Visual texture:	***Cross contours***: Can easily be perceived as "zebra stripes" appearing too far apart when used to show dimension and structure.	Andrews (2006)
Colour:	Effective to emulate important structures. Saturated colours in illustrations can influence readers' learning and cause fatigue. Students are able to recognise objects displayed in colours other than their	Tufte (1990:81) Daggett *et al* (2005:5) Hansen *et al* (2006:1368)

	original colour while still exposed to the objects' original colour. Different tones of colour applied on an object to show its angles and to emphasise depth can influence readers' spatial abilities. This can also happen when the same object's angles are displayed separately.	 Csillag (2009:135-136)
Shapes / space:	Simplistic or abstracted shapes of a real object will be recognised as the original version. Three-dimensional diagrams consisting of various shapes and colours are analysed and memorised more rapidly than two-dimensional diagrams.	DeCarlo *et al* (2010:175) Irani *et al* (2000:1)
Size / depth:	Angled views of objects may lead to distortion of dimensions, which may influence readers' sense of depth.	Duff (in Krull *et al* 2006:194)
Design principles:	**Literature pertaining to how readers learn:**	**Sources consulted:**
Unity and variety:	Incongruence of elements should be limited to aid understanding.	Stewart (2002:3-2)
Hierarchy/Dominance	***Hierarchy:*** Help readers to scan an object first before examining in detail.	 Evans *et al* (2008:5)
Balance:	None found	**-**
Proximity / Repetition	***Proximity:*** Objects close to each other are generally considered to relate to each other	 Chang *et al* (2002:3)
Movement:	Straight arrows can be comprehended two-fold. Readers sometimes focus on other visual cues than the arrows. Three-dimensional arrows are better understood than two-dimensional ones.	Krull *et al* (2006:192;196)

Table 2: A list of literature pertaining to readers' learning, applied to design characteristics relevant to this study, 2012.
Created by the author.

3.4 Labelling

Labelling is essential for the identification of different parts in an illustration (Ropinski, Praßni, Roters & Hinrichs 2007:203). Different techniques of labelling are generally used in medical illustrations to direct the readers' eye to descriptions of various features of anatomical structures. Lines, text or arrows are used as labelling techniques for medical illustrations to serve as visual connections for important structures. Ropinski *et al* (2007:203) differentiate between three different forms of labelling techniques generally used in medical textbooks and atlases, namely internal, external and hybrid. With internal labelling, the text is placed directly on the structures while external labels are placed outside the structure and connected with lines. Hybrid labelling is a combination of both (Ropinski *et al* 2007:203). The application of internal labels on anatomical structures has to be considered with care as important features can be obscured and in the process influence readers' spatial abilities negatively, especially when the anatomical structure conveys different levels of depth (Ropinski *et al* 2007:203). When external labels are used, Tufte (1997:74) feels that the label lines should be minimised in an illustration to illuminate important anatomical structures.

The selection of font and font size of the text as part of the labelling process has to be determined carefully, as labels have to be legible and congruent with the entire layout. The standard font sizes of text in anatomical and physiological atlases and textbooks vary between seven and ten points. The following illustrations in Figures 27a-b show different applications of labelling techniques: internal and external labelling demonstrating the facial nerve (CNVII). The first illustration in Figure 27a shows an example of internal labelling, demonstrating the labels being placed directly on each anatomical structure. Netters' *Facial Nerve (VII)* (Figure 27b) is an example of external labelling that contains fine label lines directing the readers' eye to each structure in the face. The fine label lines recede to illuminate important features of the face. Labelling is selected for this study as it influences the appearance and structure of medical illustrations and enhances direction and flow of information.

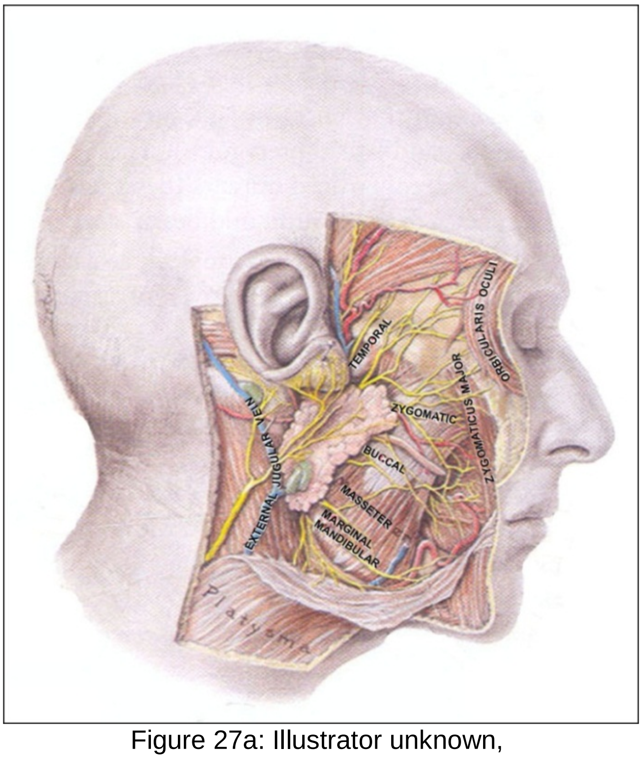


Figure 27a: Illustrator unknown,
Facial nerves. Computer-generated
Adopted from (Moore *et al* 2006:946).

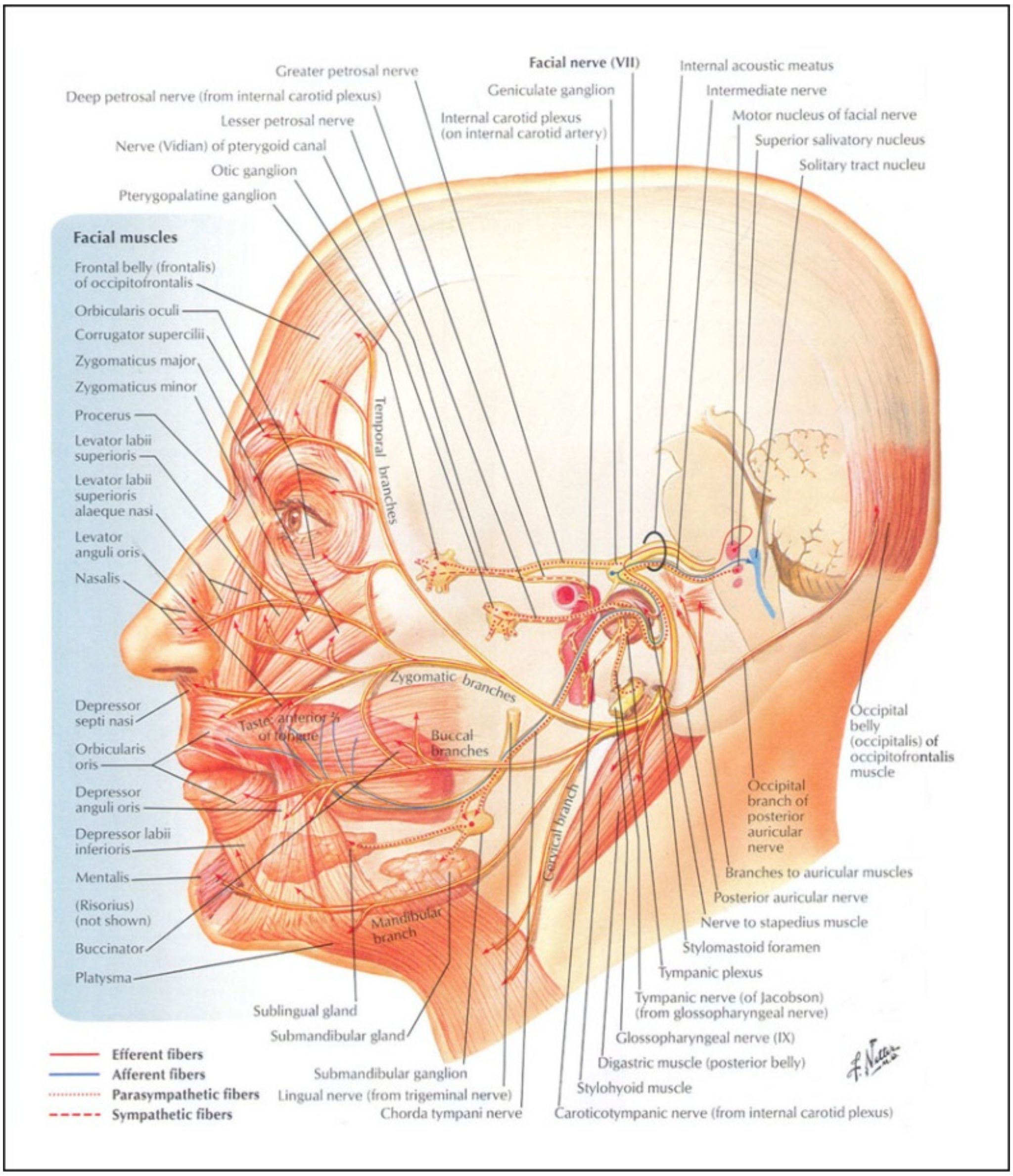


Figure 27b: Frank Netter, *Facial Nerve (VII)*.
Mixed media.
(Netter 2011:122).

3.5 Reproduction

The resolution of illustrations has to be considered carefully when displayed on the web or reproduced in a textbook or book as each of these formats requires different levels of reproduction quality. Resolution refers to the number of pixels in a given area of an image and is usually measured in dots per inch (dpi) or pixels per inch (ppi) (Understanding Image Resolution for Medical Illustration 2011:[sp]). Medical illustrations should also be reproduced in high quality for textbooks, atlases and study guides. The printing process of medical illustrations requires illustrations to have a resolution of around 300 dpi (Understanding Image Resolution for Medical Illustration 2011:[sp]). The resolution of images in medical atlases and textbooks has to be of a high quality to show detail and dimensions of anatomical structures. Due to high costs of colour printing, study guides are generally printed in black or photocopied at the SMFHS of UP.

The process of photocopying is cost-effective although poor quality of illustrations is engendered with this technique which may influence the perception of readers during learning. Medical illustrations on websites are used as additional reference to students' study material and provide recent information concerning certain aspects. In some instances, these electronic images have a low resolution which can be problematic for students as they have to examine them directly on screen or print them out on a small scale as the enlargement of the image would cause it to project mostly pixels.

The following illustrations in Figures 28a-b present different forms of reproduction qualities and a venogram[21] of the subclavian artery, maxillary and brachial veins in the shoulder is presented. The resolution of the first example in Figure 28a was reduced to illustrate the quality it would typically have on a website. Due to the low resolution of this copy, even the outline illustration on the right is not suitable for reproduction and readers are forced to examine it directly on screen or search for other examples.

The second set of images in Figure 28b is an example of a photocopy of the same venogram which demonstrates the reduction in quality when reproduced for study guides. Due to poor quality of this image, readers will have to depend on the line illustration on the right which provides a clearer version of what is shown in the venogram. The quality of reproduced medical illustrations is considered vital for this study, for these representations communicate detailed and complex information of great importance.

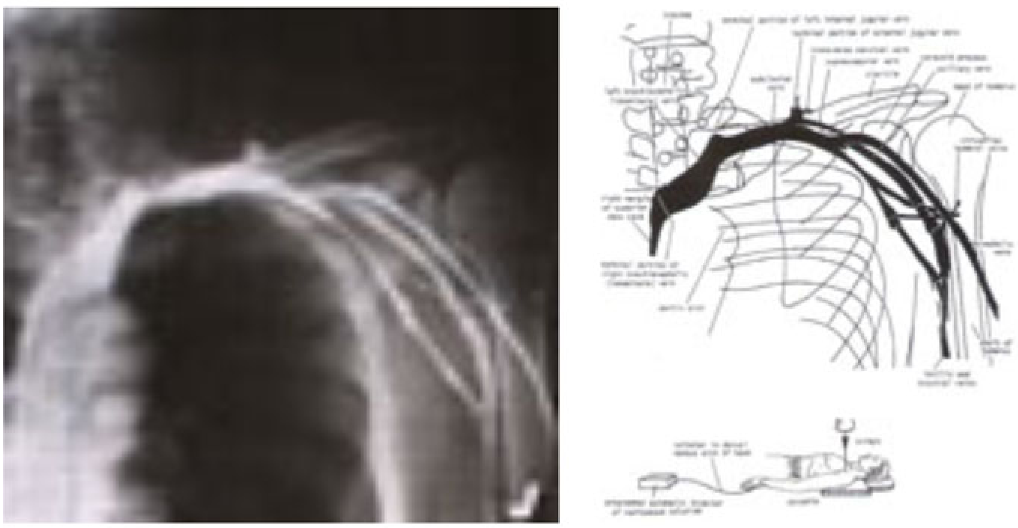


Figure 28a: Illustrator unknown, A venogram and line diagram of the subclavian artery, axillary and brachial veins in the shoulder demonstrating low quality resolution on screen.
Adopted from (Snell 2007:215-216).

[21] A venogram is a study used to evaluate the veins in a particular area of the body where a contrast medium is injected into the veins and radiographs are made (Gurley *et al* 1996:124).

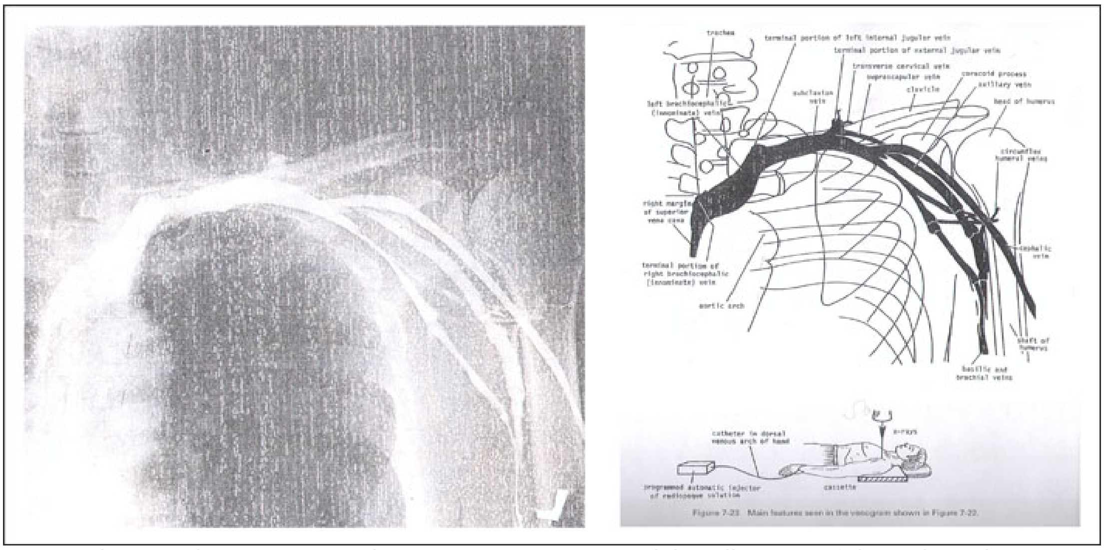


Figure 28b: Illustrator unknown, A venogram and line diagram of the subclavian artery, axillary and brachial veins in the shoulder demonstrating low quality resolution when photocopied.
Adopted from (Snell 2007:215-216).

3.6 CONCLUSION

In this chapter the importance of carefully planning the combination and application of design characteristics in medical illustrations, especially when used for learning purposes, are explained. Design elements in medical illustrations determine the structure, dimension, aesthetic quality, appearance and functionality of anatomical structures for readers to identify and discriminate. Design principles, on the other hand, are necessary to structure and organise design elements into a unified whole to enhance comprehension, especially when complex anatomical and physiological processes are perceived.

Besides the careful planning and combination of design characteristics in medical illustration, the selection of media is also vital when creating anatomical structures, as various aesthetic effects create different meaning. Decisions whether to create a medical structure in colour, black and white, with ink or on computer, depend on the amount of detail, structure and dimensions necessary to demonstrate.

Illustrators and designers also have to consider the format of labelling methods in medical illustration, as well as the quality of reproduction techniques for study guides and textbooks to enhance learning processes. Labelling methods enable readers to identify various anatomical structures while decisions about the reproduction of medical study material are important to ensure high quality standards.

In order for designers and illustrators to reach these goals, adequate information regarding medical students' learning strategies, medical knowledge and experiences are vital to determine the nature of the application of design characteristics, labelling and reproduction of medical illustrations. Close collaboration amongst educators, fellow designers and illustrators are also crucial for the designing of medical visual material that is adequate for the development of medical education.

The following chapter provides a brief description of this study's epistemological approach followed by an exposition of the methodology. A layout of the structure for data analysis is provided, as well as the discussion guide for fieldwork.

4. CHAPTER 4

4.1 Epistemological approach and methodology

Chapter two provided an overview of the role the medical illustrator plays in the fields of medical education, technology and research. Chapter three offered a comprehensive summary of the description, combination and relevance of design characteristics in medical illustrations. Before embarking on the discovery of how the application and organisation of these design characteristics in medical illustrations are perceived and comprehended by readers for learning purposes, the epistemological approach and salient methodology of this study are discussed.

Constructivism is the epistemological approach used in this study as it focuses on new knowledge constructed by readers from previous experiences. The main principles of constructivism, as well as its implications on the methodology employed in this study are discussed.

4.2 Constructivism as an epistemological approach

It is necessary to define the epistemological approach of this study as it underlines the direction of the research methodology. Epistemology is a branch of philosophy that deals with the basic questions of what constitutes knowledge, and the question of how knowledge can be discovered or studied. Constructivism as epistemological approach has a natural fit with this study because its main purpose is that individuals construct their own version of reality during learning. According to Nahid Golafshani (2003:604) constructivism endorses multiple realities of people and processes and promotes numerous methods of gathering data to ensure validity and reliability of research. The following main principles inherent to constructivism are discussed, namely against an objective truth, co-construction of meaning and research bias.

4.2.1 *Against an objective truth*

In contrast to objectivism (another epistemological approach) constructivism does not constitute an objective truth, but rather emphasises the way knowledge and truth are constructed by the reader. Knowledge, through a constructivist approach, is socially constructed based on readers' understandings, interactions and interpretations of meaningful realities and is therefore dynamic as it may change depending on circumstances (Golafshani 2003:603-604). It is this principle that makes constructivism a suitable epistemological approach for this study. An illustrator creates content with specific objectives in mind but the medical student who uses the illustration constructs meaning from his/her own context.

4.2.2 *Co-construction of meaning*

Within a constructivist framework, emphasis is placed on the role of the reader. According to Lefoe (1998:454) learning from a constructivist approach is the active process of constructing rather than acquiring knowledge. New knowledge is constructed by the reader when visual stimuli unfamiliar or new to him/her are observed. When encountering this new information, the reader constructs knowledge by comparing the latest input with existing mental models to formulate necessary changes. The mental models of second-year medical students differ from those of fifth-year medical students because of the divergence in their experience levels. Fifth-year medical students are exposed to advanced clinical information and they engage with physicians and clinical assistants on a regular basis, compared to their second-year counterparts. Constructivists argue that knowledge is both individually constructed and socially co-constructed from interactions and experiences with the world (Jonassen, Cernusca & Ionas 2007:46).

To promote co-construction of meaning within a constructivist epistemology, interaction is created in a more non-hierarchical relationship in order to tap into greater depths of mutual meaning making (Mills, Bonner & Francis 2006:10). The researcher is subordinate to the participant to a certain extent, but needs to assume a more reflective stance towards participants in order to initiate deeper conversation and opinion (Mills *et al* 2006:10). Therefore, the researcher reflects upon own opinions as well as those of the participants and encourages them to elaborate on various aspects they are familiar and less familiar with for mutual understanding.

4.2.3 *Researcher bias*

Within a constructivist framework research bias which is referred by Siau *et al* (2010:565) as the researcher's own frame of reference and worldview is acknowledged to generate a platform for deeper knowledge development. The researcher uses own experiences and knowledge to build on new meanings generated by participants. Participants, on the other hand, are encouraged to think and communicate more visually to obtain deeper understanding regarding aspects such as their learning styles, drawing abilities and how they use multimedia sources as part of learning. According to Mills *et al* (2006:10) researchers need to be cognisant of adopting a non-judgmental stance toward the participants and resist the urge to assign values to participants' responses. Engaging with participants within a constructivist enquiry involves the questioning and elaboration of current personal and objective opinions to stimulate and build on new ideas.

4.3 The application of constructivist principles to the current study

Constructivism has shifted from attempts to communicate to students about the world in efficient ways, to attempts to create learning situations that promote the engagement of learners in fields of practice (Jonassen *et al* 2007:46;47). The rapid development of digital technology makes it possible for students to obtain knowledge and engage in new ways of thinking and collaborating with fellow students and educators. Within this dynamic digital environment, technology and information play a dominant role and more focus is placed on "learning to learn" or "know how" rather than memorising explicit knowledge and facts ("know what") (McLoughlin *et al* 2008:643). Students are finding new ways to contribute, communicate and collaborate, using a variety of accessible tools that empower them to develop and share ideas (McLoughlin *et al* 2008:645). Internet sites such as YouTube and MySpace make it possible for readers to produce and consume ideas, facts and knowledge (McLoughlin *et al* 2008:645). YouTube, for instance, contains various examples of animations or video of surgical procedures valuable to improve understanding and learning. From a constructivist epistemological approach, these technologies, together with other sources such as textbooks, atlases and the web-based educational system at UP known as ClickUP (explained in Chapter two), create a platform for different ways of learning.

Illustrators and designers use these forms of multimedia to create dynamic visual materials from complex medical procedures and processes for learning and teaching purposes. Eilks *et al* (2009:146) are of the opinion that students will construct new ideas from what is seen on screen together with what they already know from previous experiences, but doubt whether break-through animations and illustrations will support the learning of complex scientific processes. Therefore, it is essential for illustrators and designers to reflect on the creation of their illustrations for learning purposes, in order to determine the way they are used and understood. Engaging in constructivist enquiry requires a transformation of the opinions, values, knowledge and experiences of illustrators and students in order to co-construct new meaning and knowledge.

4.4 Research methods

Exploratory qualitative research was selected as methodology for this study because it lends itself to the application of all the main principles of constructivism as discussed above. Qualitative research is a structured, open-ended research environment that allows new information to come to light and therefore does not assume the existence of an objective reality or single truth.

Similar to constructivism, qualitative research emphasises the unique background of each research participant and allows these backgrounds to bring new levels of depth to their interpretation of the lived reality being studied. It also uses, rather than excludes, research biases in the creation of meaning. Therefore, this study adopts a constructivist approach to grounded theory as explained in Chapter one. Within the framework of constructivism an interpretive tradition is followed as the researcher reflects on the research process, products as well as own interpretations and those of the research participants (Charmaz 2006:130-131).

Data were collected by means of semi-structured in-depth interviews and open-ended questions were asked to explore participants' opinions and views of medical illustrations as a learning tool. Based on the principles of grounded theory, as explained in Chapter one, data were then systematised and analysed and incorporated with the RGI method (described in Chapter one). The first phase of the research methodology was the recruitment of participants and sample selection which formed the foundation for further investigation.

4.4.1 *Recruitment of participants*

Potential participants were selected from class lists obtained from the anatomy department. Demographic information such as gender and ethnicity was available from the class lists. Possible relations between students' demographic information and their preferences for learning were extraneous to this study but care was taken to ensure a good spread of genders and ethnicities. Participants were contacted telephonically and asked whether they would be willing to participate in the study. Potential participants were then asked whether they experienced any form of colour blindness. Colour blindness was not an exclusion criteria but the researcher wanted to be aware if any participant was colour blind since it has been found to influence perception of red and green or other colour pairs, rendering them indistinguishable (Daggett *et al* 2008:4). No participant selected for this study experienced colour blindness.

4.4.2 *Sampling*

Purposive sampling was used as this enabled the researcher to select participants who met the inclusion criteria. As explained in Chapter one inclusion criteria determine that second- and fifth-year medical students must be from the SMFHS at UP, willing and available to participate in this study. A small group of participants were selected because the qualitative methodology emphasises depth (detailed exploration) rather than breadth (large number of participants) of enquiry. Six medical students in their second year and six in their fifth year of study at the SMFHS of UP were selected during the second semester of the medical curriculum. With the elevation of the second semester, second-year medical students had already been exposed to cadaver dissections, while fifth-year medical students already commenced with clinical rotations in government hospitals. The reason for selecting junior and senior students was to be able to compare how second-year students with limited medical knowledge experience illustrations as a learning tool, compared to fifth-year students with advanced medical and clinical knowledge.

4.4.3 *Data collection*

Data were collected by means of semi-structured in-depth interviews with individual medical students. Semi-structured interviews are commonly used to substantiate data emergent from other data sources and usually require the participant to answer a set of predetermined questions (Maree 2007:87). The interview guide (Appendix A) was set up containing a list of questions and illustrations designed to guide the interview process in a focused, albeit flexible and conversational manner. Open-ended questions were asked to each participant as set out in the interview guide and were effective for eliciting depth of information. Open-ended questions were used in the interview guide to prompt students to elaborate on their opinions instead of answering only 'yes' or 'no'. According to Mills *et al* (2006:10) it is important to maintain a flexible and unstructured approach to questioning so that participants assume more power over the direction of the conversation and sharing the researcher's understanding of key issues. This approach also ensures students' co-construction of meaning. Second-year and fifth-year students were prompted to elaborate on aspects they are familiar with as well as those which are unknown to them. Interview sessions were scheduled at a time of the participants' choice. At the beginning of the interview the researcher introduced the objective of the study to the participant and explained the structure of the interview. A consent form was handed over to the participant to be read through and signed if he/she agreed to participate in the study. The participant's permission was then asked to audio tape the duration of the interview. After permission was granted, the interview proceeded. Interviews with participants were conducted in the researcher's office in the form of an informal conversation. The duration of interviews with each participant was approximately an hour.

Fourteen sets of medical illustrations formed part of the interview guide; with three or four illustrations per set (Appendix A). The first 13 sets of illustrations consisted of the representation of a design characteristic selected for this study. Illustrations in each set contained a different application of the same design characteristic, but similar in content or nature of information. Examples of the illustrations were based on Anatomy and Physiology as these disciplines form the foundation of medical training.

Most of the illustrations originated from the list of prescribed anatomical and physiology textbooks and atlases recommended to second- to fourth-year medical students. The collection of examples also included various anatomical and physiology textbooks and atlases available in the UP pre-clinical medical library. Several examples were the researcher's own illustrations. These illustrations were also selected based on seminal scholars' perspectives regarding design elements and principles. Two animations were created by the researcher in Adobe Flash CS5 which formed part of the last set of illustrations and were displayed after all static illustrations were shown. The animations were displayed in ShockWave Flash (swf) format and were played several times on request as they consisted of only 20 frames per second. The last two sets of illustrations represented different applications of labelling in medical illustrations and various examples of reproduction of illustrations as appearing in study guides respectively.

The RGI technique of preference and comparison was used to discover participants' opinions of medical illustrations as a learning tool from a constructivist approach. The RGI technique as explained in Chapter one, is a method of organising and comparing rich data during a structured, reflective process where participants individually provide their own understandings of a specific concept. This is in line with constructivist principles of co-constructed meaning. Within the constructivist framework, research bias is acknowledged with the use of the RGI technique, as the researcher uses his/her own experiences and knowledge as an illustrator to build on new ideas and create meaning. The RGI technique contains three major components, namely elements, constructs and links (Fransella & Bannister in Siau *et al* 2010:566). Elements are the objects of attention in a scientific investigation which for this study are the medical illustrations, while constructs refer to the participants' own interpretation or understanding of the elements (Siau *et al* 2010:566). During the interviews, each participant uncovered his/her own understanding or construct of each illustration. Linking, as the third component of the RGI technique, shows how the participants interpret and link elements relative to each construct (Siau *et al* 2010:566). For this study, linking elements to constructs served no purpose as the researcher was primarily interested in the participants' formulation of constructs from elements, according to their categorisation of preference for learning.

In contrast to the studies of Siau *et al* (2010) and Alexander *et al* (2010) where participants were asked to select a pool of elements, the researcher provided the list of elements or illustrations for this study. The same collection of illustrations was used for all participants. This study adopted an adaptation of the triadic sort method[22] as a construct elicitation technique. During the interviews, the researcher displayed one set of illustrations at a time and asked the participant to select an illustration he/she preferred to be the most suitable to learn from and understood the best. Each illustration was individually labelled with a code for instance D1 and B2 for the participant to refer to effortlessly and for the researcher to distinguish during analysis. After a selection of the first preference, the participant was asked to elaborate on his/her choice and to specifically state why it was better than the other examples. After the first selection was discussed, the researcher removed the illustration and requested the participant to select the illustration he/she regarded as second best to learn from untill the last illustration in the set was selected and discussed.

The researcher made notes in cases where an individual pointed at certain areas of an illustration which he/she found difficult to comprehend. With each set of illustrations, the researcher asked the question as set out in the interview guide for the participant to elaborate on at first. When it was necessary to obtain more information, the laddering technique was used. The researcher used laddering to delve deeper into participants' answers by asking 'how' and 'why' questions (Siau *et al* 2010:567). In the process this technique enabled the researcher to obtain deeper understanding of students' interpretations or constructs of the illustrations and other aspects such as learning styles and their drawing abilities during learning. In certain instances, it was necessary for the researcher to prompt participants to think why they liked the use of colour in a specific anatomical structure, for instance, and how this application contributed to their understanding. This information contributed to deeper understanding regarding participants' preferences for certain drawing styles of medical illustrations, their own drawing abilities as well as the type of media they used when creating these drawings during learning.

[22] The triadic sort method is when three elements (a triad) are randomly selected from a set where the research participant is asked to identify a way in which two elements are similar yet different from the third element (Siau *et al* 2010:566).

Nonverbal communication such as facial expressions and hand gestures is also an important aspect for gaining a deeper shared meaning (Onwuegbuzie, Leech & Collins 2010:699). During the interviews several participants used hand gestures to refer to certain areas on illustrations which they pointed out as essential or problematic. Facial expressions were used at times when there was uncertainty. A laugh or sigh was also an indication of an illustration participants found difficult to learn from or it was an indication of difficulty when expressing themselves. A pause or the use of 'uhm' before providing an answer was also an indication of uncertainty or an attempt to conceptualise the images been observed. The point of redundancy was reached within a set of illustrations when the participant could not formulate any additional comments regarding an illustration. The researcher then moved to the following set.

To conclude each interview, additional questions were asked regarding students' access to the internet, and their use of the internet and ClickUP for learning. Other questions such as their use of additional sources besides prescribed material and a general description of how medical illustrations are learned were asked. These questions provided additional information regarding participants' learning styles and how the internet and other sources are integrated during learning.

4.4.4 *Transcribing*

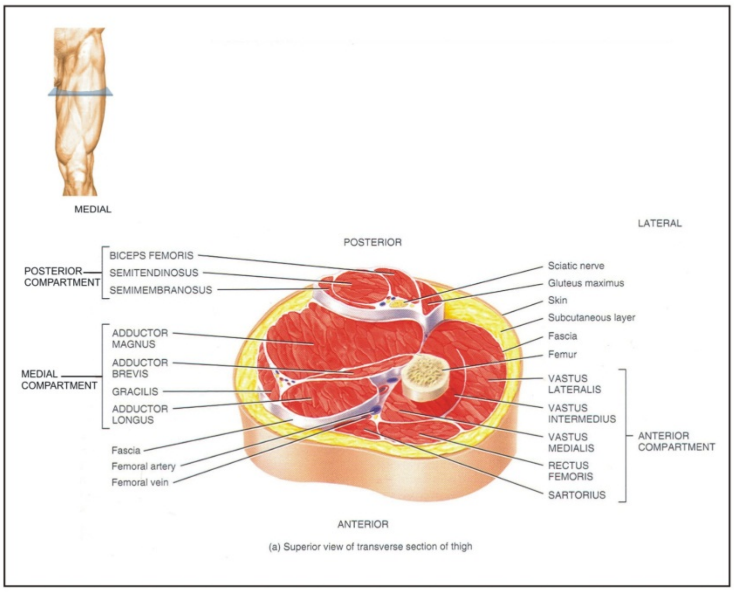
Data were transcribed by the researcher verbatim and organised following the principles of grounded theory. The format of the data sheets is an adaptation of the RGI method. The RGI method accepts a constructivist approach as it is a concrete framework drawn up around interpretations and understandings emerging from in-depth interviews for the researcher to analyse and identify comparisons and variations within the data (Butt & Burr 2009:[sp]). During the formulation of data sheets, perspectives, experiences and knowledge of the researcher as a medical illustrator were included and conceptualised with participants' opinions regarding illustrations as a learning tool. The researcher decided to transcribe responses of participants herself as students used anatomical terminology in certain instances which may be difficult for a transcriber working outside the scope of medicine.

4.4.5. *Coding of data*

The data sheets for coding were adopted from the RGI method. The data sheets are in table format and divided into several columns depending on the number of illustrations per set. Each data set contains a list of categories of preferences divided over each column vertically while the ranking of participants' opinions within these preferences are spread horizontally (Appendix B). Open coding was used as first step of data analysis to break up and identify personal constructs formulated by second- and fifth-year students' regarding each illustration from the interview transcripts. Open coding is an analytical process through which data are broken down to identify their properties and dimensions in order to understand the logic behind the analysis (Strauss *et al* 1998:101).

Although different forms of open coding can be used such as line-by-line coding or to peruse the entire document, this study used a method of open coding by analysing a whole sentence or paragraph (Strauss *et al* 1998:120). The coding of whole sentences or paragraphs was necessary for this study in order to understand participants' opinions within the context of learning and how that coincides with the attributes of design characteristics.

The most prominent constructs formulated among both groups of participants were identified and captured from transcripts and documented on data sheets for further analysis. As previously mentioned constructs refer to participants' personal understandings of the illustrations (Siau *et al* (2010:566). In the example of Figure 29 personal constructs formulated by both groups of research participants with regard to the cross sections of the leg and thigh are demonstrated. The design characteristic relevant to this set is size and depth.



Second year student:	"The illustration contains enough spaces along the sides. The titled angle of the cross-section is understandable".	CLEAR
Fifth year student:	"The illustration provides context. raised areas in the cross-section helps to distinguish between areas.	CONTRAST

Figure 29: An example of the determination of constructs with reference to the cross section of the leg and thigh depicting size and depth as design characteristic.
Adopted from
(Tortora *et al* 2009:307).

Participants' descriptions or constructs were ranked from first to last category of preference on each data sheet representing a set of illustrations. These categories contain a scale from a high degree of success in demonstrating the relevant design element (labelled as "very positively demonstrates") to an inability to demonstrate the design element in question (labelled as "very negatively demonstrates").

In the example of Figure 30 the inferior base of the skull is used to show the placement of the list of participants' constructs according to category of preference. Visual texture with cross contour lines is the design characteristic relevant to this set. In the first category of preference the list of both groups of participants' constructs represents attributes of visual texture very positively from a learning as well as design perspective, as compared to the third category.

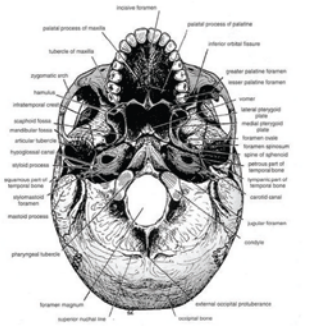
Inferior base of the skull - visual texture - cross-contour lines			
Illustration D9 	**Categories:** **First preference for use and comprehension during learning:** **Constructs:** <u>Very positively demonstrates:</u> structure/ depth/clarity/ distinction/ realism/ vibrancy/ detail/even contrasts	**Second preference for use and comprehension during learning:** <u>Relatively demonstrates:</u> structure/ depth/clarity/ distinction/ realism/ vibrancy/ detail/even contrasts	**Third preference for use and comprehension during learning:** <u>Very negatively demonstrates:</u> structure/ depth/clarity/ distinction/ realism/ vibrancy/ detail/even contrasts

Figure 30: An example showing the categorisation of preferences and constructs of the illustration showing the inferior base of the skull, 2012.
Created by the author.

Through axial coding additional opinions of participants were added on each data sheet and placed in the relevant categories. According to Strauss *et al* (1998:124) axial coding is the process of relating categories to their subcategories to form more precise and complete explanations about the topic under investigation. The codes allocated to each participant with the commencement of the interviews, for instance Resp# 1, were sustained to differentiate between possible comparisons and relations concerning opinions (Appendix B).

Axial coding allows the researcher to identify further comparisons and relations regarding participants' use, comprehension and preference of illustrations and how their selections coincide with the attributes and relevance of each design characteristic. Through axial coding relations between participants' learning styles were analysed within the context of their personal experiences, medical knowledge, as well as the relevance of each design characteristic. Participants' opinions were then further labelled positive (<u>*P*</u>), positive negative (<u>*P/N*</u>), negative positive (<u>*N/P*</u>) or negative (<u>*N*</u>) within each category of preference to differentiate between the nature of opinions. This form of labelling is necessary as the opinions of several participants regarding an illustration when selected first preference contain positive as well as negative orientations.

4.5 Conclusion

An epistemological approach underlines the nature of this study's methodology and provides guidelines for the analysis and conceptualisation of data during the research process. Constructivism as an epistemological approach accepts an interpretive stance during the research process as it focuses on the co-construction of new meaning derived from interpretations and perspectives from research participants, as well as the researcher regarding the topic studied. This study selected semi-structured in-depth interviews as research method which provided the platform for the collection of dynamic and/or new information within a constructivist framework. For this study research bias is vital within a constructivist position as experiences and knowledge of the researcher serve as platform to reflect upon new or well-meaning ideas formulated by participants.

This study adopts a constructivist approach to grounded theory where focus is placed on the topic studied and considers analysed data as creations of shared experiences and knowledge between research participants as well as the researcher. Grounded theory allows for the systematic analysis through open and axial coding in order to conceptualise new information and understand underlying conditions and circumstances which may contribute to the nature of categories and opinions been formulated. The RGI method is also in line with constructivist principles for it provides the framework to organise and structure individual opinions regarding the topic under study and determine necessary comparisons and relations for further analyses.

In the following chapter analysed data are discussed and interpreted with summarised colour charts. Preferences of illustrations by second- and fifth-year medical students during learning are demonstrated by these charts and brought into relation with the influence and attributes of design characteristics selected for this study. A tabulated comparison between findings from this study and the most pertinent literature set out in Chapter three is then provided to demonstrate the influence of design characteristics' in illustrations on South African second- and fifth-year medical students' learning strategies.

5. CHAPTER 5

5.1 Discussion and interpretation

Chapter four provided an inclusive summary of the exploratory qualitative research methodology of this study from a constructivist epistemological position. Constructivism has shown a natural fit for this study, because new and valuable data were structured and analysed based on multiple perspectives of second- and fifth-year medical students regarding illustrations as a learning tool.

In this chapter, the analysed data are discussed and interpreted in the form of summarised colour charts designed for each set of illustrations. All colour charts consist of two distinctive colours to differentiate between the two groups of students. Within every colour chart illustrations are categorised according to preferences for learning. The number of participants who selected an illustration, as well as students' opinions is presented with the following symbols: positive (+), positive-negative (±), negative (−) and negative-positive (∓) for each colour chart. As explained in Chapter four these symbols were used for analysis and indicate the orientation of participants' opinions within every category of preference because certain opinions vary from positive to negative remarks about an image.

This chapter concludes with a tabulated comparison between findings from this study and the most pertinent literature set out in Chapter three. This table summarises similarities and differences between findings from literature and those of this study to demonstrate the influence of design characteristics in illustrations on South African second- and fifth-year medical students' learning strategies.

5.2 The influence of design elements on medical students' learning

The design elements selected for this study are line, visual texture, shape and space as well as size and depth (refer to Table 1 in Chapter three). These elements were selected based on the perspectives of Stewart (2002) and Tufte (1990; 1997) who emphasise the way they provide structure, flow and definition to objects in a composition. A colour chart is drawn up for each set of illustrations representative of the selected design elements to demonstrate the order of preferences between the groups of students. The influence of the design elements on the use, comprehension and preferences of illustrations by medical students during learning are discussed below.

5.2.1 *Line*

As explained in Chapter three, line accentuates the inner and outer structures of objects and can project expression when applied in illustrations. Two aspects of line, actual and implied lines were selected to determine the influence they may have on students' preferences, use and comprehension of medical illustrations during learning. Actual lines outline dimensions of an object while implied lines are open for readers to mentally complete. The illustrations representing actual and implied lines were converted to greyscale so that students would not be distracted by colour.

5.2.2. *Actual lines*

Participants were shown four examples of the lymph drainage of the head and neck with actual lines as the design characteristic relevant to this set. They were asked to select the most suitable illustration from which to learn. The colour chart in Figure 31 demonstrates students' order of preferences of illustrations for learning purposes when perceiving various applications of actual lines visible in the images below.

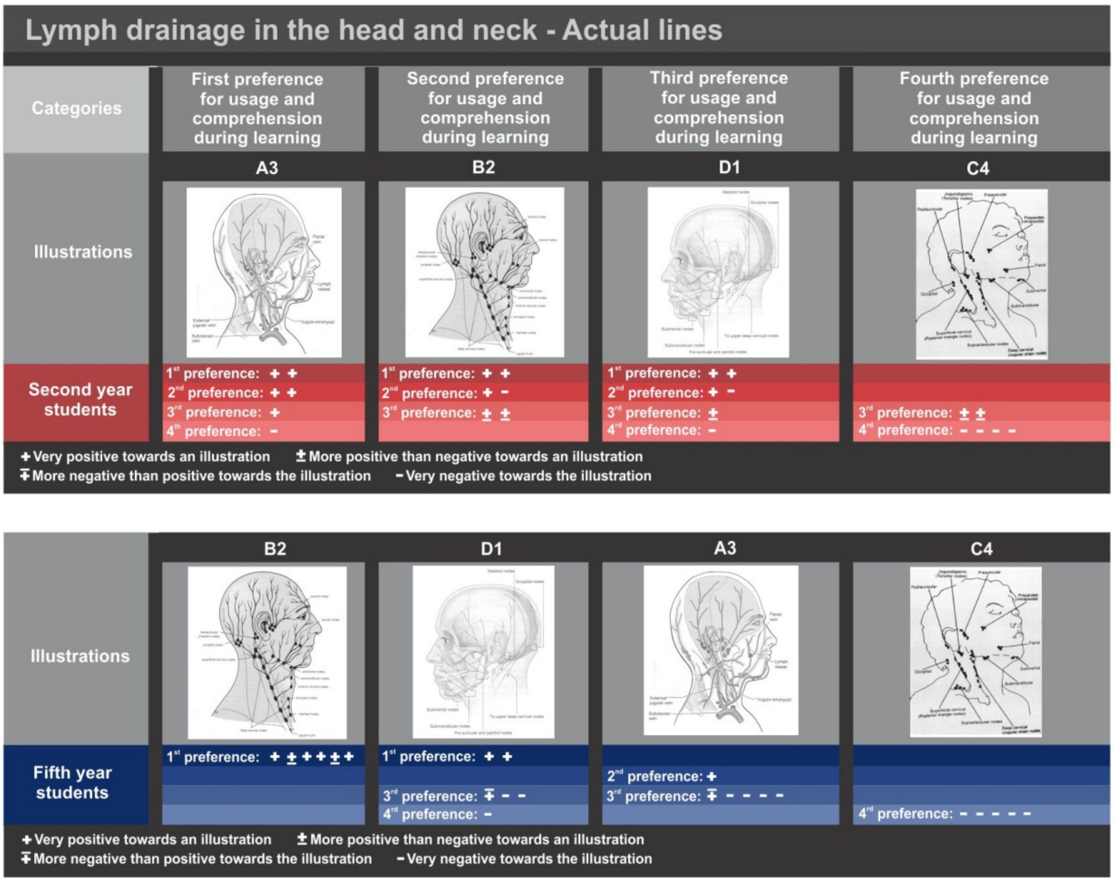


Figure 31: A summary of participants' categorisation of illustrations depicting actual lines according to preference for learning the lymph drainage of the head and neck, 2012. Created by the author.

One illustration (C4) was consistently selected as the least preferred illustration to learn from, as both groups of participants considered it too simplified, lacking detail and unrealistic. With regards to the three remaining illustrations pronounced differences in preferences between the second-year and fifth-year students were evident. Five second-year students selected A3 as first preference to learn from as they regarded it most informative as it shows relations between different structures. With regards to B2 as second preference, five second-year students appreciated it for demonstrating main structures and functionality, although more underlying structures would be necessary for learning purposes. Four second-year students selected D1 as third preference and considered it useful for showing lymph drainage in relation to other structures on different levels of depth for better understanding locality and function.

All the fifth-year students selected B2 as first preference as they favoured the application of the arrows and pronounced lines in the vessels and nodes to demonstrate function of the lymph drainage effectively. D1 emerged as second preference, because three fifth-year students believed the illustration successfully demonstrates relations between structures as well as depth (with the skull in the background). Four fifth-year students selected A3 as third preference because they believed it appeared too complex, for it mainly demonstrates underlying structures without illuminating the function of the lymph drainage.

The use of actual lines in the illustrations above has a major influence on both groups of participants' use, comprehension and preferences of medical illustrations during learning. Second-year students preferred detail and contrasting actual lines in medical illustrations that accentuate underlying structures on different levels of depth, as evident in D1 and A3. Due to second-year students' limited level of clinical and medical knowledge, they need to view anatomical structures in relation to adjacent features to understand locality and functionality of a process such as lymph drainage.

The fifth-year students, on the other hand, are able to understand the lymph drainage process illustrated with prominent actual lines but with less variation and detail to accentuate the function of the process. Due to their advanced clinical and medical experience, fifth-year medical students do not need to understand the lymph drainage process in relation to adjacent structures. They also know which areas to focus on for better understanding. Both groups of participants preferred illustrations demonstrating lymph drainage in the face and neck to be shown realistically which is not apparent in C4.

Participants were also asked whether they make their own line drawings of anatomical structures while learning them from one or more sources. Only one second-year but five fifth-year students reported making basic or schematic drawings of structures when they study. Although the rest of the second-year students did not make drawings when studying, it is evident that they recognise actual lines of objects in order to remember shape, structure, dimension and function.

5.2.3 *Implied lines*

Participants were shown four examples of the course of the optic nerve with implied lines as the design characteristic relevant to this set. They were asked to select the most suitable illustration from which to study. Figure 32 summarises students' preferences of illustrations for learning purposes when depicting various applications of implied lines as demonstrated below.

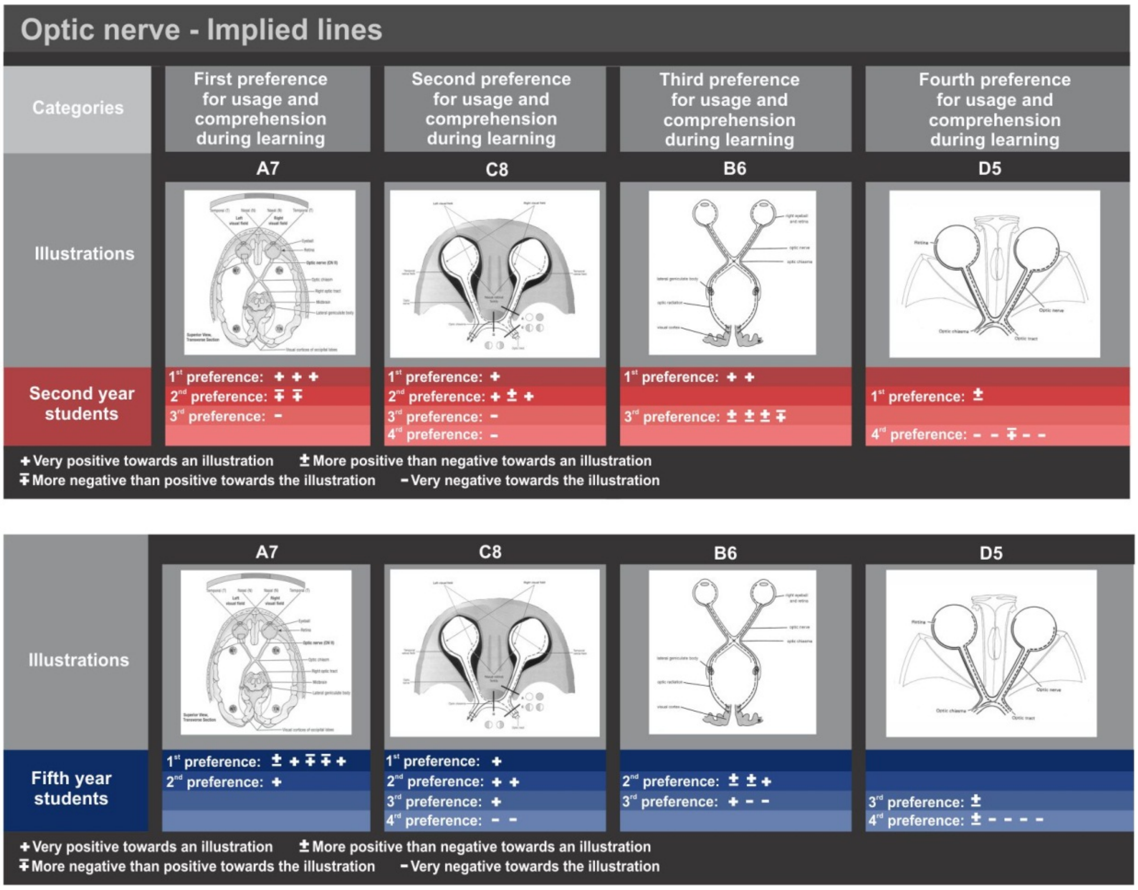


Figure 32: A summary of the participants' categorisation of illustrations depicting implied lines according to preference for learning the optic nerve, 2012.
Created by the author.

On an overall level categorisation of the implied line illustrations according to preference for learning were consistent across both groups of participants. One illustration (D5) was most consistently selected as the least preferred illustration from which to study. Participants considered it incomplete and unrealistic. Illustration A7 was selected as the most favourable illustration for learning purposes, as four second-year and all fifth-year students considered it most complete for better understanding the optic nerve. Three fifth-year students added that A7 appeared complex when viewed for the first time. Four second- and four fifth-year students felt that C8 contained additional information for better understanding, although it was too simplistic. With regard to B6, all second-year students considered the illustration sufficient for basic understanding, although they realised it to be incomplete. Three second- and four fifth-year students added that B6 was useful for revision or a quick overview before a test.

In contrast to actual lines, the application of implied lines in medical illustrations has no influence on both groups of participants' use, comprehension and preference during learning. The application of dashed lines in B6, D5 and C8 to accentuate direction of the course of the optic nerve has no impact on either of the participant groups' comprehension of the process. Participants were able to associate and relate to different appearance of lines whether opened or solid to show direction of flow of the optic nerve. With regard to the partial depictions of structures visible in B6, D5 and C8, participants could identify and understand the objects.

5.2.4 *Visual textures*

In Chapter three visual textures were described as the quality and nature of a surface or object in illustrations. Two aspects of visual texture, combined textures and cross-contour line textures were selected to determine the influence they may have on students' preferences, use and comprehension of medical illustrations during learning. Illustrations representing visual textures were converted to greyscale to ensure that students focus on the different attributes of visual texture.

5.2.5 *Combined textures*

Participants were shown four examples of the medial section of the head and neck with combined textures as the design characteristic relevant to this set. They had to select the most suitable illustration from which to learn. The colour chart in Figure 33 demonstrates both groups of students' order of preferences of illustrations for learning purposes when different applications of combined textures were viewed.

Preferences of illustrations for learning purposes were consistent overall. One illustration (A14) was consistently selected as the least preferred illustration by both groups of students. A14 was considered lacking contrast as all shaded areas appeared uniform, making it difficult to distinguish between different areas. Four second- and four fifth-year students selected B13 as their first preference as it conveyed realism and clarity with contrasting anatomical areas although both groups recognised it to be less informative. With regard to D12, the majority of second- and fifth-year students described it to be realistic and most informative. Two second-year and three fifth-year students showed their dislike for the drawing style applied in D12. There were some inconsistencies in comments by both groups with regard to C15 as third preference. All second-year students would prefer a more realistic application of texture than the abstract patterns evident in C15. Only three fifth-year students preferred the textures in C15 to be more realistic, while the other participants considered it vibrant and sufficient for learning purposes.

The application of combined textures in medical illustrations has an important influence on second- and fifth-year students' use, comprehension and preference for learning. It is evident that both groups of participants prefer medical illustrations that contain visual textures with a realistic and clear appearance (as applied in B13) for better understanding. The clinical, but diagrammatic appearance of B13 was favoured more than the organic feel visible in D12. Participants preferred illustrations with smooth but contrasting areas and solid lines to differentiate between various anatomical features, particularly when viewed for the first time. Overall, preference for realistic depictions of visual texture in medical illustrations is more effective for learning purposes than abstract and distinctive patterns evident in C15. Both groups of students used combined textures to help them recall and memorise location and appearances of structures.

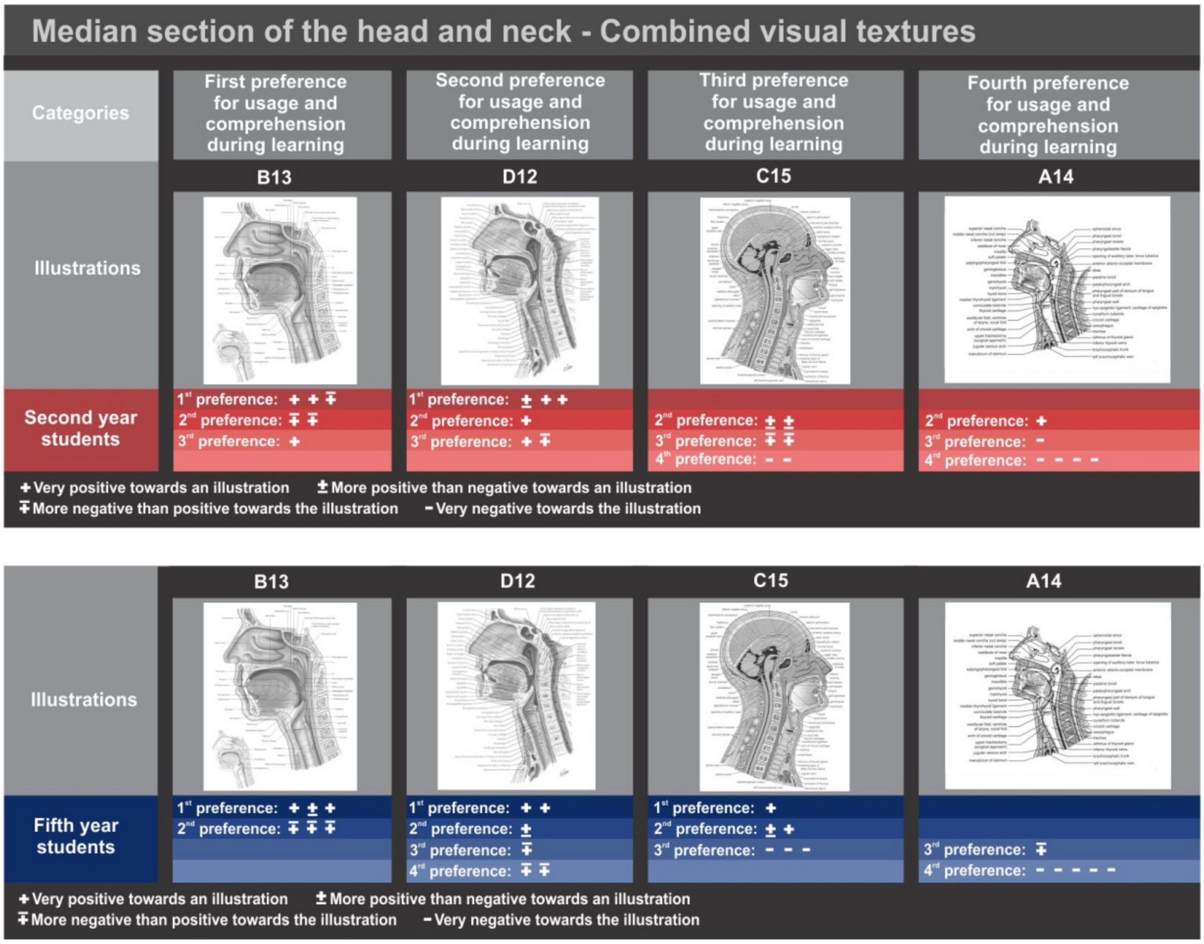


Figure 33: A summary of the participants' categorisation of illustrations depicting combined textures according to preference for learning the median section of the head and neck, 2012. Created by the author.

The variation in media application on each of these examples has also shown a notable influence on participants' preferences. The example of B13 created on computer, was considered more understandable and distinctive compared to the hand-drawn depiction of D12. The application of vibrant textures and lines in mixed media (C15) was favoured over the hand-drawn depiction of A14. The excessive use of similar textures in different areas of an illustration such as A14 makes it difficult for participants to distinguish between different areas during learning.

5.2.6 *Cross-contour line textures*

Participants were shown three examples of the inferior base of the skull with cross-contour line textures as the design characteristic relevant to this set. They had to select the most suitable illustration from which to learn and Figure 34 provides a colour chart showing the different applications of cross contour line textures and its influence on participants' preferences.

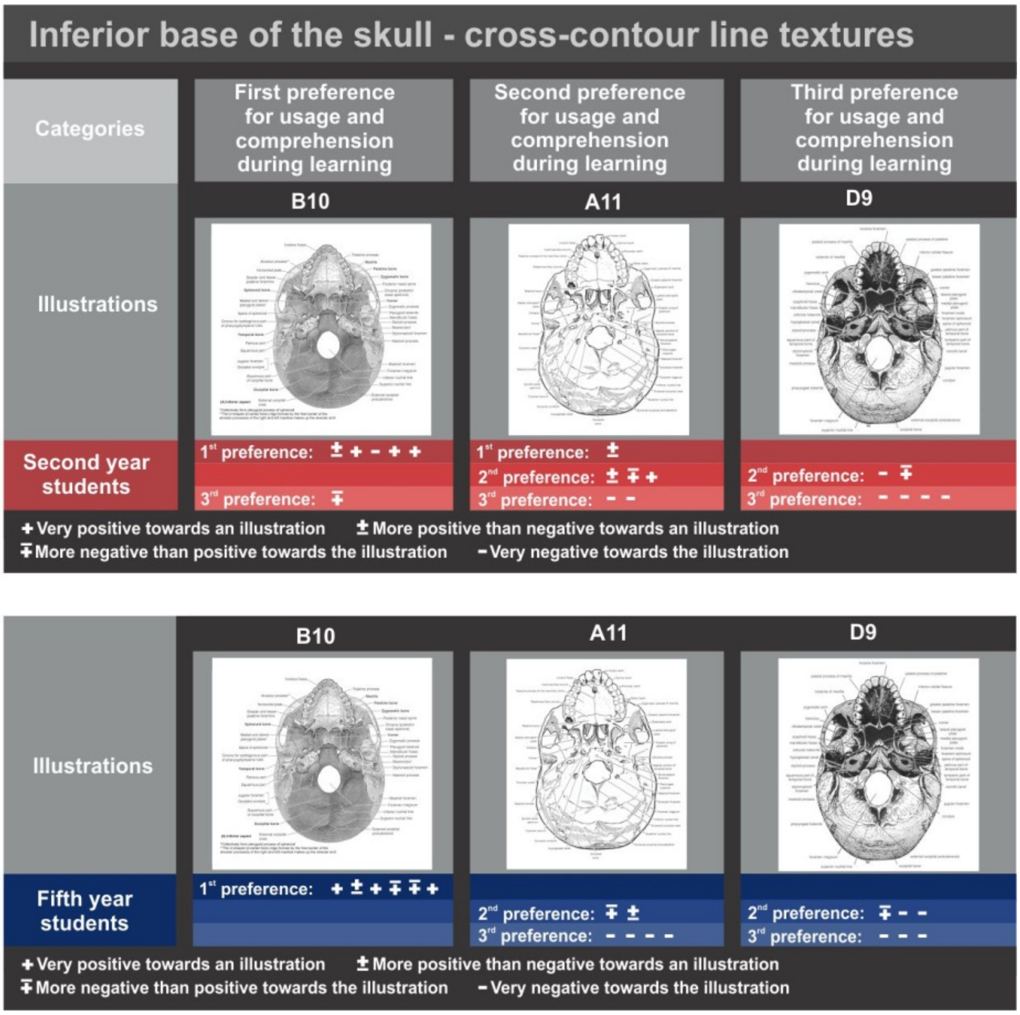


Figure 34: A summary of the participants' categorisation of illustrations depicting cross-contour line textures according to preference for learning the inferior base of the skull, 2012.
Created by the author.

Preferences of illustrations for learning purposes were consistent overall. One illustration (B10) was constantly selected by the majority of students as the most preferred illustration from which to learn, as it conveys essential information, clarity, depth and distinction between different areas. D9 was consistently selected as the least preferred illustration by both groups of participants. Five second years and all fifth-year students considered D9 too dark and showed a dislike of the drawing style of the illustration. Two second-year and two fifth-year students considered the application of shadowed label lines in D9 insufficient as they were not visible. A11 emerged as the second preference although there were some inconsistencies in students' attitude to the illustration. Four second-year students considered A11 a clear and understandable illustration compared to D9 while four fifth-year students found A11 as not distinctive and lacking dimension, depth and contrast.

The application of cross contour line textures in medical illustrations demonstrates prominent impact on the way in which second- and fifth-year students' use, comprehend and prefer these images for learning purposes. It is evident that both groups of participants prefer cross-contour line textures consisting of structured lines that suggest depth, clarity, dimension and reality. The structured patterns of lines in B10 contribute to an understandable and organised composition of balance, clarity and dimensions of the skull. With regard to A11 and D9 it is clear that a balanced application of contrast in cross contour line textures in medical illustrations has to be maintained. The vibrant lines applied in D9 were not experienced positively by participants as they could not associate the illustration with a real skull and important areas were obscured. On the other hand, the texture detected in A11 is too subtle, not showing dimensions of important structures. The variation of media application in each of these examples also had a noteworthy influence on participants' preferences. The application of computer and traditional media in B10 was considered most explanatory and distinctive when compared to the hand-drawn illustrations of A11 and D9.

5.2.7 *Colour*

Colour accentuates important structures and enables readers to distinguish between different areas in illustrations. Colour also plays an important role in medical illustrations for it resembles realistic appearances of anatomical structures and enables readers to distinguish between them. Standard coding of colours are used in medical illustrations to emphasise appearance and functions of anatomical structures. Participants were shown four examples of the surface of the heart with colour as the design characteristic relevant to this set. They had to select the most suitable illustration from which to learn. Their selections are displayed in the colour chart of Figure 35 based on preferences of various applications of colour as demonstrated below.

One illustration (D16) was consistently selected as the most preferred illustration from which to learn. Both groups of students felt that D16 attests to clarity, structure, realism and essential application of good colour contrasts. Marked differences emerged in participants' opinions of the remaining illustrations. Four second-year students selected C19 as their second choice as they believed it conveyed realism and clarity. With regard to A18 as third preference, four second-year students considered it realistic and clear, while three participants felt that it did not contain essential information for learning. B17 emerged as the illustration least suitable from which to learn for the second-year group, as three respondents felt it was unrealistic and confusing. The remaining second-year students found B17 understandable, clear and simplistic but they preferred the other examples.

The fifth-year students selected A18 as second preference as they described it to appear clear with less intense colour, although four participants added that it did not contain sufficient information for learning purposes. With regard to the selection of B17 as third preference by the fifth-year group, three respondents believed it conveyed sufficient information while the rest felt it was not realistic. The fifth-year students selected C19 as last preference for they did not favour the application of high saturated colours in the illustration. Only three fifth-year students recognised C19 for its preservation of sufficient information.

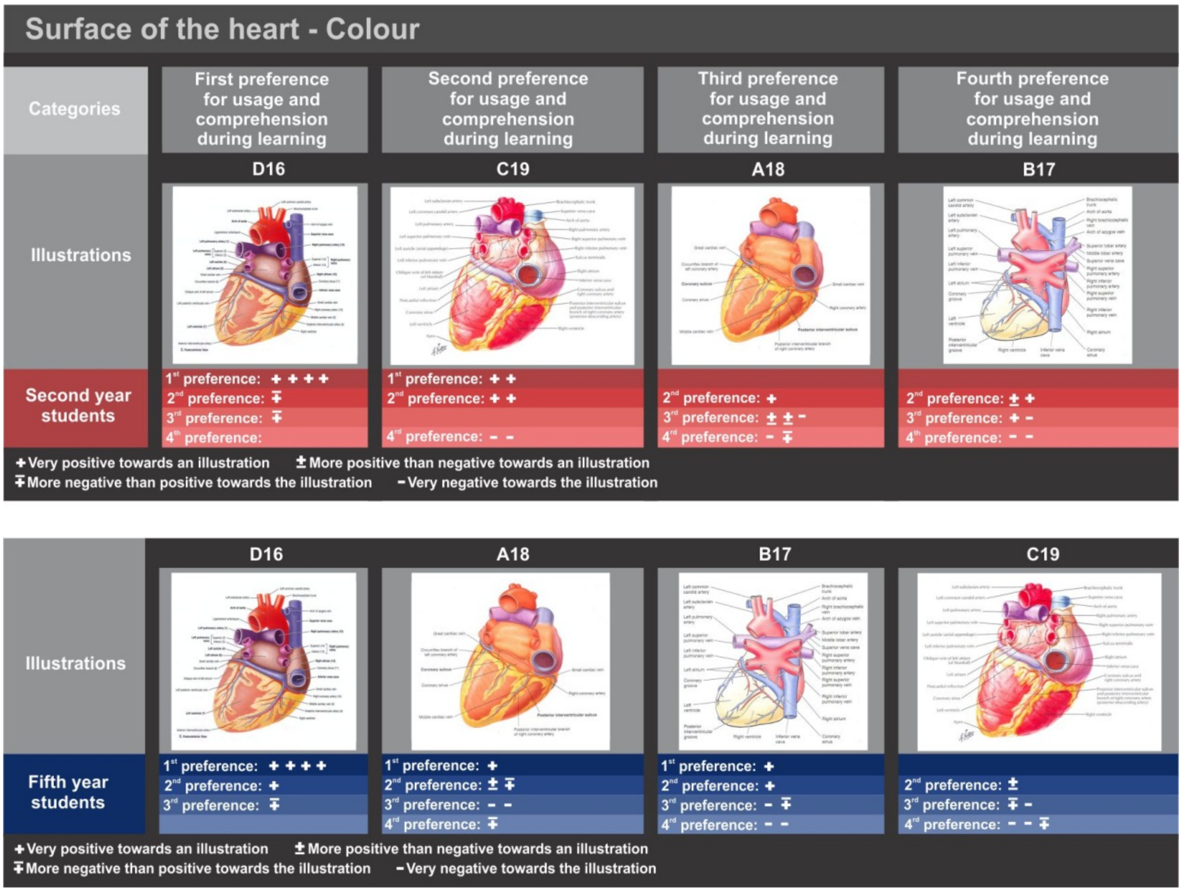


Figure 35: A summary of the participants' categorisation of illustrations depicting colour according to preference for learning the surface of the heart, 2012.
Created by the author.

The application of colour as a design characteristic in medical illustrations is an important factor in the way these illustrations are comprehended by students and therefore colour has a pronounced impact on students' preferences and usage of medical illustrations. Second-year students prefer realistic and even high saturated colours when compared to the fifth-year group. A possible explanation is that second-year students need to easily distinguish between different features of an anatomical structure due to their limited level of medical experience and exposure to human material. The second-year students are also familiar with C19 as it originates from a prescribed atlas and it is regularly used in teaching and other learning material. Although the fifth-year group is also familiar with C19, it is evident that they prefer realistic and untainted colours with lower saturation to enable them to relate to human material for the identification of clinical conditions.

During interviews participants were asked whether they were influenced by the intensities of colour during learning as demonstrated in the four illustrations of the heart. It was found that only two second-year students were influenced by the intensities of colour while four fifth-year students gave their preference for realistic and untainted colours in anatomical structures. Both groups emphasised the need to learn from illustrations that use standard coding of colours for each anatomical structure as they have become familiar with this form of coding since high school education. Both groups of students did, however, mention that they would be able to identify anatomical structures drawn in colours different from their standard form of coding as explained in Chapter three.

When each participant was asked how they would learn from a black and white illustration, four second-year students replied that they would highlight important areas with either different or coded colours while four fifth-year students said they would colour black and white illustrations with mainly coded colours. Most of the second-year students would use highlighters to illuminate text and labels of illustrations during learning, while their fifth-year counterparts would colour in important areas of anatomical structures.

5.2.8 *Shape and space*

In Chapter three shape was defined as the creation of a connection of lines to enclose an area presenting figure or form, while space is the environment which emerges the moment it is activated by shape. Participants were shown four examples of the autonomic nervous system with shape and space as the design characteristic relevant to this set. They had to select the most suitable illustration from which to learn. The colour chart in Figure 36 shows both groups of students' order of preference of illustrations containing various applications of shape and space for learning purposes.

One illustration (B21) was consistently selected by both groups of students as the least favourite from which to learn, for it conveys too much detail and appears confusing, especially when viewed for the first time. All second-year participants regarded C23 most favourable to learn from as they found it clear, simplistic and understandable. With regard to D20 as second preference, four second-year respondents felt it to be understandable, simplified and containing sufficient detail for learning. Three second years considered A22 understandable, simplistic and structured, although the rest found it too schematic and unrealistic.

The majority of fifth-year participants selected A22 as first preference for they believed it to be understandable and a good foundation for adding additional information during learning. Four fifth-year students considered C23 acceptable as it appears not too complex for learning purposes, placing it second. D20 was selected as third preference, as three fifth-year respondents considered it a good platform for adding additional information while the other three students found it to be too complex.

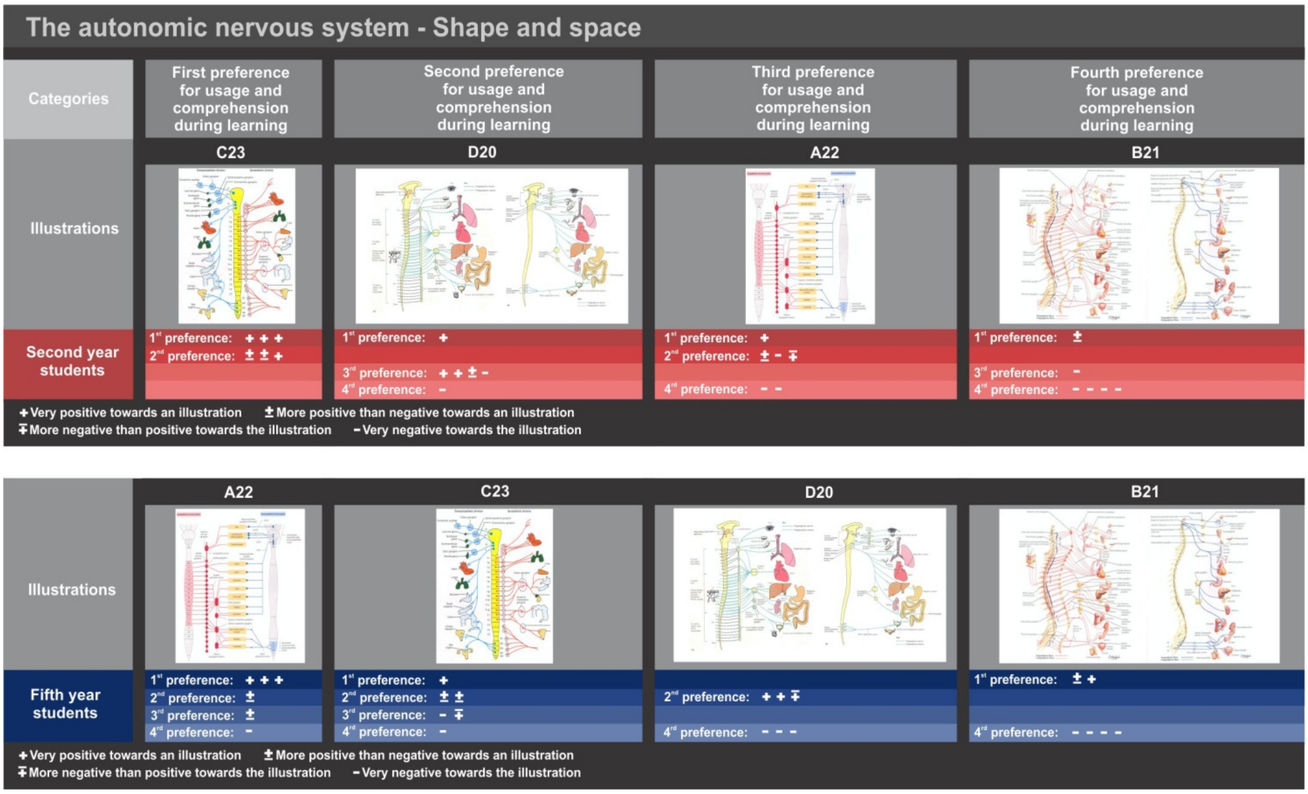


Figure 36: A summary of the participants' categorisation of illustrations depicting shape and space according to preference for learning the autonomic nervous system, 2012.
Created by the author.

The application of shape and space in medical illustrations had a notable influence on second- and fifth-year students' use, comprehension and preferences during learning. Participants' categorisation of B21 as the least preferred to learn from is an indication that they do not need to study from anatomical structures drawn three-dimensionally and detailed while learning. Although second-year students preferred curvilinear shapes of different anatomical structures when learning a complex process such as the autonomic nervous system, the appearances of objects were more two-dimensional and simplistic. The shapes of anatomical structures applied in C23 are realistic though simplistic, enabling the second-year group to understand, especially when viewed for the first time. None of the second-year respondents made any remarkable comments regarding the availability of space for adding additional information on any of the illustrations. The illustration of C23 promotes good balance between the application of shape and space for the second-year students to absorb during learning.

The fifth-year group preferred rectilinear shapes as demonstrated in A22 when learning complex processes such as the autonomic nervous system. During interviews, each participant was asked how he or she would learn the autonomic nervous system and most of the second-year students responded to learn the process from the examples as they appear in atlases or textbooks. The fifth-year students preferred to make blocks with words to help them understand the process. It is evident that fifth-year students are already familiar with various detailed depictions of anatomical structures as part of the autonomic nervous system and are able to focus and understand the functionality of the process (while second-year students have to focus on anatomical structures). For the fifth-year group the role of space in medical illustrations was also important when learning such a complex processes, as they need to add and integrate additional information for completion of knowledge.

5.2.9 *Size and depth*

Depth defines different distances of objects in relation to others, while size accentuates the dimensions of the objects on different levels of depth. Participants were shown three examples of the cross sections of the leg and thigh with size and depth as the design characteristic relevant to this set. Participants' categorisations of illustrations for learning purposes are shown in the colour chart of Figure 37 based on their depiction of various applications of size and depth.

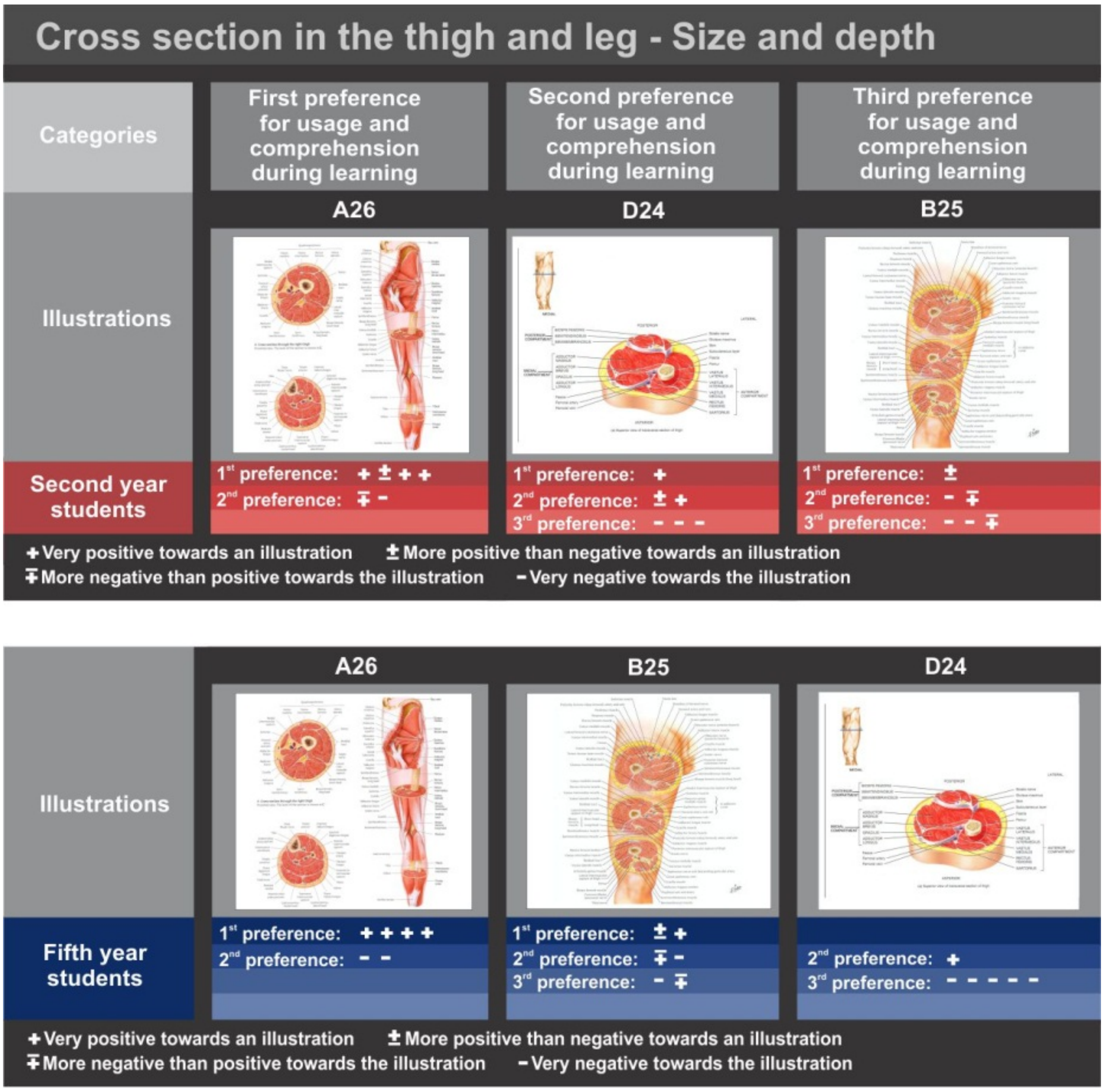


Figure 37: A summary of the participants' categorisation of illustrations depicting size and depth according to preference for learning the cross sections of the leg and thigh, 2012. Created by the author.

One illustration (A26) was consistently selected as the most preferred illustration from which to learn. Both groups of students considered it the most clear, especially with the cross sections shown in relation to the leg. Marked differences emerged in participants' opinions of the remaining illustrations. D24 was selected as second preference by the second-year students as three respondents considered it easy to understand, while the rest felt it to be complete and considered the cross section to appear unrealistic. None of the second-year students favoured B25, as they found it confusing and complex. Three second-year respondents recognised B25 to be complete and informative.

The majority of fifth-year students selected B25 as second preference and considered it to be complete. Three participants added the viewing of angles demonstrated in B25 to be confusing. Five fifth-year students regarded D24 to appear unrealistic, as they showed a dislike of the appearance of the cross section and three respondents added that the illustration was incomplete.

The application of size and depth in medical illustrations has a notable influence on the way second- and fifth-year students comprehend these images and has an impact on students' preferences and use of the illustrations for learning purposes. It is evident that both groups of students prefer to see cross sections of anatomical structures demonstrated from various angles and in relation to the rest of the body as shown in A26. When participants were asked whether the appearance of the cross section rotated or anterior (from the front) influences their comprehension, three second-year and three fifth-year students replied that it did not influence their comprehension in any way. Both groups of students prefer illustrations of cross sections in relation to the anatomical structure as a whole to be drawn realistically.

It is also evident that second-year students have a need to view cross sections from various angles and sizes in relation to adjacent structures for better understanding before being comfortable with more complex illustrations such as B25. The latter shows cross sections in relation to the leg with a magnified view although demonstrating limited adjoining structures for the second-year group to make necessary connections. Second-year students also need to see a clear indication of angles or a description of the view. The depiction of B25 is less problematic for fifth-year students due to their advanced level of medical experience and attentiveness to obtain as much possible information on the appearance of the cross sections in the leg and thigh.

Design elements have a noteworthy influence on second- and fifth-year medical students' use, comprehension and preferences of illustrations during learning. Both groups of students depend on the valuable information accentuated by design elements in terms of anatomical structures. The influence of design principles on second- and fifth-year medical students' use, comprehension and preferences of illustrations for learning purposes are discussed below.

5.3 The influence of design principles on medical students' learning

The list of design principles selected for this study is unity and variety, hierarchy and dominance, balance, proximity and repetition, as well as movement set out in Table 1 of Chapter three. The design principles were selected based on the perspectives of White (2002) and Evans *et al* (2008) who consider them essential to present design elements in a structured and well-balanced composition for better understanding. A colour chart was drawn up for each set of illustrations representing these design principles to demonstrate the order of preferences for the groups of students. The influence of the selected design principles on the use, comprehension and preferences of illustrations by medical students during learning are discussed below.

5.3.1 *Unity and variety*

Unity promotes a sense of belonging between different elements in a composition, while variety emphasises different attributes of the elements. Participants were shown three examples of the fifth cranial nerve in the face, the trigeminal nerve (CNV). They had to select the most suitable illustration to learn from and the colour chart in Figure 38 demonstrates their order of preferences based on perceptions of various applications of unity and variety evident in the images below.

Notable differences emerged in the preferences of the two groups. The majority of second-year students selected A28 as first preference and regarded it to be most comprehensible. Three second-year participants added that the corresponding colours applied in A28 contributed to better understanding of the location of function of the trigeminal nerve. Four second-year students considered B27 effective for basic understanding of the trigeminal nerve, therefore selected it as second preference. Three second-year students did not favour C29 as they considered it too complex and confusing while the rest of the group regarded it complete and informative.

The majority of the fifth-year group selected C29 as first preference as they considered it to be most complete. Four second-year students acknowledged A28 for the application of corresponding colours that contribute to better understanding of the location and function of the trigeminal nerve. Illustration B27 was selected as third preference by most of the fifth-year students as they felt it to be incomplete, although they acknowledged it to be effective for basic understanding.

The application of unity and variety in medical illustrations has a pronounced influence on particularly second-year students' use, comprehension and preference of these images for learning purposes. It is evident that second-year students prefer the application of contrasting colours that corresponds in various elements showed in A28 which is essential for better understanding and memorisation. Although C29 does not contain a notable pattern of corresponding colours to illustrate the course of the trigeminal nerve, it forms a unique whole with the application of less contrasting shades of colours in the face, as well as surrounding areas to demonstrate function and location. No remarkable influence of the application of unity and variety in medical illustrations on the learning of fifth-year students was noted. Fifth-year students understand the functionality and location of the trigeminal nerve without the structure to be demonstrated in various, though corresponding colours, due to their level of experience and need for an illustration which is more informative.

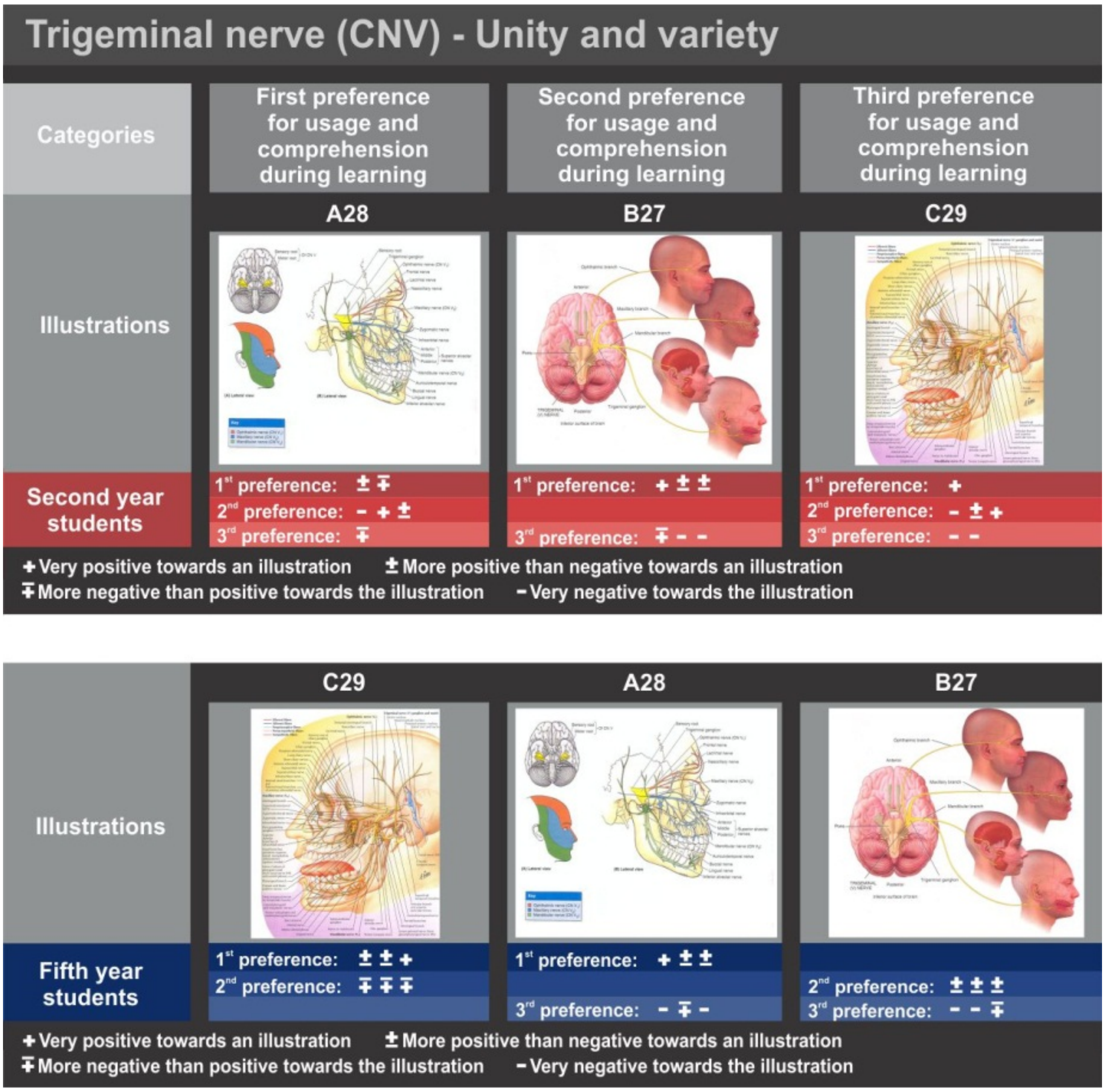


Figure 38: A summary of the participants' categorisation of illustrations depicting unity and variety according to preference for learning the trigeminal nerve in the face, 2012. Created by the author.

5.3.2 *Hierarchy and dominance*

Hierarchy determines the level of objects ranging from most to less prominent in a composition, while dominance illustrates the influence of one element over another. Participants were shown three examples of the taste pathways with hierarchy and dominance as the design characteristic relevant to this set. They had to select the most suitable illustration to learn from and their preferences are displayed in the colour chart of Figure 39 based on depictions of different applications of hierarchy and dominance visible in the images below.

One illustration (D31) was selected by most as the least preferred to learn from as it is considered incomplete and not understandable. Notable differences in preferences between the groups were evident with regard to the two remaining illustrations. Five second-year students selected A32 as first preference because they found it to be clear and informative. Three second-year students noted the application of detail in the brainstem (A32) which enabled them to better understand the process of the taste pathway. Four second-year students regarded B30 to be the most informative although three respondents added that it appeared complex in certain areas such as the different angles of the brain.

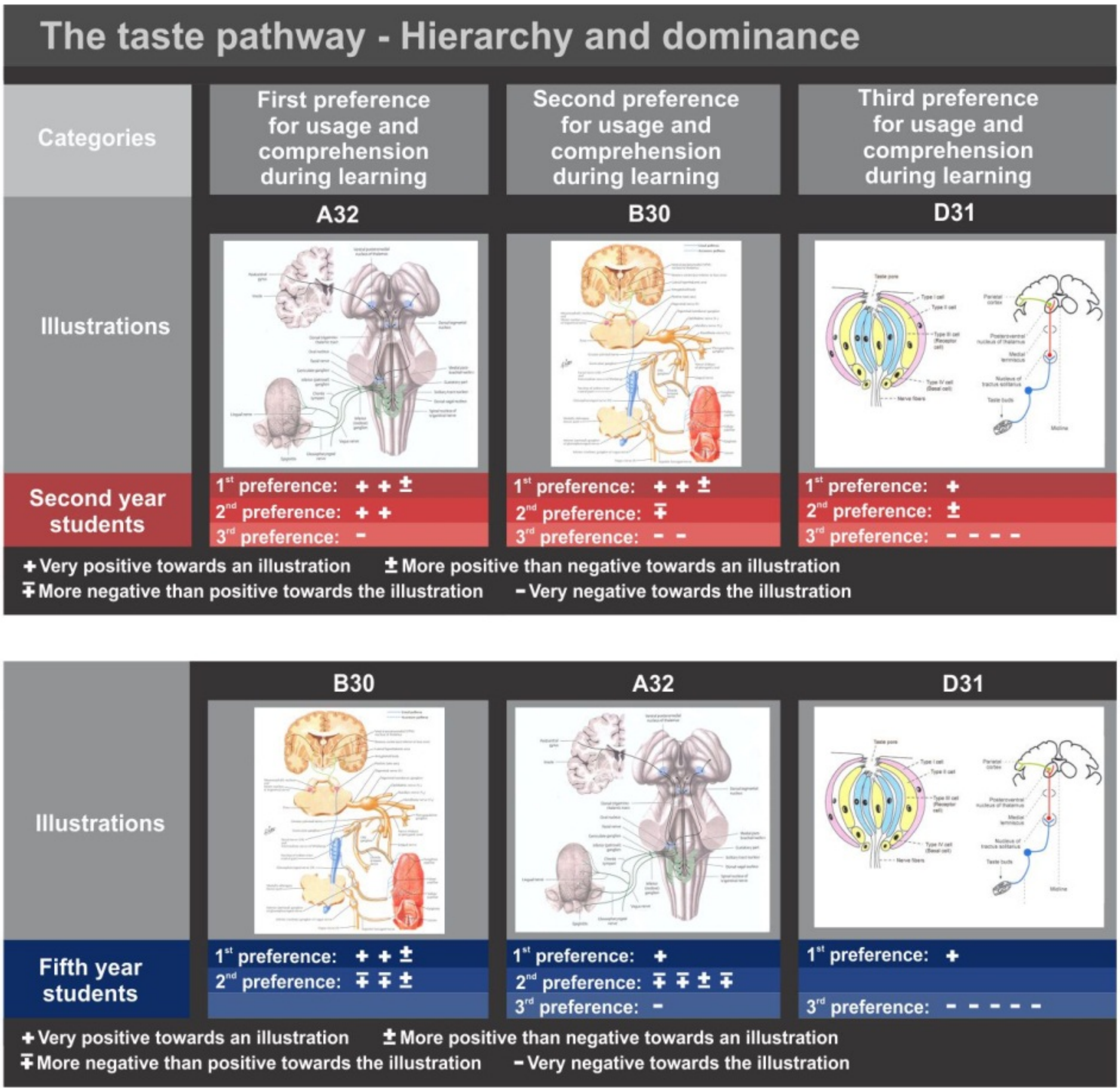


Figure 39: A summary of the participants' categorisation of illustrations depicting hierarchy and dominance according to preference for learning the taste pathway, 2012. Created by the author.

All fifth-year students selected B30 as their first preference because they considered it to be most complete and easy to understand. The majority of fifth-year students selected A32 as second preference as they considered it to contain sufficient information for overview purposes or when viewed for the first time. Three fifth-year students referred to the application of detail in the brainstem demonstrated in A32 to be helpful when learning the taste pathway process.

The application of hierarchy and dominance in medical illustrations showed to have more influence on the use, comprehension and preferences of the second-year students than on their fifth-year counterparts. The second-year group preferred to learn from an illustration such as A32 which contains high contrast between dominant features to explain the course of a process, especially when viewed for the first time. The brainstem in A32 is drawn in much detail and expanded in relation to the other structures to illuminate the origin and direction of the process. The use of dark contrasting lines against a backdrop of a soft background colour in A32 enables second-year students to follow the course of the process. In B30 all structures are illuminated with saturated colours which make it difficult for second-year students to distinguish between dominant features.

The fifth-year students, on the other hand, were able to identify and understand the position of dominant structures within a specific hierarchy as shown in the detailed depiction of B30. Due to their exposure to an advanced clinical environment, they are familiar with complex and detailed illustrations and know where to focus to identify important areas for better understanding.

5.3.3 *Balance*

Balance promotes the visual distribution of elements in a composition and consists of three components; symmetrical, asymmetrical and mosaic balance. As explained in Chapter three, symmetrical balance is the placement of similar objects on either sides of a central axis, while asymmetrical balance is the arrangement of uneven objects in a dynamic and unsystematic fashion. Mosaic balance is the enforcement of too many elements on one page. Participants were shown three examples of the muscles of mastication with balance as the design characteristic relevant to this set. The following colour chart of Figure 40 show students' preferences of illustrations for learning when viewing the different components of balance.

Preferences of illustrations for learning purposes were consistent overall. One illustration (D34) was selected as the most preferred illustration to learn from although there were inconsistencies in comments amongst both groups. The majority of second-year students as well as three of the fifth-year group considered D34 preferable as the distended figure at the top of the page serves as an introduction or overview of what is displayed by the rest of the figures. The rest of the fifth-year group felt that the anatomical sequence[23] of figures needs to be maintained when showing the muscles of mastication which is not evident in D34.

In terms of A35, four second-year and three fifth-year students selected it as second preference and considered the layout to be overwhelming. Three fifth-year students recognised A35 to be complete although they disliked the overlapping of images and preferred structures to be distributed

[23] Anatomical sequence refers to the order of different layers of muscles of mastication visible during dissection.

over different pages. With reference to B33, the majority of second- and five-year students felt that the figures were too small with them all displayed in a straight line. Only two second-year and two fifth-year students recognised the importance of the maintenance of the correct sequence of figures, especially when learning the muscles of mastication.

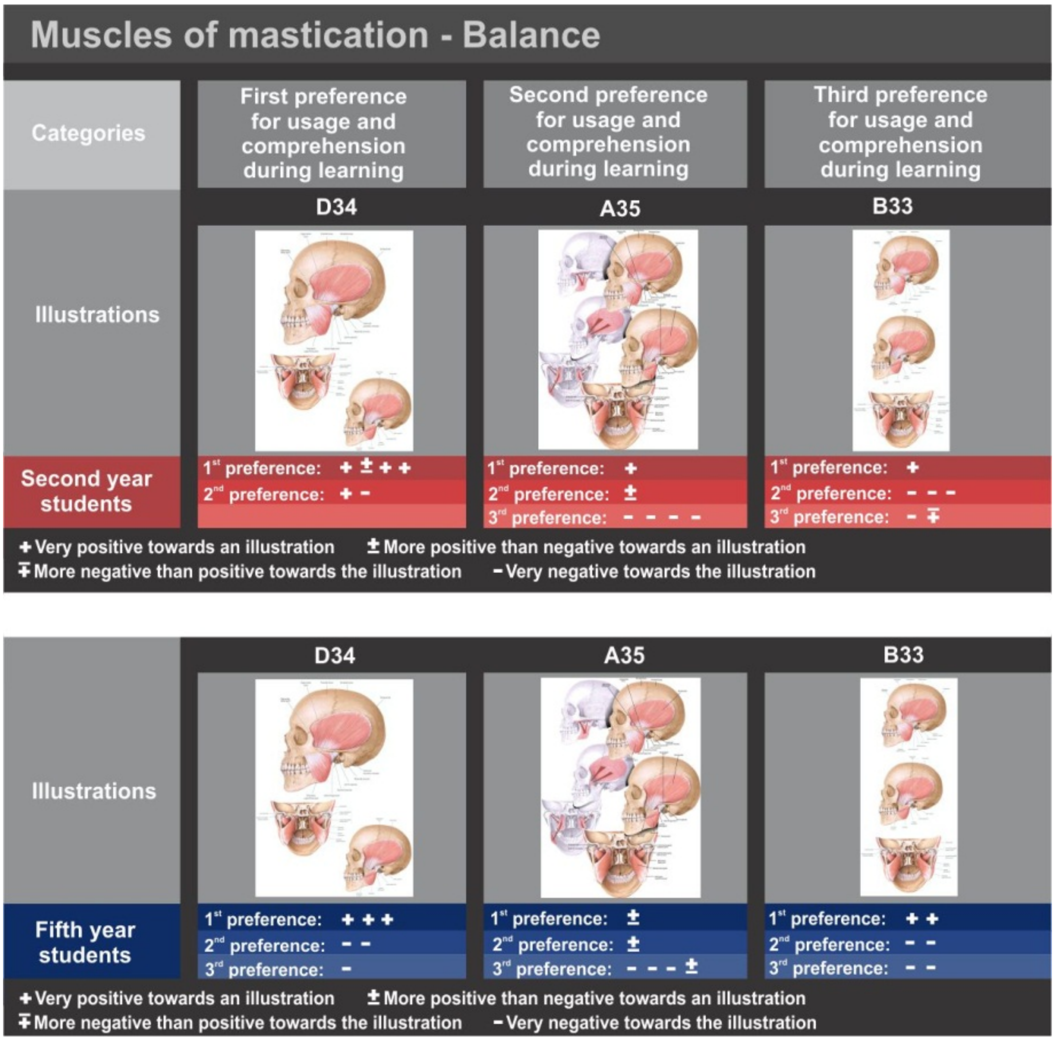


Figure 40: A summary of the participants' categorisation of illustrations depicting balance according to preference for learning the muscles of mastication, 2012. Created by the author.

The muscles of mastication are generally presented with symmetrical or asymmetrical balance in anatomical atlases and textbooks and an anatomical sequence is followed. In this study the order, size and number of the figures were altered to illustrate the different formats of balance. The posterior view (view from the back) of the skull, evident at the bottom of B33 and A35 and in the middle of D34, is generally presented on a separate page in anatomical textbooks and atlases due to its level of complexity and detail. For this study, the posterior view of the skull was displayed with all the other angles on one page to emphasise the dynamism of the three formats of balance.

The application of asymmetrical balance in medical illustrations has a noteworthy influence on the second- and fifth-year students' use, comprehension and preferences of illustrations for learning.

Asymmetrical balance promotes a dynamic composition with the placement of several elements in various appearances on one page. Both groups of participants selected the enlarged top image in D34 to be effective for understanding as it provides an overview of what is revealed by the following images. Although the figures in D34 are not placed in correct anatomical sequence, it was considered easy to understand for both groups even if they were not familiar with this form of presentation. It is therefore evident that familiarity with the content enabled both groups to understand muscles of mastication, even if not displayed in anatomical sequence.

Mosaic balance illustrated in A35 is not generally applied in anatomical atlases and textbooks due to the overload of information offered to readers. Although mosaic balance is not effective when portraying anatomical structures for learning purposes, A35 was selected by both groups of participants as second preference due to its complete level of information. Both groups of students preferred mosaic balance of anatomical structures for overview purposes or revision even if they were not familiar with this form of presentation.

The symmetrical balance of structures illustrated in B33 confines dynamic interaction between figures and space on the page as the objects appear similar in size and structured in a straight line. Although the correct sequence of anatomical structures in B33 was maintained to show the muscles of mastication, there is imbalance between the great volume of space available and the size of the objects. Both groups of students felt the figures in B33 were too small and experienced difficulty in reading the labels.

5.3.4 ***Proximity and repetition***

Proximity and repetition promote unity in a composition with the placement of similar or different elements close together and in a certain pattern to demonstrate an action or process for better understanding. Participants were shown three examples of the functioning of the eye muscles with proximity and repetition as the design characteristic relevant to this set. Participants had to select the most suitable illustration to learn from and the colour chart in Figure 41 demonstrates the order of students' preferences of illustrations for learning purposes when different applications of proximity and repetition are displayed.

Preferences of illustrations for learning purposes were consistent overall. One illustration (A38) was selected as the least preferred to learn from as both groups of participants considered it insufficient to show function of the eye muscles, although the application of the view was favoured. Several second- and fifth-year students emphasised the need to see illustrations showing functions and anatomy of the eye muscles from various angles for better understanding. All second- and fifth-year students selected B36 as first preference as they considered the illustration to show anatomy of the eye muscles effectively from various angles. Three second-year students and four fifth-year students stated that the bottom figure of B36 did not show function of the eye muscles effectively. With reference to D37, both groups of participants felt that movement is effectively demonstrated especially with the images showing the gazing of the eyes. Four second- and three fifth-year students disliked the images at the top of D37 and felt that these figures did not clearly demonstrate function of the eye muscles.

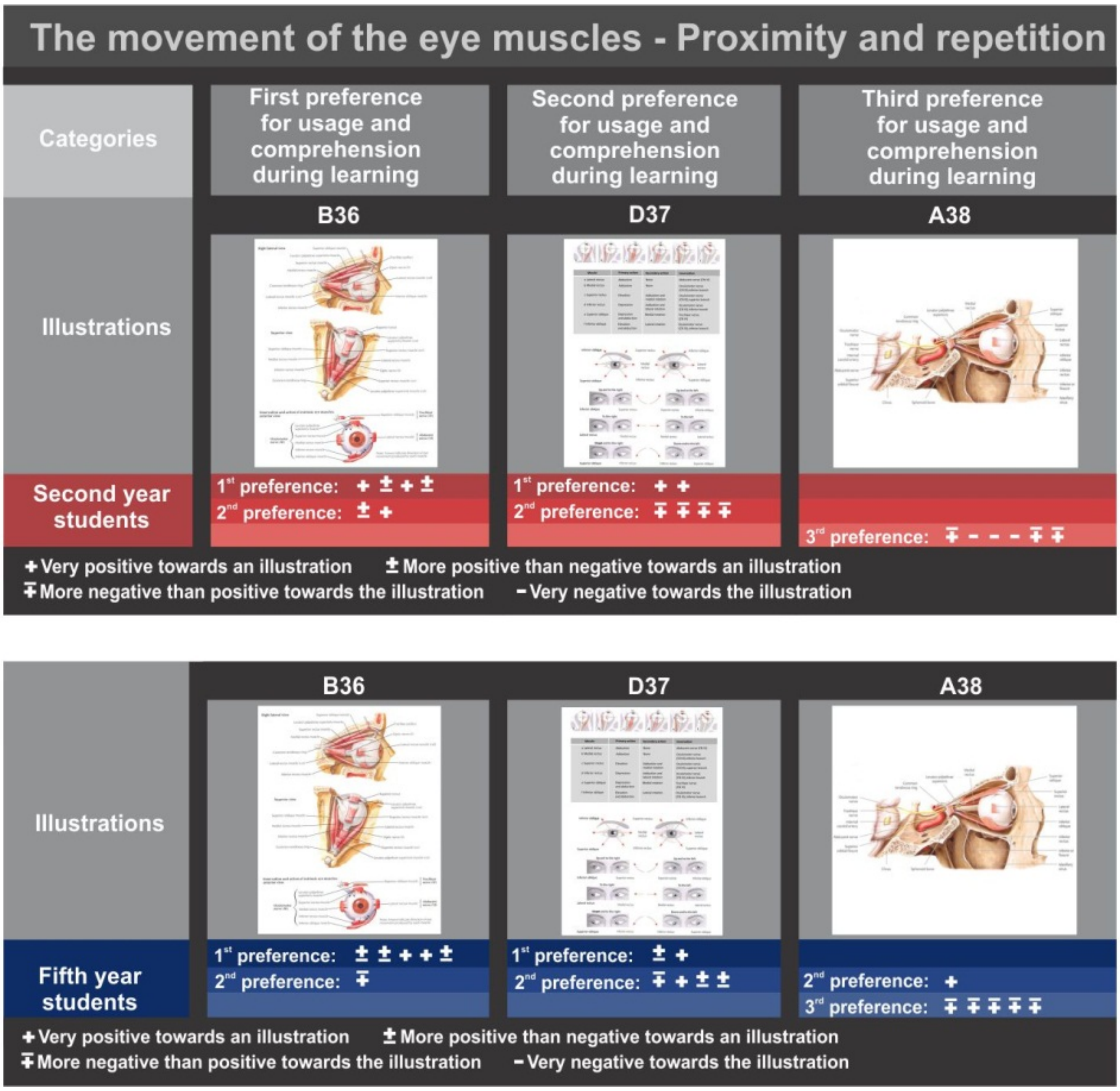


Figure 41: A summary of the participants' categorisation of illustrations depicting proximity and repetition according to preference for learning the functioning of the eye muscles, 2012.
Created by the author.

Proximity and repetition as design characteristics have a noteworthy influence on the use, comprehension and preference of illustrations for learning by second- and fifth-year students. Both groups of participants preferred to see a pattern of similar and various anatomical angles and structures when learning the function of the eye muscles evident in B36 and D37. Repetitive application of shape and colour in B36 and D37 was immediately understood and enabled participants to follow and comprehend movement of the eye muscles. The placement of structures close to each other in A38, B36 and D37 also enabled participants to understand movement of the eye muscles in relation to each other. In contrast to the other illustrations, A38 forms a unified pattern with the eye muscles structured around the eye and embedded in the skull. Similar shapes and colours are used to demonstrate the eye muscles structured around the eye ball in A38. However, the latter is considered incomplete as more angles are necessary when the eye muscles are shown.

5.3.5 *Movement*

Movement is important in medical illustrations to show actions or processes of anatomical structures. The application of arrows to suggest movement in static and animated medical illustrations plays a vital role in aiding comprehension. The lateral rectus eye muscle was used to demonstrate the effectiveness of arrows demonstrating movement. Participants were shown five examples of the functioning of the lateral rectus eye muscle of which two illustrations were animated as explained in Chapter four, p71. Participants had to select the most suitable illustration to learn from when exposed to different applications of arrows to convey movement as demonstrated in Figure 42.

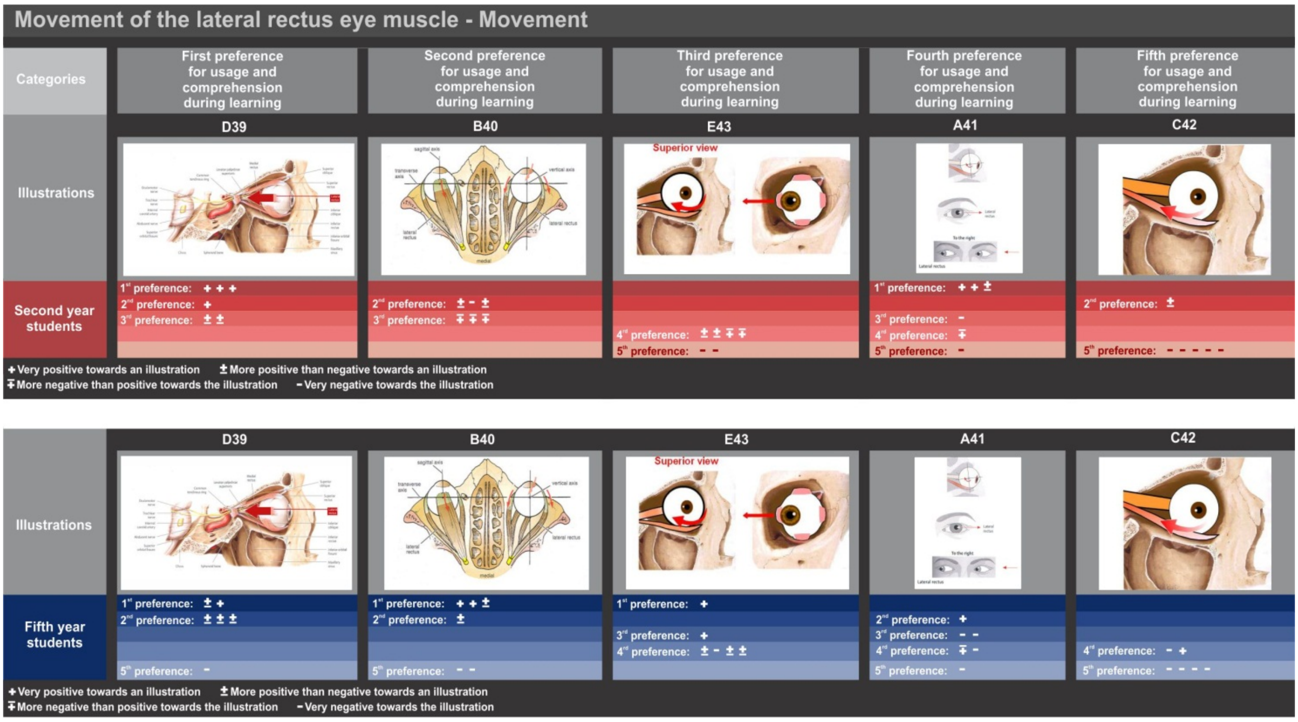


Figure 42: A summary of the participants' categorisation of illustrations depicting movement according to preference for learning the movement of the lateral rectus eye muscle, 2012.
Created by the author.

Overall, preferences of illustrations for learning purposes were consistent across the groups. Illustration D39 was selected as the most preferred illustration to learn from by both groups of students as the application of the view and direction of the arrow are most comprehensive. Three fifth-year students added that they needed to see movement of the lateral rectus from more than one view. The majority of second- and fifth-year students selected B40 as second preference as they preferred the application of arrows to suggest movement. Most of the second-year students added that they preferred B40 to be demonstrated more realistically. The majority of second- and fifth-year students selected the animation of E43 as third preference as the image on the right was considered most explanatory when viewing the arrow appearing from the right corner of the screen. With A41 selected as fourth preference, three second-year students considered it easy to understand while four fifth-year students felt that one view of the eye was not sufficient for understanding. The animation of C42 was selected as the least preferred illustration to learn from as the majority of second- and fifth-year students did not consider the animation to be clear. Both groups felt that movement of the eye ball was accentuated in C42, rather than the actual muscle. Three fifth-year students indicated that they would prefer the arrow in C42 to be straight to aid comprehension.

Arrows in medical illustrations have an important impact on the use, preference and comprehension of these images by second- and fifth-year students, especially when movement is displayed for learning purposes. For the purposes of this study, actual movement of the lateral rectus eye muscle in the animations of E43 and C42 was removed to determine the influence of the different applications of arrows on participants' understanding. Both groups of students considered the demonstration of the straight arrows in D39 and in the animation of E43 to be more effective when showing the outward movement (away from the nose) of the lateral rectus eye muscle. A possible explanation is that the placement of the arrows in D39 and E43 suggest a pulling effect of the eye ball in both illustrations which accentuates direct movement to the right and both arrows are shown in context with other angles or anatomical structures. Participants also preferred illustrations of the lateral rectus eye muscle showing movement and appearances to be created realistically, similar to the example of D39.

The application of curved arrows in B40 and in the animation of C42 also had a notable influence on the comprehension and learning by both groups of students of the lateral rectus eye muscle. The positioning of these forms of arrows is vital for sufficient understanding. In B40 the application of various curved arrows showed in various directions and positioned around the muscle and eye ball accentuate the dynamism of the movement of the muscle and provide context. In C42 only one distended curved arrow is in motion when the animation is demonstrated. The position of the arrow close to the eye ball places more emphasis on the shape of the eye ball than on the actual movement of the muscle. The appearances of arrows in B40 and C42 did not have any remarkable influence on either of the groups of participants' understanding of the process.

Design principles have a notable influence on the use, comprehension and preferences of illustrations by second- and fifth-year medical students during learning. These design characteristics demonstrate various angles of anatomical structures and enhance the order of placement of these objects for better understanding during learning. Two other aspects, namely labelling and reproduction are also considered essential to the learning of medical illustrations and are discussed below.

5.4 The influence of labelling on medical students' learning

Labelling is essential in medical illustrations as it directs the readers' eye to a specific point of importance and is considered the connection between visual and textual material. Three different formats were used for this study namely internal, external and hybrid labelling. As explained in Chapter three, internal labelling demonstrates text directly on structures, while it is placed next to the structures in the case of external labelling. Hybrid labelling is a combination of external and internal labelling. Participants were shown four examples of the facial nerve (CNVII) muscle in which different aspects of labelling are applied and had to select the most suitable illustration from which to learn. The colour chart in Figure 43 shows the order of preferences of illustrations by students when different applications of labelling methods were perceived.

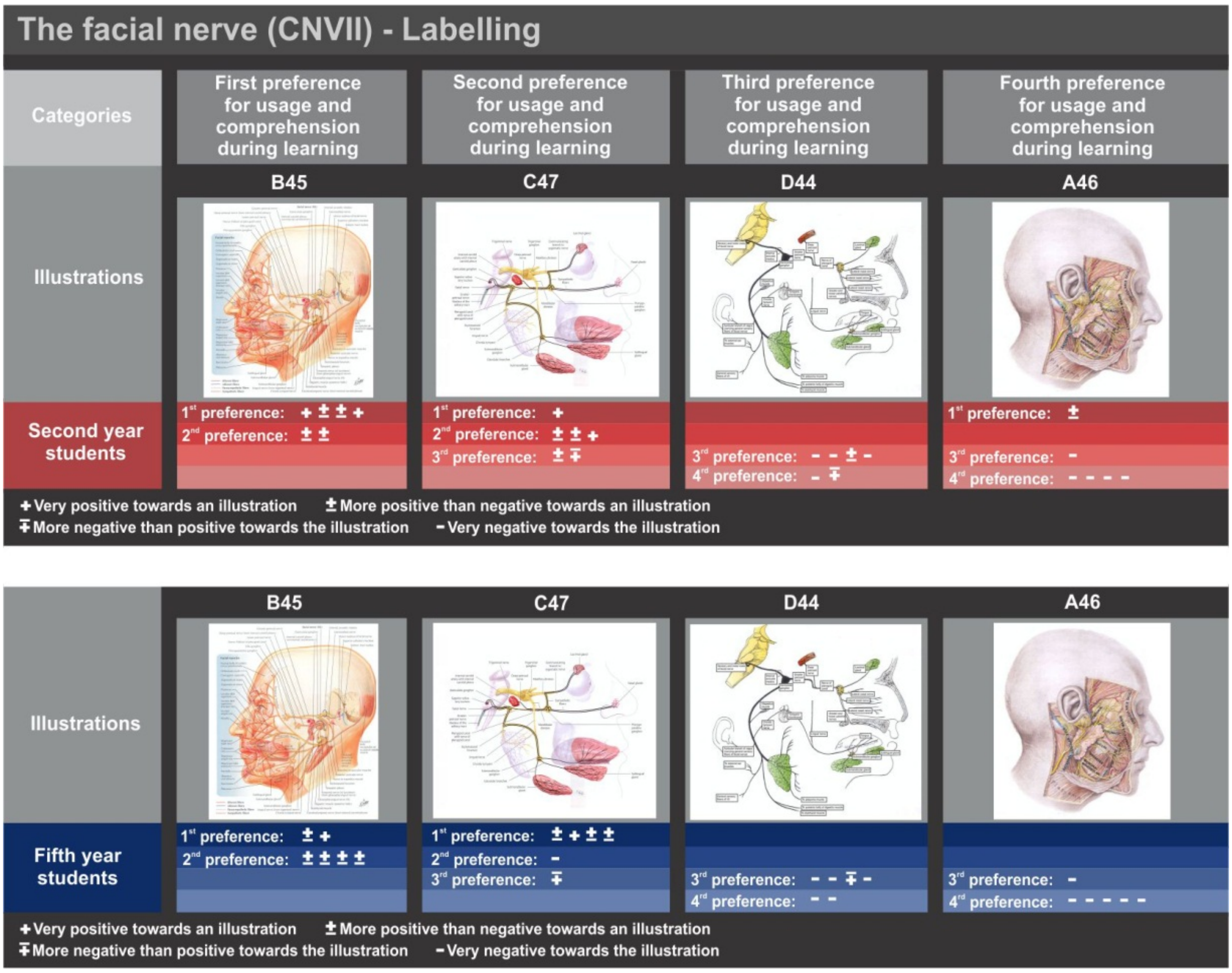


Figure 43: Summary of participants' categorisation of illustrations depicting labelling according to preference for learning the facial nerve, 2012.
Created by the author.

Overall, participants were consistent in their preferences. The majority of second- and fifth-year students selected B45 as first preference for they considered it to be most informative and they were familiar with the method of labelling. In terms of C47 as second preference, the majority of second- and fifth-year students recognised the illustration for its realism, clarity and method of labelling, although three second-year and four fifth-year students felt it to be sufficient for knowledge introduction as it was not complete. With reference to D44, four second-year students did not favour the structuring of labelling as they experienced it as confusing while five fifth-year respondents strongly felt that important information could be concealed. Five second-year students selected A46 as last preference since they felt that the labels did not stand out clearly, while all fifth-year students believed the illustration to be confusing and incomplete.

Labelling in medical illustrations has an important influence on the use, comprehension and preference of these images by second- and fifth-year students when it comes to learning. External labelling is used most often in anatomical textbooks and atlases. For the purpose of this study the illustrations in A46 and D44 were altered to determine their influence on medical students' learning. The illustration in A46 was changed to demonstrate internal labelling while a different application of external labelling is shown in D44. It is evident that both groups of participants preferred external labelling as demonstrated in B45 and C47 when learning a complex structure such as the facial nerve as they are familiar with the labelling technique.

Although several students from both groups mentioned that the text of the labels in B45 appeared too small and the label lines were overwhelming, they were familiar with the illustration and regarded it as most informative. Neither of the groups of participants were familiar with the illustration of C47, although they immediately understood the content and accepted the method of labelling and size of fonts. Both groups of students considered the application of hybrid labelling (D44) and internal labelling (A46) sufficient for presentations or teaching methods where they can be explained.

5.5 The influence of reproduction on medical students' learning

As explained in Chapter three, medical illustrations have to be reproduced with a high resolution for study purposes. Participants were shown three examples of the venogram of the subclavian artery, maxillary and brachial veins in the shoulder with different methods of reproduction. With the presentation of various applications of reproduction, participants had to select the most suitable illustration to learn from and their preferences are shown in the colour chart (Figure 44) below.

Overall, participants were consistent in their preferences of illustrations for learning. Illustration B49 was selected as most preferred by all participants as it conveys the best quality for learning purposes. The majority of second- and fifth-year students added that it is important to learn the venogram and line diagram in relation to each other for better understanding. With regard to D48, four second-year students felt that they would rely on the line diagram when learning from it, while four fifth-year students emphasised that it is insufficient for learning purposes. In terms of A50, four second-year students stated they would try to learn from an enlarged printout of the image before searching for other sources. Five fifth-year students immediately stated that they would discard A50 and search for other sources.

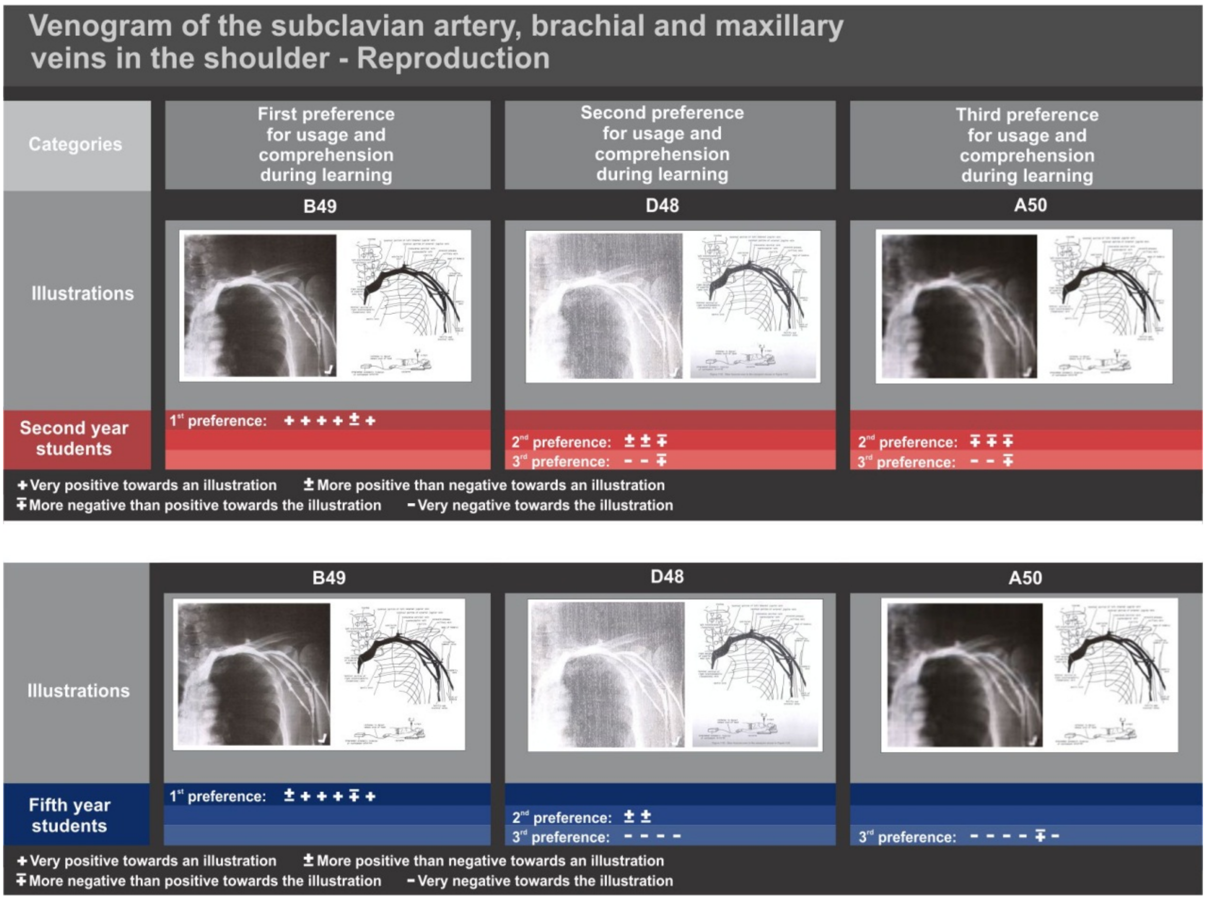


Figure 44: Summary of participants' categorisation of illustrations depicting reproduction according to preference for learning the venogram of the subclavian artery, maxillary and brachial veins in the shoulder, 2012.
Created by the author.

The quality of the reproduction of learning material has a major influence on second- and fifth-year students' use, comprehension and preferences of illustrations during learning. In circumstances where diagnostic radiology techniques such as venograms, MRIs and x-rays are included in study material, high quality of reproduction of these materials need to be preserved for better understanding. Although the venogram (B49) shows high quality, both groups of participants realised the need to learn it in conjunction with the line drawing for better understanding and use. The second-year students are still in the process of learning how to examine MRI, venograms or x-rays, and therefore need to study these images in conjunction with line diagrams or labels. With reference to D48, the second-year students would gain as much possible information from the line diagram as they need to familiarise themselves with the content. Although the fifth-year students have more experience in examining MRIs, venograms and x-rays, they understand the need to study these entities in conjunction with the line diagram in order to obtain as much possible information pertinent to patient care.

5.6 Synthesis of literature with findings of this study

Table 3 is a synthesis of findings from the colour charts (discussed above) as well as conclusions from literature (set out in Table 2 of Chapter three) to demonstrate similarities and differences in the influence that design characteristics have on the use, comprehension and preference of second- and fifth-year medical students' learning.

Design characteristics	Literature pertaining to how readers learn:	Second-year medical students:	Fifth-year medical students:
Actual lines:	Line illustrations can be misinterpreted because of abstraction or simplification (Andrews 2006). Line can simplify complex structures for better understanding (Cole *et al* 2009:28:1).	Cannot learn from simplified illustrations, need to view illustrations containing actual lines showing various detail and contrast to accentuate anatomical structures on different levels of depth. Need to view anatomical structures in relation to other structures for better understanding.	Are able to comprehend simplistic illustrations with less actual lines and prefer illustrations that focus on main structures demonstrated with bold lines. They do not need to view certain structures in relation to others due to their level of expertise.
Implied lines:	Can be perceived as incomplete rather than viewed as a whole (Fisher *et al* in Chang *et al* 2002:2).	Are able to comprehend incomplete lines and partially drawn backgrounds.	Are able to comprehend incomplete lines and partially drawn backgrounds.
Visual texture: Combined textures:		Prefer illustrations of anatomical structures that contain realistic and clear textures to associate with real human structures and to help determine location and memorise appearance. Favour illustrations containing smooth, though contrasting textured areas to distinguish between various areas.	Prefer illustrations of anatomical structures that contain realistic and clear textures to associate with real human structures and to help determine location and memorise appearance. Favour illustrations containing smooth, though contrasting textured areas to distinguish between various areas.
Cross contour line textures:	The effect of zebra stripes can easily be perceived as appearing too far apart when used	Prefer illustrations containing anatomical structures that are created with structured	Prefer illustrations containing anatomical structures that are created with structured cross

	to show dimension and structure (Andrews 2006).	cross contour line textures to accentuate depth, clarity and dimension of anatomical areas. Do not favour illustrations containing cross contour lines drawn too far apart (zebra stripes), as dimension and detail of anatomical structures are not emphasised. Prefer illustrations created with computer rather than hand-drawn images, for cross contour lines are more structured and organised to perceive a structure as a whole.	contour line textures to accentuate depth, clarity and dimension of anatomical areas. Do not favour illustrations containing cross contour lines drawn too far apart (zebra stripes), as dimension and detail of anatomical structures are not emphasised. Prefer illustrations created with computer rather than hand-drawn images, for cross contour lines are more structured and organised to perceive a structure as a whole.
Colour:	Colour emulates important structures (Tufte 1990:81). Saturated colours can cause fatigue (Dagget *et al* 2005:5). Students are able to recognise objects displayed in other colours different from their original colour while still expose to the objects' original colour (Hansen *et al* 2006:1368). Different tones of colour applied on an object to show its angles and depth can influence readers' spatial abilities as well as when the same object's angles are displayed separately (Csillag 2009:135-136).	Use colour to highlight important structures. Prefer to learn from illustrations demonstrating anatomical structures with saturated colours for recognition and memorisation. Prefer to learn from illustrations showing anatomical structures in their general coding of colours. Illustrations showing dispersed anatomical structures were not used as part of the study. They are not influenced by different intensities of colour demonstrated on an anatomical structure.	Use colour to highlight important structures. Prefer to learn from illustrations demonstrating anatomical structures with pure colours for understanding and clinical reference. Prefer to learn from illustrations showing anatomical structures in their general coding of colours. Illustrations showing dispersed anatomical structures were not used as part of the study. They are influenced by different intensities of colour demonstrated on an anatomical structure for it may indicate a clinical condition.

Shape and space:	Simplistic or abstracted versions of the actual or original object will be understood (DeCarlo *et al* 2010—:175). Three-dimensional diagrams are analysed and memorised more rapidly compared to two-dimensional diagrams (Irani *et al* 2000:1).	Learn from realistic shapes of structures. Prefer to learn complex diagrams containing curvilinear shapes of anatomical structures to make necessary connotations. Prefer three-dimensional or two-dimensional drawings of anatomical structures as long as they are realistic.	Can learn from abstracted or simplistic shapes of structures. Prefer to learn complex diagrams containing rectilinear shapes of anatomical structures as students are able to make connotations with structures. Prefer two-dimensional conceptual representations of anatomical structures.
Size and depth:	Angled views of objects may lead to distorted views and influence sense of depth (Duff in Krull *et al* 2006:194).	Prefer various angles of structures to understand relationship. Need to see cross sections in relation to the whole structure.	Do not need various angles of structures. Need to see cross sections in relation to the whole structure.
Unity and variety:	Incongruence of elements should be limited to aid understanding (Stewart 2002:3-2).	Prefer to view a congruency of colours, size or shape for better understanding.	Are able to understand incongruent elements of structures.
Hierarchy and dominance:	Hierarchy of elements enables readers to scan objects first before examining detail (Evans *et al* 2008:5).	Rely on dominant or illuminated structures to understand hierarchy.	Are able to identify dominant structures without any emphasis.
Balance:	Asymmetrical, symmetrical and mosaic balance are introduced (White 2002; Evans *et al* 2008).	Familiar with symmetrical balance, but prefer asymmetrical balance of anatomical structures in an illustration. Not focused on the anatomical sequence of structures.	Familiar with symmetrical balance but prefer asymmetrical balance as long as anatomical sequence is maintained.
Proximity and repetition:	Objects close to each other are generally considered to relate to each other (Chang *et al* 2002:3).	Comprehend structures close to each other as a whole. Prefer a pattern of similar or dissimilar elements in anatomical structures.	Comprehend structures close to each other as a whole. Prefer a pattern of similar or dissimilar elements in anatomical structures.

Movement:	Straight arrows can be understood two-fold (Krull *et al* 2006:192). Readers sometimes focus on other visual cues than the arrows (Krull *et al* 2006:196) Three-dimensional arrows are better understood than two-dimensional arrows (Krull *et al* 2006:196).	Comprehend straight arrows better than curved arrows. Focused on movement of the eye ball when the animation was viewed, rather than the arrow. Appearance of arrows has no influence on learning.	Comprehend straight arrows better than curved arrow. Focused on movement of the eye ball when animation was viewed, rather than the arrow. Appearance of arrows has no influence on learning.

Table 3: The list of literature significant to readers' learning, applied to design characteristics and synthesised with current findings of this study, 2013. Created by the author.

5.7 Conclusion

The summarised colour charts demonstrate differences and comparisons in preferences of illustrations by second- and fifth-year medical students for the purposes of learning. These colour charts also demonstrate the remarkable influence of the design characteristics, labelling methods and reproduction on both groups' categorisation of illustrations for learning purposes. Certain design characteristics, however, have a greater influence on either one or both groups of students, compared to others.

In terms of design elements, the role of actual lines, for instance, is more prominent than the impact of implied lines on both groups of students. Due to the level of complexity, certain anatomical structures are partially drawn to accentuate important features evident in medical textbooks and atlases. Both groups of students are familiar with this form of emphasis and implied lines therefore have less impact.

Colour is another element which has more impact on fifth-year students' learning than on their second-year counterparts. Fifth-year medical students are more attentive to the application of different intensities of colours in medical illustrations due to the fact that they may indicate important clinical information. With reference to visual textures, both groups of students prefer illustrations consisting of anatomical structures filled with realistic textures associated with real human material. However, fifth-year students are able to learn from anatomical structures filled with abstract textures. Shape and space have different influences on second- and fifth-year medical students' learning as the second-year group prefer to learn from shapes that portray realistic appearances of objects. Fifth-year medical students on the other hand, are able to learn abstract, rectilinear shapes of anatomical structures. In terms of size and depth, both groups prefer to perceive a section of an anatomical structure in relation to adjacent objects.

As is the case with design elements, several design principles have less impact on fifth-year medical students' learning than on their second-year counterparts. Unity and variety, as well as hierarchy and dominance show no remarkable influence on the fifth-year group, for they are able to immediately identify dominance, as well as the order of anatomical structures evident in the illustrations used for this study. Fifth-year medical students' superior clinical knowledge allows them to understand and analyse substandard to complex medical illustrations compared to the second year group.

Both groups are consistent about the relevance of proximity and repetition, as well as movement in medical illustrations. They prefer to view a pattern of similar and/or dissimilar objects and are not influenced by the appearances of arrows to demonstrate movement. Similar to shape and space, balance has different influences on second- and fifth-year medical students' learning. While second-year medical students prefer to learn from illustrations showing asymmetrical balance, their fifth-year counterparts are able to learn from objects structured symmetrically in anatomical sequence. Fifth-year medical students realise the need to learn structures in anatomical order to understand the location and function of different structures which is relevant to their clinical knowledge.

Furthermore, labelling methods, as well as the quality of reproduction, show a noteworthy influence on both groups of students when it comes to learning. Both groups of students are consistent about the organisation of labelling lines to learn from. In terms of the quality of reproduced study material, both groups prefer high quality reproduced images, especially when black and white examples of x-rays or MRIs are printed or photocopied for study guides and/or textbooks. Additionally, fifth-year medical students would immediately discard printed copies of x-rays or MRIs with a low quality, as they realise the need to gain optimal medical information from these materials when treating a patient.

Although this study selected a small group of participants, remarkable differences in opinions among these groups were evident. This chapter has shown remarkable influence of design characteristics in the use, comprehension and preferences of illustrations by second- and fifth-year medical students during learning. Differences in personal and cultural orientations, learning styles, medical knowledge, experience, interaction with various sources, multimedia as well as interaction with fellow students and educators are important factors that contribute to their selections.

The following chapter provides a new model containing a synthesis of literature, as well as the interpretation of the findings discussed in this chapter and brought into the context of second- and fifth-year medical students' learning styles within the environment of a South African medical institution. The conceptual model set out in Chapter two is used as backdrop for the new model to demonstrate the latest findings regarding the use, preference and comprehension of illustrations as a learning tool by South African medical students.

6. CHAPTER SIX

6.1 Conclusion

This chapter continues the discussion and interpretation of findings from Chapter five. The first half of the chapter provides a new conceptual model that is a synthesis of the most pertinent literature and new findings from this study. This model is the foundation for theory, as the data collected for this study were systematically analysed, interpreted and consolidated to bring new insights to the topic studied. The second half of the chapter is a reflection on the methodological rigour of this study, which includes a discussion on the contributions and limitations of the study, as well as suggestions pertaining to further research and development in medical illustrations and education.

6.1.1 *A new model: Synthesis of literature and interpretations of findings*

The new model (Figure 45) is a synthesis of literature and interpretations of findings regarding the influence that design characteristics in illustrations have on the learning of second- and fifth-year medical students of the SMFHS at UP. The conceptual model in Chapter two is used as backdrop to illustrate how second- and fifth-year medical students' use and comprehension of illustrations during studying correspond with their learning styles, as well as their use of sources within the curriculum system of the SMFHS at UP. This model demonstrates that all design elements selected for this study, except for implied lines have a notable influence on the use, comprehension and preferences of illustrations for both groups of medical students. The selected design principles, on the other hand, have a greater impact on the comprehension and preferences of the second-year group, compared to their fifth-year counterparts.

Furthermore, labelling techniques, as well as the quality of reproduction of medical illustrations which have an important influence on both groups' learning, are illustrated in the new model (Figure 45). The second- and fifth-year medical students prefer labels that are grouped around an anatomical structure in an illustration. In terms of the quality of reproduced study material, both groups prefer high quality reproduced images, especially when black-and-white examples of x-rays or MRIs are printed or photocopied for study guides.

In the new model set out in Figure 45, the second- and fifth-year medical students are represented by the same colours used in the colour charts of Chapter five. The shaded areas which are located in the middle of the model indicate preferences shared by both groups of students regarding the influence of a design characteristic within a set of illustrations.

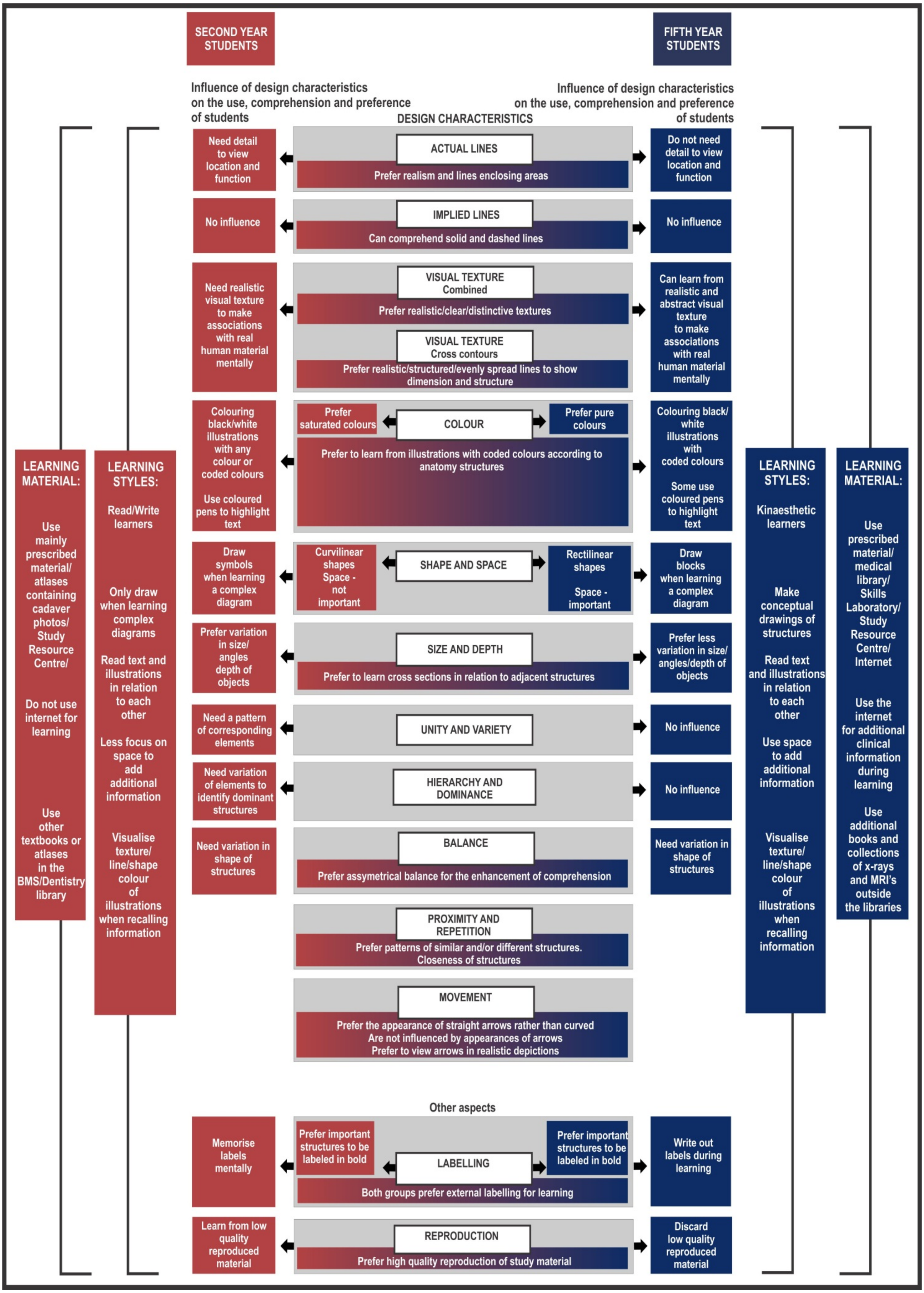


Figure 45: A new model to demonstrate the influence of design characteristics on the use, comprehension and preference of second- and fifth-year medical students at the SMFHS at UP, 2012. Created by the author.

6.1.2 *Learning styles of second-year medical students*

Figure 45 demonstrates notable differences between second- and fifth-year medical students' learning styles, as well as their use of various sources during learning within a specific learning environment. The new model (Figure 45) shows how these factors have a notable influence on the way these groups of students use, comprehend and prefer medical illustrations during learning. With these findings the importance of the careful preparation of learning material for better understanding by students within a specific learning environment are illustrated. As explained in Chapter one, the SMFHS at UP implemented a problem-orientated system as current curriculum structure where the second- and fifth-year medical students are exposed to different phases of the disciplines. This structure requires students to gain an integration of medical, as well as clinical knowledge, depending on their level of training. This curriculum structure embraces horizontal, as well as vertical thinking for students to enhance clinical and practical medical knowledge. Horizontal thinking promotes integration of knowledge between various disciplines such as anatomy, histology and physiology within themselves or each year of the curriculum. Vertical thinking includes integration of disciplines that are taught in different phases or years of the course such as the introduction to the Skills Laboratory at UP from second year of medical training.

Second-year medical students' training within the structure of the medical curriculum system of the SMFHS at UP encompasses the exposure of medical and clinical information on an introductory level. Second-year medical students have restricted medical and clinical knowledge due to their limited exposure to the clinical environment. During second-year medical training, students are mainly exposed to the dissection of cadavers, as well as the use of the Study Resource Centre. As explained in Chapter two, second-year medical students are exposed to introductory clinical training in the Skills Laboratory during the second semester.

The nature of clinical procedures conducted during dissection of cadavers is also introductory and related to dissections of different anatomical regions. Second-year medical students are also in the process of learning how to examine radiographic materials such as x-rays, MRIs and venograms. Most of the x-rays used during dissections are labelled so that second-year medical students can easily identify structures.

Second-year medical students rely on prescribed material, the Study Resource Centre and other anatomical textbooks and atlases in the BMS/Dentistry library during learning. In contrast to their fifth-year counterparts, second-year students prefer to learn from detailed and realistically drawn illustrations associated with real human anatomy. Second-year medical students need to view an anatomical structure in relation to adjacent structures to understand it as a whole. Anatomical atlases and textbooks containing cadaver photos together with illustrations of anatomical structures are generally favoured by second-year medical students, as these materials enable them to make the necessary associations and understand the location and function of structures.

Furthermore most of the second-year medical students prefer to make notes of anatomical structures instead of drawing during learning. Second-year medical students prefer to learn from a realistic illustration as it appears in an anatomical textbook or atlas. When learning complex diagrams such as the autonomic nervous system, for instance, most of the second-year students prefer to study the process directly from the source by making notes or trying to recall the facts from memory when closing the book. When studying from black-and-white illustrations, second-year medical students use any colour to fill important areas of anatomical structures and not necessarily the standard coding of colours, as explained in Chapter three.

This study has shown that second-year medical students can be categorised as read/write learners according to Fleming's VARK model (1995:309) introduced in Chapter two. Second-year medical students read the content of the illustration, as well as the text in relation to each other. This group of students does not rely on diagrams or symbols of complex structures, but they need to make notes from detailed and realistic anatomical structures for recognition and memorisation.

6.1.3 *Learning styles of fifth-year medical students*

Fifth-year medical students on the other hand, are exposed to advanced clinical procedures in the Skills Laboratory from their third year of medical training onwards. Compared to the second-year medical students, the fifth-year group uses the Medical library more frequently to obtain clinical information. Due to the fact that fifth-year medical students have superior clinical knowledge compared to second-year students, the fifth-year group has the ability to understand, for instance, the examination of x-rays and MRIs. Fifth-year medical students use various sources such as the internet and other books outside the UP medical libraries to gain sufficient information valuable to patient care. Some of the fifth-year students own collections of atlases or x-rays other than those they are exposed to during medical training. They will use the internet to look at certain clinical procedures on YouTube for better understanding. Fifth-year medical students are also more aware of ethical and administrative regulations regarding patient care, due to their exposure to the clinical environment during hospital rounds.

This study has shown that fifth-year medical students can be categorised as kinaesthetic learners according to Fleming's VARK model (Fleming 1995:309). Fifth-year medical students study illustrations in relation to text, by making rough drawings of anatomical structures and add additional information to their creations where necessary. They are able to learn from abstract concepts and diagrams derived from complex anatomical processes such as the autonomic nervous system. When learning from black-and-white illustrations of anatomical structures, fifth-year medical students would fill them with the standard coding of colours, as this group realises the important role colour plays in anatomical structures to indicate a clinical condition.

6.1.4 *Preference for drawing styles of medical illustrations*

Medical illustrations created in various drawing styles have an important influence on second- and fifth-year medical students' preferences for learning. Most of the second- and fifth-year medical students preferred medical illustrations that contain clear and realistic textures of structures that were created digitally rather than by hand. The textures applied in the hand-drawn illustrations selected for this study provided an organic feel and were drawn realistically. However, second- and fifth-year medical students preferred the clinical and smooth surfaces of structures in the illustrations generated by computer which is contrary to the findings of the study by Isenberg *et al* (2006).

With regard to preference for detail, second-year students prefer to view simplistic illustrations first before consulting complex compositions for completion of knowledge. Fifth-year medical students on the other hand, are able to consult and learn from complex illustrations from the start, due to their advanced level of medical and clinical experience.

6.1.5 *Preference for media*

Not only is the media that the illustrations are created with important, but also the way medical students interact with various media such as pen, pencil, highlighters or the mouse during learning. Second-year medical students in this study reported to use mainly highlighters to accentuate important text and labels.

The fifth-year group on the other hand, prefers to use any form of media such as pen, pencil, coloured pen or highlighters to accentuate important medical structures drawn in black and white. Fifth-year medical students will use different media when creating their own drawings of complex anatomical structures, although the standard form of colour coding of structures will be maintained. With the new model in Figure 45 as foundation, this study identify marked differences between second- and fifth-year medical students' learning styles and is able to draw conclusions about their preference and use of various media, as well as sources when learning from illustrations.

This model is therefore successful in showing how the application of design characteristics in medical illustrations influence second- and fifth-year medical students' use, comprehension and preferences of these images during learning. Due to the advanced medical and clinical knowledge pursued by the fifth-year medical students, they develop the ability to strategically use medical illustrations as a learning tool. Fifth-year medical students are able to understand illustrations of complex anatomical structures and are capable of creating simplistic diagrams of these images during learning. These learning skills of the fifth-year group can serve as foundation to assist junior medical groups in the development of learning strategies to better understand complex medical information.

6.2 Reflection on the research methodology of this study

The following section is a reflection on this study's success in accomplishing its purpose within the framework of qualitative research. Reflection is also necessary to define the reliability and validity of this study in order to determine whether the requirements of rigour in qualitative research have been reached.

Unlike quantitative studies where the focus is placed on the experimental measures of hypothesis testing and generalisation, this study selected an exploratory qualitative approach in order to understand the way medical illustrations are used by medical students as a learning tool. Exploratory qualitative research lends itself to the application of constructivism as epistemological approach. Within a constructivist framework emphasis is placed on the medical student's construction of multiple realties regarding a single aspect which brings new levels of depth to his/her interpretations based on personal experience as medical student, as well as his/her learning strategies.

This study therefore adopted a constructivist approach to grounded theory to determine how medical illustrations are comprehended and used during learning by medical students and what type of images are preferred. Data were systematically gathered, analysed and interpreted. Through this systematic process, new information was conceptualised regarding the topic under study. This ensured a platform to reflect upon findings from both the researcher as a medical illustrator, as well as from the viewpoints of medical students.

6.2.1. *The aim and objectives of this study*

The aim of the study was to explore how design characteristics influence the use, comprehension and preference of medical illustrations as part of the learning experience. In this study the focus was on undergraduate medical students. The objectives of this study was to determine the influence of design characteristics on 1) how students use medical illustrations; 2) the way students comprehend the content of illustrations during learning; and 3) the salient preferences they have for certain illustrations.

Overall, this study was able to demonstrate the important influence design characteristics had on second- and fifth-year medical students' use, comprehension and preference of illustrations for learning purposes. As explained in Chapter three, the design characteristics selected for this study, were based on the perspectives of a group of seminal authors and were limited to a smaller selection that were practical to be implemented in one study. Due to the accessibility of a large number of medical textbooks and atlases, only the collection of anatomical and physiological sources in the BMS/Dentistry library was used for this study, as well as several books available in the Department of Anatomy. Most of these sources form part of the list of prescribed material for second- to fourth-year medical students.

Illustrations were firstly selected according to the availability of three or more different representations of one anatomical structure or process. Illustrations were then also selected according to the availability of different attributes of a selected design characteristic present. In certain instances, when no suitable samples were available, illustrations were altered to accentuate attributes of certain design characteristics selected for this study. Regardless of these limitations, a wide range of illustrations was collected demonstrating more than one variation of the same anatomical or physiological structure and applied in different features of each design characteristic selected for this study. The selection of illustrations was also representative of what medical students should be familiar with regarding anatomy and physiology.

This study was able to show that design characteristics listed in the new model (Figure 45) influenced the use, comprehension and preferences of illustrations by second- and fifth-year medical students during learning. Although the main purpose of this study was not a comparison between second- and fifth-year medical students when using illustrations as a learning tool, comparative factors were noted which are valuable. Deeper understanding was gained regarding second- and fifth-year medical students' learning styles, their use of various sources and media, drawing abilities and preference for certain drawing styles over others. These factors were valuable to determine the influence of design characteristics in illustrations on second- and fifth-year medical students during learning.

6.2.2 *Validity and reliability*

As mentioned previously, it is important to determine the validity and reliability of this study in order to evaluate its stability, quality and rigour within the framework of qualitative research. Although reliability and validity are generally recognised within a logical positivism or quantitative approach, their position within qualitative studies are also necessary to determine the quality and stability of the research.

According to Golafshani (2003:600) reliability and validity are not viewed separately within qualitative research and encompass factors such as transferability, credibility and trustworthiness. While credibility in quantitative research depends on instrument construction, the credibility of qualitative research depends on the ability and effort of the researcher (Patton in Golafshani

2003:600). The relevance of validity and reliability evident in this study are now discussed with reference to this study's research methods.

6.2.2.1 *Conceptual framework*

The first measure implemented to enhance the validity and reliability of this study was the strong reliance on a conceptual framework formulated on the foundation of recent literature. This study started with a literature review that served as background in order to outline the role of medical illustrations in an educational environment. The outcome of the literature review was a conceptual model presented in Chapter two, summarising possible learning styles of students as well as the position of the medical illustrator against the backdrop of the medical educational environment of the SMFHS at UP.

This initial model is more than a summary of all the literature, as it encompasses the researcher's knowledge and experience as medical illustrator at the SMFHS at UP. In line with the epistemological framework of this study, the researcher allowed her own knowledge to form part of the interpretive process from the initial stages and throughout the study.

This initial exploration, analysis and interpretation of the context in which the study is situated, served as foundation. This information guided the selection of illustrations for the next phase and set the stage for the later interpretation of the findings. This initial model, demonstrated in Chapter two, enhances the reliability and validity of this study, as it includes important aspects from recent literature to which this study hopes to contribute. This model also included information relevant within the context of the educational environment of South Africa. Limitations and shortcomings specifically experienced in the South African educational system such as budget constraints, lack of academic preparedness and multilingualism would not necessarily have relevance if this study were to be conducted internationally. These endemic factors were considered in this study, as they have an impact on teaching strategies and the development of dynamic skills used by educational designers and illustrators in South Africa.

For future research, a similar model can serve as a foundation to identify various other learning and teaching strategies, as well as other factors pertinent within the curriculum of an institution. The role and position of illustrators, as well as educational designers within such a system can then be determined and analysed.

6.2.2.2 *Data collection by means of in-depth interviews*

Reliability and validity in qualitative research are also enhanced when the procedures implemented during the research process fit the theoretical approach. This study focused on research methods that generate deeper insights regarding the topic under study. These methods are in line with the epistemological approach selected for this study, namely constructivism which acknowledges the importance of multiple realities (Golafshani 2003:603;604). Specific decisions were implemented during data collection to enhance the reliability and validity of this study.

Potential participants were selected by means of non-probability purposeful sampling and were randomly selected from class lists obtained from the anatomy department. At the beginning of the interview the researcher introduced the objective of the study to the participant and explained the structure of the interview. After permission was granted, the interviews proceeded.

The discussion guide used for interviews consisted of 15 sets of medical illustrations with three or four images per set. With reference to the first 13 sets of illustrations, each set represented a design characteristic selected for this study. Illustrations within each set contained a different application of the same design characteristic, but similar in content or nature of information. Examples of the illustrations were based on Anatomy and Physiology as these disciplines form the foundation of medical training. All students were exposed to the same sets of illustrations which provided consistency to the study, so that differences and comparisons of students' opinions could be documented.

Data were collected by means of semi-structured interviews in which care was taken to probe for deeper understanding of multiple realties. Open-ended questions were asked to explore participants' opinions regarding medical illustrations as a learning tool. Open-ended questions enhanced the validity and reliability of this study because they created a platform for a structured approach to questioning where students provided interpretations based on their personal experiences and preferences regarding the illustrations. The introduction of the illustrations was structured to ensure that all students were exposed to the same sets of design characteristics.

Furthermore, the largest part of the interview was an adaptation of the RGI technique which is a method of organising and comparing rich data from participants during a structured and reflective process. The RGI method ensures a flexible though structured foundation to organise various sets of illustrations, as well as participants' own understandings of the illustrations under study. The RGI technique has a natural fit with constructivism as epistemological approach selected for this study, as it incorporates research bias and allows co-construction of meaning. This method enabled the researcher to seek comparisons and variations within the raw data and determined the relevance of design characteristics in illustrations for both groups of students' learning respectively. In essence, the RGI method as applied in this study allowed for rich information gathering, yet still in a systematic manner, that would not have been possible using alternatives such as questionnaires.

Approval from various committees was necessary before this study could be conducted[24]. Strict measures were taken to ensure confidentiality and non-coercion of information provided by participants[25]. According to UP's ethical standards, original recordings and transcriptions of interviews are archived at the Department of Visual Arts for 15 years.

6.2.2.3 *Data analysis*

Effort was also made to enhance the reliability and validity of this study through specific strategies during data analysis and interpretation. As mentioned previously the data sheets adopted the structure of the RGI method and were systematically gathered and analysed through the principles of grounded theory. The analysis of data sheets remained loosely structured and open in order to allow new factors to emerge regarding the use of medical illustrations as a learning tool. According to Strauss *et al* (1998:12) grounded theory is likely to offer insight, enhance understanding and serve as a meaningful guide to the formulation of theory. This proved to be true in this study.

The data sheets were perused several times to determine comparisons and differences between second- and fifth-year medical students' interpretations of the illustrations for learning purposes. Through the application of open and axial coding both groups of students' own personal understandings or constructs were identified, listed and analysed in conjunction with their learning styles as well as attributes of the design characteristics selected for this study.

Open coding is important as it is used to break up raw data in order to determine the logic that lies behind analysis (Strauss *et al* 1998:101). Open coding increased the reliability and validity of this study, as it would allow other researchers to conduct related studies by following a similar methodological path, however, with the understanding that the researcher uses his/her background of existing knowledge to arrive at slightly different conclusions. Although different forms of open coding can be used as explained in Chapter four, this study used a method of open coding by analysing a whole sentence or paragraph as part of students' comments to define their understanding of an illustration. This method enhanced the reliability and validity of this study, because it remained as close as possible to the students' own interpretation of their experiences.

Furthermore, axial coding was used for this study that allows the researcher to reassemble fractured data in order to identify further comparisons and relations regarding the topic under study. Axial coding was essential in order to understand underlying conditions with reference to the participant's categorisation of illustrations for learning. Relations between students' medical experience and knowledge within a specific learning environment, as well as their preference for

[24] Approval was initially obtained from the Ethics and Research committees in the Faculty of Humanities at UP. Permission was then obtained from the Deputy Dean of the School of Medicine at UP to involve medical students in this research.

[25] A consent form was signed by the participant if he/she agreed to participate in the study. The participant's permission was then asked to be audio taped during the duration of the interview.

drawing styles and drawing abilities were taken into account through axial coding to determine the impact of illustrations' design characteristics on their learning. Open and axial coding applied in this study contributed to the consistency of analysing raw data for interpretation. These procedures could be replicated by other researchers, even though they may arrive at different conclusions.

A limitation of the data analysis would be a restriction in terms of time, since the process to analyse data depended on the interpretation of the researcher. The volume of transcripts formulated from the interviews varied between 17 – 30 pages per participant. However, without this scope of data, this study would not have yielded such depths of understanding.

6.2.2.4 *Interpretation and synthesis of data*

The conceptual model set out in Chapter two was used as general framework to interpret and synthesise findings from the current study and to test the relevance of the developments in literature for the South African context. Summarised colour charts were created for each set of illustrations based on analysed data to interpret and demonstrate the order of preference between the second- and fifth-year medical students respectively.

The colour charts are clear visual summaries of preferences and show the number of students who selected an illustration within a certain preference. The format of these charts is dynamic to be used for future research on different groups of medical students or medical illustrators. The outcome of the interpretation process was formulated and synthesised within a new conceptual model demonstrated in Figure 45 which incorporated new findings relevant to a South African medical educational environment. This model is a dynamic and versatile tool which can be used for further research into other medical educational institutions or practices specialising in the field of illustration.

6.3 Limitations of this study

6.3.1 *Sampling*

One of the limitations of this study is the selection of the sample. Six medical students in their second year and six in their fifth year of study at the SMFHS of UP were purposively selected to determine how differences in their level of medical experiences and knowledge impact their perception of medical illustrations during learning. The sample of this study was relatively small because of the qualitative framework in which it was implemented. Future studies may wish to use a larger sample to the test the differences and similarities between other sub-groups of students, such as third- and fourth-year medical students. Different medical schools can be used for these studies which could include students of more diverse range of years of studies or those who experience colour blindness.

6.3.2 *Design characteristics*

Due to the scope of this study it was not possible to use more than 12 design characteristics. Although this study only focused on the relevance of one design characteristic per illustration, more than one design characteristic could be applicable which may influence the outcome of participants' interpretations. In some cases other design characteristics other than those selected for this study were identified by participants as favourable and/or problematic. Further research is necessary to determine combined influences of a combination of design characteristics in medical illustrations for learning purposes.

For this study only illustrations related to physiology and anatomy were used. Further research is necessary to determine the relevance of design characteristics in illustrations from other medical disciplines such as histology or family medicine.

6.3.3 *The RGI method*

The RGI method ensures a flexible though structured foundation to organise various sets of illustrations, as well as participants' own understandings of the illustrations under study. For this study, illustrations or elements were selected beforehand by the researcher as the images had to be representative of a specific design characteristic. Van Kan *et al* (2010:1555) are of the opinion that participants should be actively involved in the selection process of the elements. When the elements are provided by the researcher, participants' freedom to select elements that are meaningful to themselves is compromised (van Kan *et al* 2010:1555). Both groups of participants were familiar with most of the illustrations selected for this study, although a few illustrations were altered to accentuate attributes of certain design characteristic selected for this study. Future research is therefore necessary to determine the outcome when medical students select their own illustrations originating from prescribed material or other sources accessible to them.

6.4 Suggestions for future research

Several suggestions emerge from this study that can be valuable for future research. The same sets of illustrations in the discussion guide formulated for this study can be used for future research on other groups of medical students such as third and fourth years or students who study in other medical disciplines such as nursing or dentistry. During interview sessions students can be requested to create their own drawings of anatomical structures or to provide rough drawings from previous study sessions. Examining medical students' own conceptualisations of anatomical structures will provide deeper insight into how they comprehend these structures. Better understanding in terms of the influence of design characteristics on medical students' use of illustrations could also be obtained. More information regarding medical students' preference for media during learning, as well as deeper understanding of their learning styles can be gained.

There is a need for further research by conducting similar studies in other medical schools in South Africa and abroad to determine the influence of design characteristics in medical illustrations on the learning of students at these institutions. In the current medical educational environment, these comparisons would add to the understanding of the importance of the construction and design of medical illustrations for learning purposes. In this this study no participants with colour blindness could be found. Future research could be conducted to determine the influence of design characteristics in illustrations on the learning of medical students with colour blindness.

This study opens up the possibility of research collaboration with other medical illustrators in South Africa and abroad. Through effective collaboration, the current role of illustrations in the fields of medical science, research and technology can be developed. The role of the medical illustrator also needs to be evaluated through collaboration, due to continuous developments in technology and the restructuring of educational environments.

6.5 Contributions to the field of medical illustration

The planning and application of design elements and principles in medical illustrations have important implications for medical illustrators, especially when these images have to be used for learning and teaching purposes. This study has shown the importance of design characteristics in medical illustrations, for they are essential to emphasise appearance, function and location of anatomical and physiological structures and processes. Careful planning of the structure and combination of design characteristics in medical illustrations remains important when used for learning purposes, as these images have to portray realism and accuracy. The importance of the quality of the reproduction of study material, as well as the application and nature of label lines in illustrations and diagrams is also illustrated by this study, showing how they are preferred by medical students for better understanding.

In South Africa medical illustrators, educational designers and educators working in tertiary institutions are often forced to use limited dynamic technological resources for the enhancement of learning, due to an unremitting decline in budgets. This study accentuates the necessity of promoting close collaboration amongst illustrators, physicians and educators in order to design and create illustrations that meet the learning needs of medical students on different levels of training. The quality and content of medical illustrations have to meet the requirements of medical educational institutions' curriculum systems in order to enhance teaching and learning skills.

This study set the foundation for collaboration with medical students which is necessary to enhance the position of medical illustration in education and research. Medical students are the users of learning material and collaboration with them can provide valuable contributions to the development of user-centred design. Students' opinions on medical illustrations can indicate whether an image is understandable and practical for students at a specific level of medical training.

With reference to the field of medical illustration, this study has shown the importance of having knowledge of medical disciplines such as anatomy and physiology in order to apply this knowledge when creating illustrations for learning purposes. Illustrators specialising in similar fields such as veterinary science or botanical illustration will also benefit from gaining sufficient knowledge in their field, in order to create understandable representations of complex processes for learning purposes. Reflection on created illustrations is essential to determine the sufficiency of the illustrations especially when used for learning purposes.

6.6 Personal reflection of the medical illustrator

This study empowered the researcher in her capacity as a full-time medical illustrator to determine the efficiency of illustrations selected when created for learning purposes. The challenge was to move from the role of illustrator to the role of academic researcher. The researcher had to accept and understand the second- and fifth-year medical students' interpretations of her own work when it was not selected as first preference for learning. During interviews with students the researcher was able to enrich her own personal orientation with new meaning and knowledge generated through the interviews. Both groups of students provided new scientific and medical knowledge based on what is learned from anatomical textbooks, atlases and other sources such as cadaver dissections, classroom discussions and clinical rounds in hospitals. The researcher used students' medical knowledge as reference to determine the usability and sufficiency of the illustrations for learning purposes. New insights were obtained about the usability and practicality of medical illustrations within the structure of the current curriculum at the SMFHS at UP.

6.7 Conclusion

This study has shown the importance of careful planning when combining design characteristics in medical illustrations for learning purposes. Design elements in medical illustrations determine the structure, dimension, location, aesthetical qualities, appearances and functionalities of anatomical structures for readers to identify and recognise. Design principles, on the other hand, are necessary to structure and organise design elements into a unified whole to enhance comprehension, especially when complex anatomical and physiological processes are displayed. Besides these important design decisions, the medical illustrator has to be aware of students' experience levels regarding a discipline, visual perception, visual literacy skills, spatial abilities, learning strategies and socio-economic backgrounds when constructing and designing illustrations for learning purposes.

Furthermore, the selection of media is essential when creating anatomical structures, as various aesthetic effects are produced which can generate different meanings. Decisions whether to create a medical structure in colour or black-and-white or in various media, depend on the amount of detail, structure and dimensions needed to be demonstrated when these are created for learning purposes. This study has also shown the importance of the application, appearance and position of symbols such as arrows, when used in animated medical structures or processes. The application of arrows in medical illustrations is vital, as medical students depend on these symbols, especially when an image is not clear.

The quality of the reproduction of study material such as study guides is essential especially when radiographic material such as x-rays, MRIs and venograms are incorporated. This study also showed the importance of the application of labelling methods when used in medical illustrations. These methods are essential when directing the reader's eye between the text and structures, especially when a large amount of detail is portrayed.

This study generated deeper understanding regarding the use, comprehension and preferences of illustrations by second- and fifth-year medical students. Deeper insights concerning their learning styles, as well as their use of media during learning were obtained. More information concerning the second- and fifth-year medical students' preferences for various anatomical and physiological textbooks and atlases during learning have also been gained. This information is important for educators and medical illustrators when planning and designing illustrations for learning and teaching purposes.

South African tertiary institutions are affected by various endemic challenges. Factors such as increasing pressure from government to meet social transformation needs, the lack of academic preparedness, the rapid growth in student numbers in classes and multilingualism are challenges these groups of people continuously face. Illustrators and educational designers who work in these environments are forced to create dynamic visual material for learning and teaching purposes with limited dynamic resources for certain periods of time due to budget constraints and severe regulations. With the high costs of colour printing, for instance, study guides at the SMFHS at UP are generally printed in black-and-white which force illustrators and educators to plan the structure and layout of these study material in such a way to be sufficient for learning purposes. One of the study guides currently used in the Department of Anatomy at the SMFHS at UP has already been transformed due to the information gained from this study. However, close collaboration with educators, physicians, as well as students remains essential in order to create understandable illustrations that meet the standards and requirements of a medical educational institution.

In essence, this study has accomplished its aim and objectives. The important role of the illustrator to communicate complex medical information visually has also been accentuated. The founding of associations for medical illustrators such as the AMI and IMI, as well as the establishment of institutions presenting collective courses in science and illustration create the foundation for continuous development of visual material within the fields of medical research and education. Medical illustration as a profession in South Africa, however, is still in its infancy and no degree or course is currently offered for medical illustrators. This study emphasises the need to develop programmes or courses in medical illustration for illustrators in South Africa, in order to enhance medical knowledge and visual skills when creating medical and scientific visual material for learning and teaching purposes. The development of medical illustration programmes or courses in South Africa would improve the role of the medical illustrator in the fields of research, education and technology and enhance the development of close collaboration with fellow medical illustrators and educational designers.

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APPENDIX A: THE DISCUSSION GUIDE FOR INTERVIEWS

Recruitment questionnaire

Students will be phoned and asked whether they want to participate in this study individually. The nature, purpose and duration of this study will be explained. Demographic information such as gender and ethnicity are already obtained from the class lists. If he/she are willing to participate, the following question will be asked:

Question 1: Do you experience colour blindness or any problems with sight?
The participant may answer yes or no. If yes, it gives the interviewer an indication he/she may experience the perception of medical illustrations differently, which can serve as a valid contribution to the study. If the participant answers no, he/she will not be disqualified from this study.

A date and time is set for the interview to take place.

The day of the interview

The participant is thanked for his/her time to meet for the interview. The participant will be informed of the purpose of the study which will be positioned as a study to obtain more information about their use, preferences and comprehension of medical illustrations during learning.

While the consent form will be handed over to the participant, the interviewer will further explain how the aim of this study is to make a valid contribution to the future of medical education and illustration. The interviewer will explain to the participant how she believe the contributions of the participant may provide new insights to the way medical structures are educated and illustrated to enhance learning.

The duration of the interview should not be longer than 45 minutes.

The interviewer will present fourteen sets of three to five contrarily created medical illustrations of similar content. Each set will be presented to the participant for him/her to select the most appropriate illustration to learn from. The participant will then be asked to elaborate on his/her selection in the form of an informal discussion. The participant needs to make a further selection between the rest of the illustrations of the set and elaborate on the choices made. The conversation between the participant and interviewer will be audio recorded to allow transcribing and further analysis. The interviewer will make notes where participant refers to a specific area of interest on an illustration.

Opportunity for questions from the participant will be provided.

The participant signs the form of consent and gives permission to proceed.

Questions

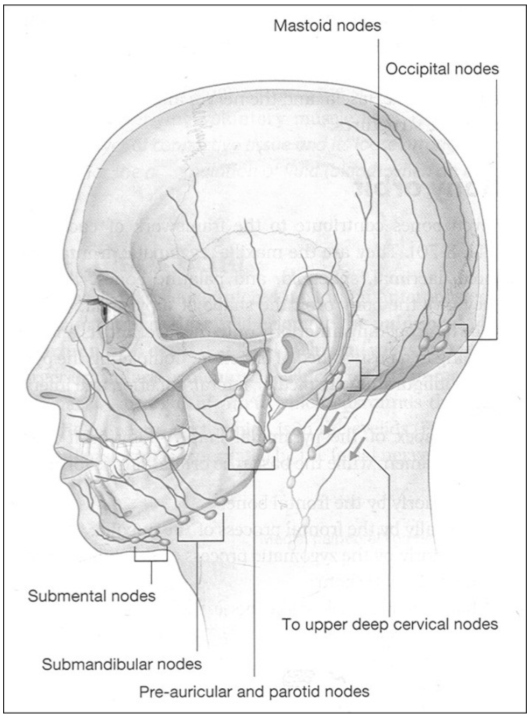
Design elements

Line

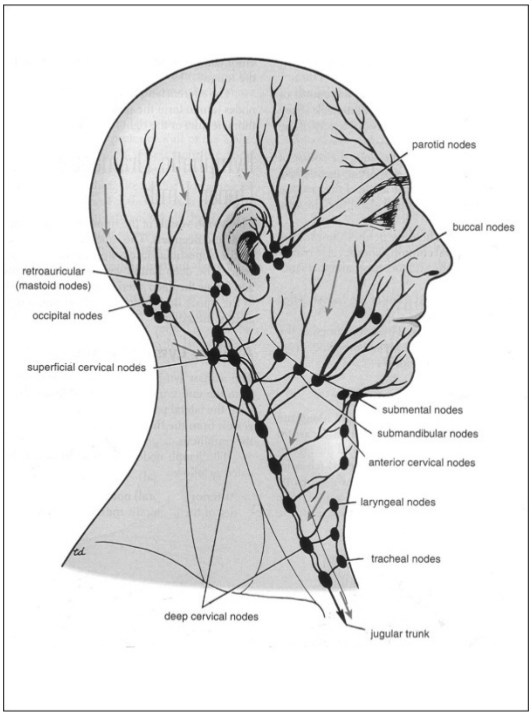
Actual lines

Present the four examples of illustrations about lymph drainage in the scalp and face. If you had to pick one of these illustrations to learn the lymph drainage in the scalp and face from, which one would you use? Why do you prefer this one? How does this picture aid comprehension? Between the two other pictures, which one do you prefer the most? Please elaborate.

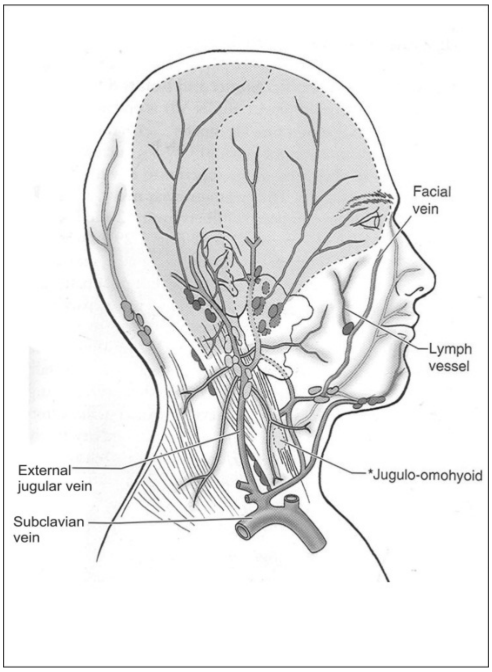
D1



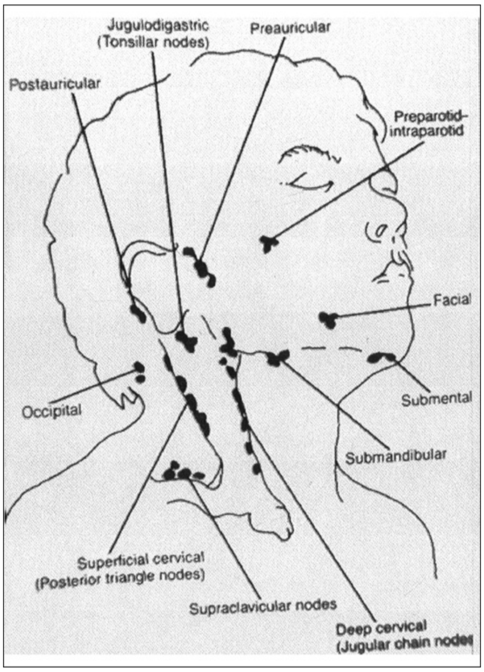
B2



A3



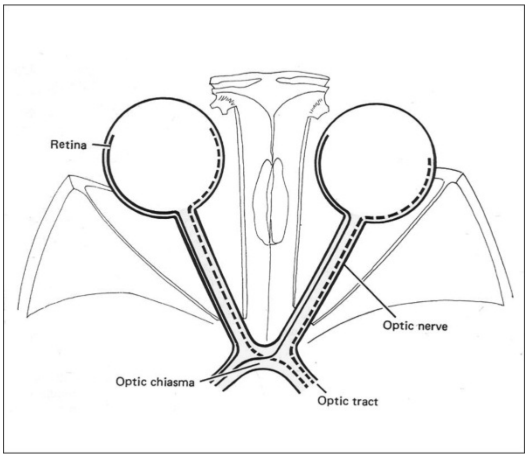
C4



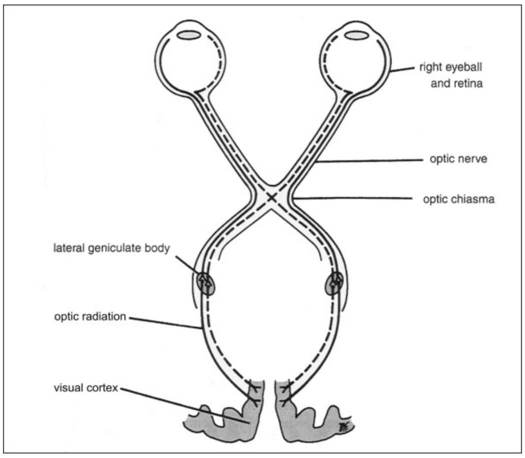
Implied lines

Present the four examples of illustrations about the optic nerve. Which illustration would you prefer and understand to learn the optic nerve from and why? Between the other three pictures, which one do you prefer the most? Please elaborate.

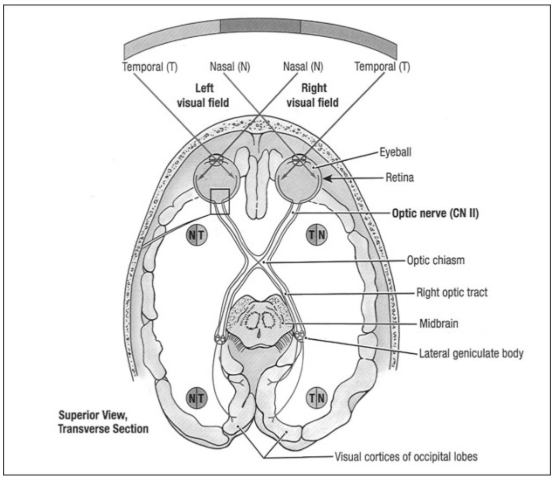
D5



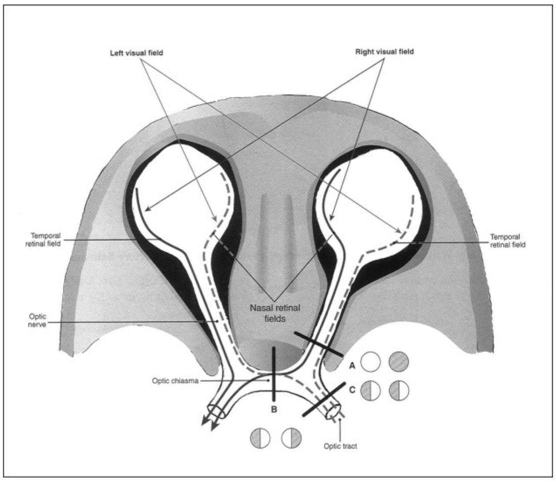
B6



A7



C8

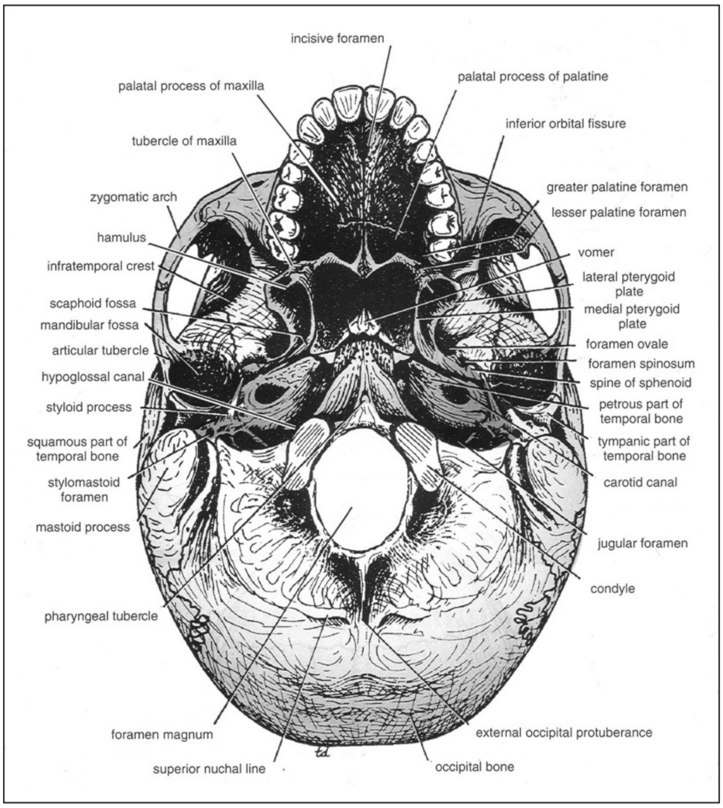


Visual texture

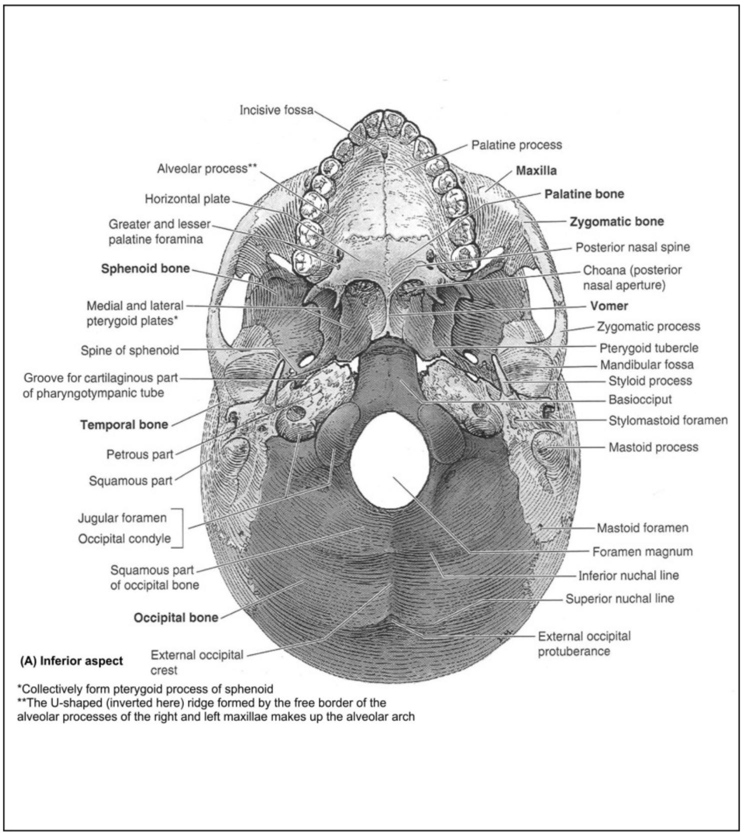
Cross-contour line textures

Present the three examples of illustrations about the inferior surface of the base of the scull. Which illustration would you prefer to learn the inferior view of the base of the scalp from and why? Between the other two pictures, which one do you prefer the most? Please elaborate.

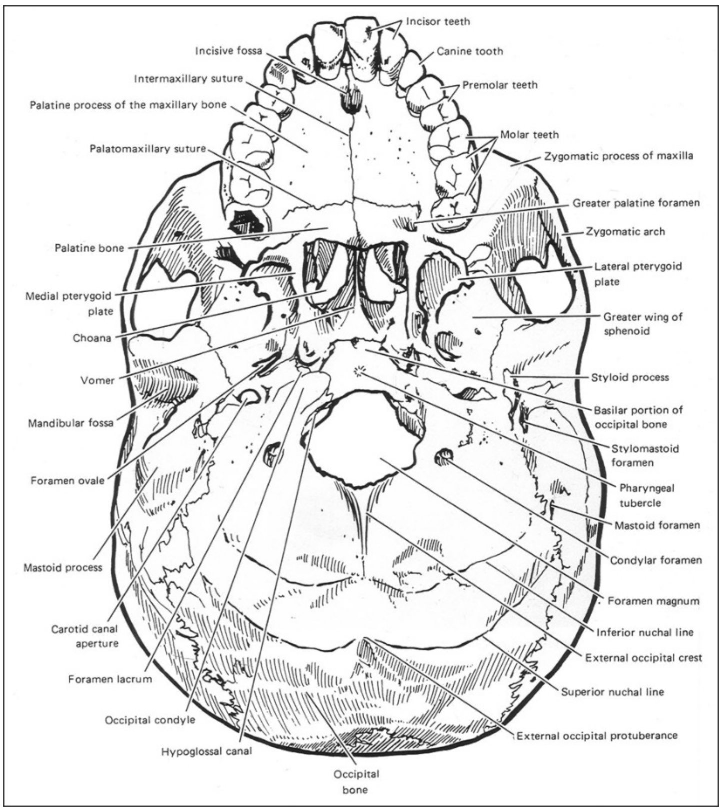
D9



B10


Incisive fossa
Palatine process
Alveolar process**
Maxilla
Horizontal plate
Palatine bone
Greater and lesser palatine foramina
Zygomatic bone
Posterior nasal spine
Sphenoid bone
Choana (posterior nasal aperture)
Medial and lateral pterygoid plates*
Vomer
Zygomatic process
Spine of sphenoid
Pterygoid tubercle
Mandibular fossa
Groove for cartilaginous part of pharyngotympanic tube
Styloid process
Basiocciput
Temporal bone
Stylomastoid foramen
Petrous part
Mastoid process
Squamous part
Jugular foramen
Occipital condyle
Mastoid foramen
Foramen magnum
Squamous part of occipital bone
Inferior nuchal line
Superior nuchal line
Occipital bone
External occipital protuberance
(A) Inferior aspect
External occipital crest
*Collectively form pterygoid process of sphenoid
**The U-shaped (inverted here) ridge formed by the free border of the alveolar processes of the right and left maxillae makes up the alveolar arch

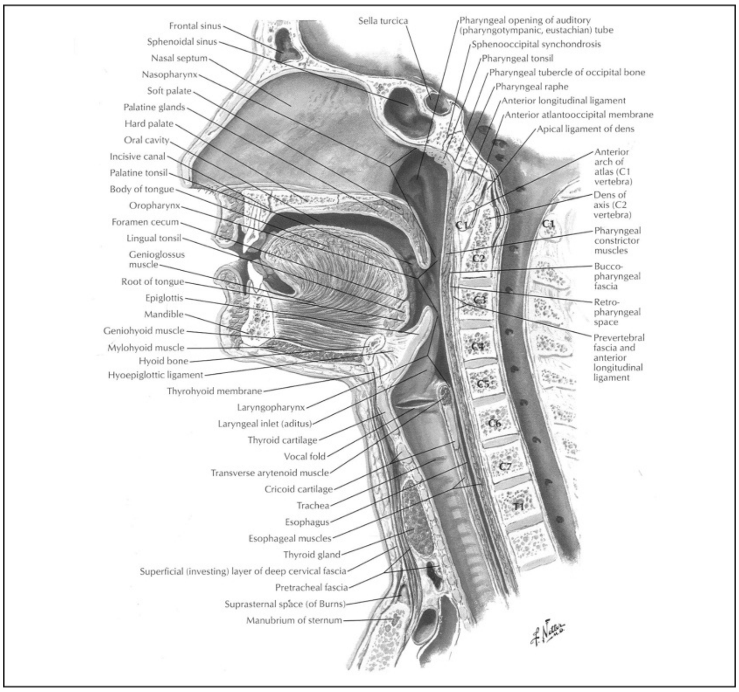
A11


Incisor teeth
Canine tooth
Incisive fossa
Intermaxillary suture
Premolar teeth
Palatine process of the maxillary bone
Molar teeth
Palatomaxillary suture
Zygomatic process of maxilla
Greater palatine foramen
Zygomatic arch
Palatine bone
Lateral pterygoid plate
Medial pterygoid plate
Greater wing of sphenoid
Choana
Vomer
Styloid process
Basilar portion of occipital bone
Mandibular fossa
Stylomastoid foramen
Foramen ovale
Pharyngeal tubercle
Mastoid foramen
Mastoid process
Condylar foramen
Foramen magnum
Carotid canal aperture
Inferior nuchal line
External occipital crest
Foramen lacrum
Superior nuchal line
Occipital condyle
External occipital protuberance
Hypoglossal canal
Occipital bone

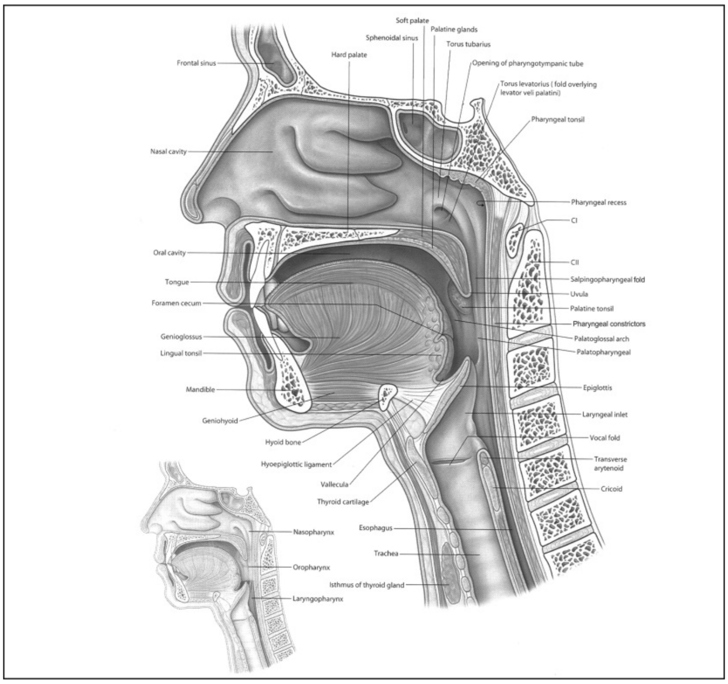
Combined textures

Present the four examples of illustrations about the median section of the pharynx. Which illustration would you prefer to learn the median section of the pharynx from and why? Between the other four pictures, which one do you prefer the most? Please elaborate.

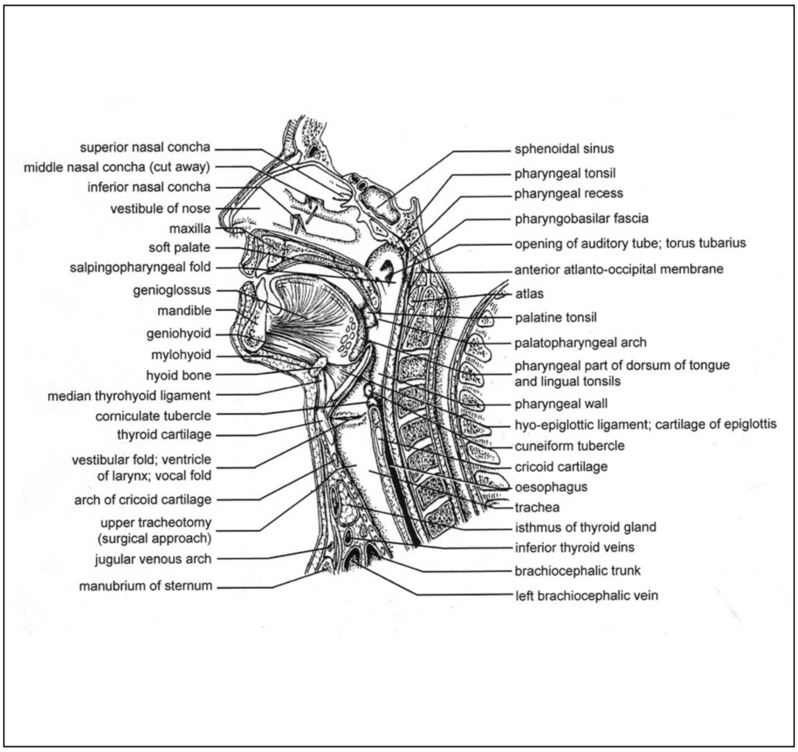
D12



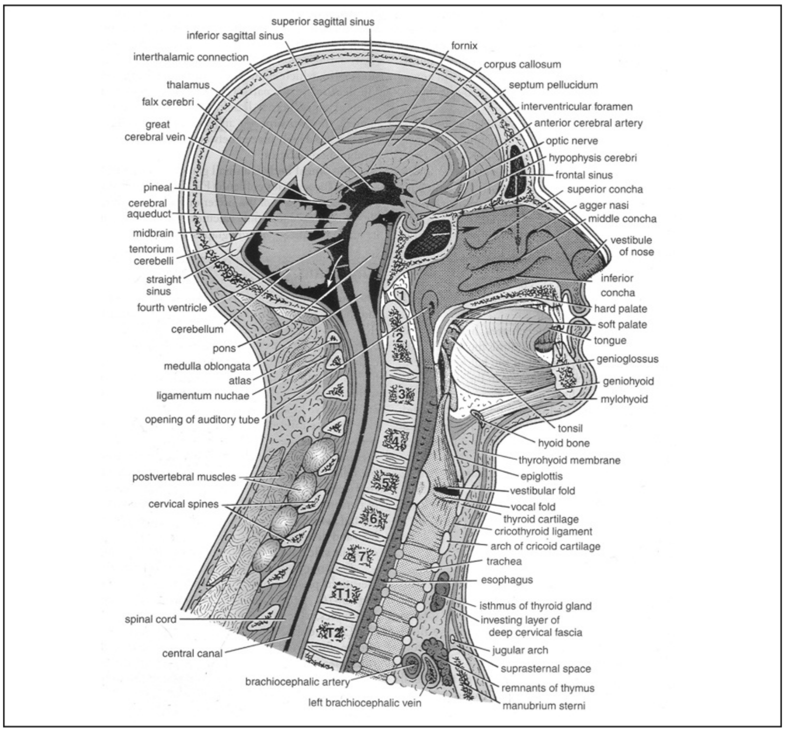
B13



A14


superior nasal concha
middle nasal concha (cut away)
inferior nasal concha
vestibule of nose
maxilla
soft palate
salpingopharyngeal fold
genioglossus
mandible
geniohyoid
mylohyoid
hyoid bone
median thyrohyoid ligament
corniculate tubercle
thyroid cartilage
vestibular fold; ventricle
of larynx; vocal fold
arch of cricoid cartilage
upper tracheotomy
(surgical approach)
jugular venous arch
manubrium of sternum
sphenoidal sinus
pharyngeal tonsil
pharyngeal recess
pharyngobasilar fascia
opening of auditory tube; torus tubarius
anterior atlanto-occipital membrane
atlas
palatine tonsil
palatopharyngeal arch
pharyngeal part of dorsum of tongue
and lingual tonsils
pharyngeal wall
hyo-epiglottic ligament; cartilage of epiglottis
cuneiform tubercle
cricoid cartilage
oesophagus
trachea
isthmus of thyroid gland
inferior thyroid veins
brachiocephalic trunk
left brachiocephalic vein

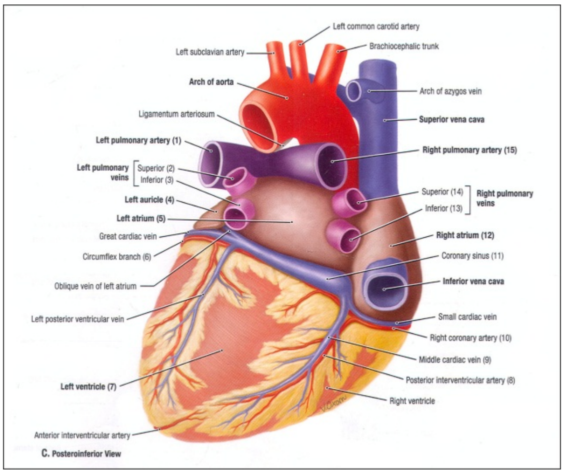
C15


superior sagittal sinus
inferior sagittal sinus
interthalamic connection
thalamus
falx cerebri
great
cerebral vein
pineal
cerebral
aqueduct
midbrain
tentorium
cerebelli
straight
sinus
fourth ventricle
cerebellum
pons
medulla oblongata
atlas
ligamentum nuchae
opening of auditory tube
postvertebral muscles
cervical spines
spinal cord
central canal
brachiocephalic artery
left brachiocephalic vein
fornix
corpus callosum
septum pellucidum
interventricular foramen
anterior cerebral artery
optic nerve
hypophysis cerebri
frontal sinus
superior concha
agger nasi
middle concha
vestibule
of nose
inferior
concha
hard palate
soft palate
tongue
genioglossus
geniohyoid
mylohyoid
tonsil
hyoid bone
thyrohyoid membrane
epiglottis
vestibular fold
vocal fold
thyroid cartilage
cricothyroid ligament
arch of cricoid cartilage
trachea
esophagus
isthmus of thyroid gland
investing layer of
deep cervical fascia
jugular arch
suprasternal space
remnants of thymus
manubrium sterni

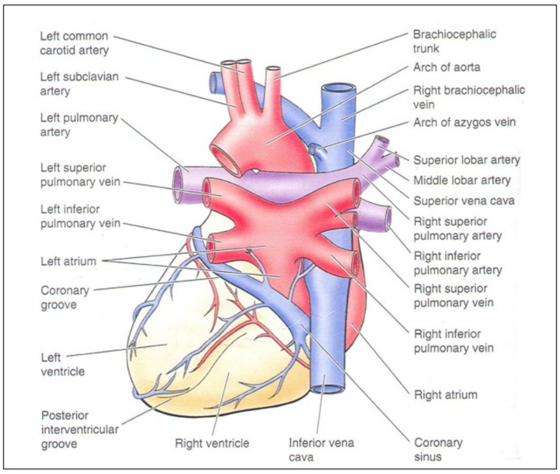
Colour

Present the four examples of illustrations about the surface of the heart. Which illustration would you prefer to learn the surface of the heart from and why? Between the other three pictures, which one do you prefer the most? Please elaborate.

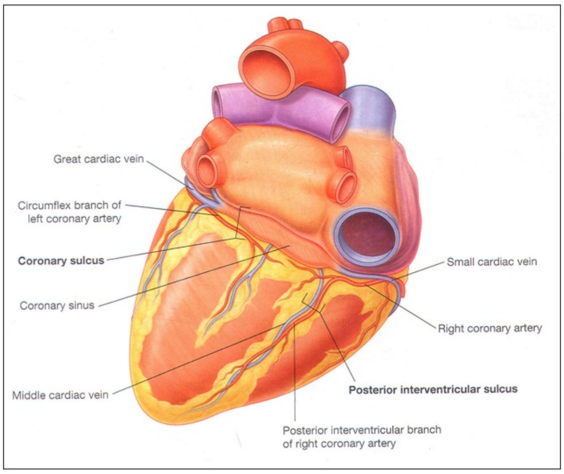
D16



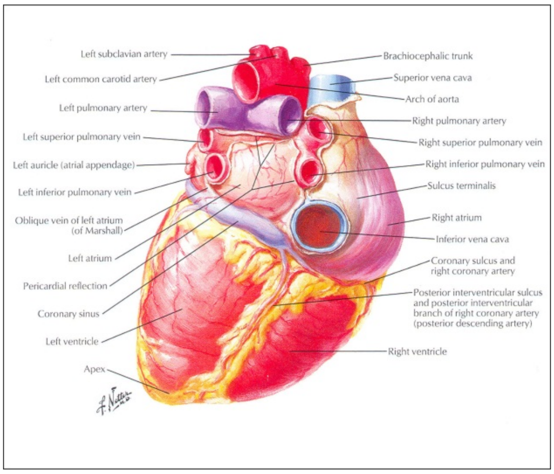
B17



A18



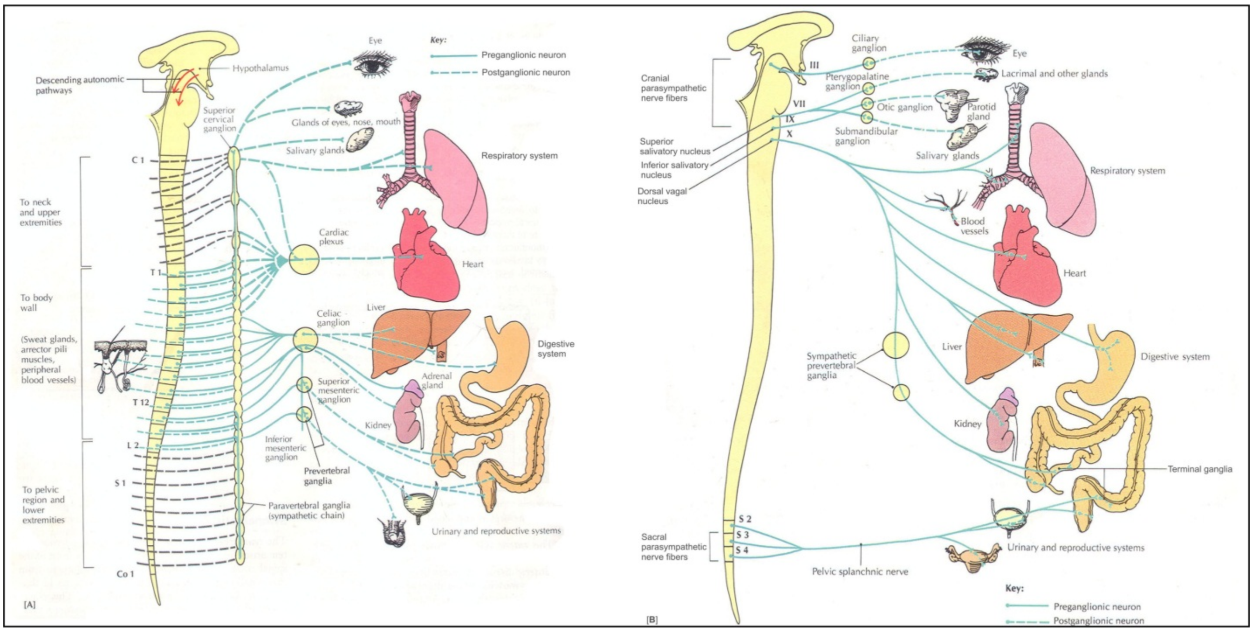
C19



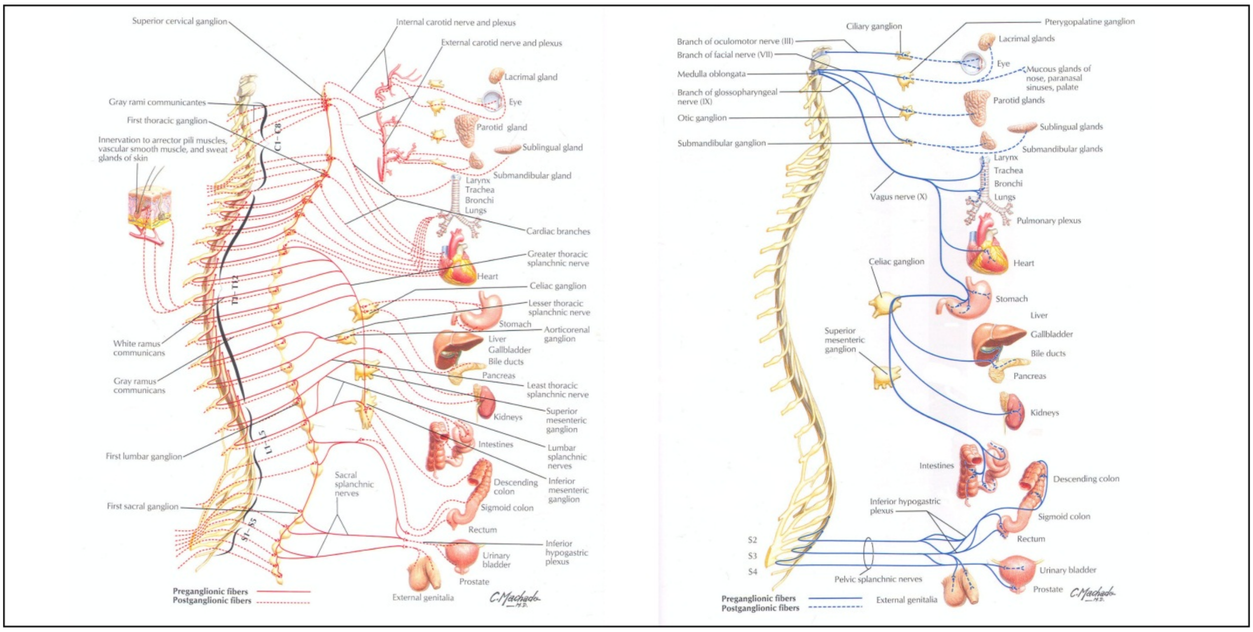
Shape and space

Present the four examples of the autonomic nervous system. Which illustration would you prefer and understand to learn the autonomic nervous system from and why? Between the other three pictures, which one do you prefer the most? Please elaborate.

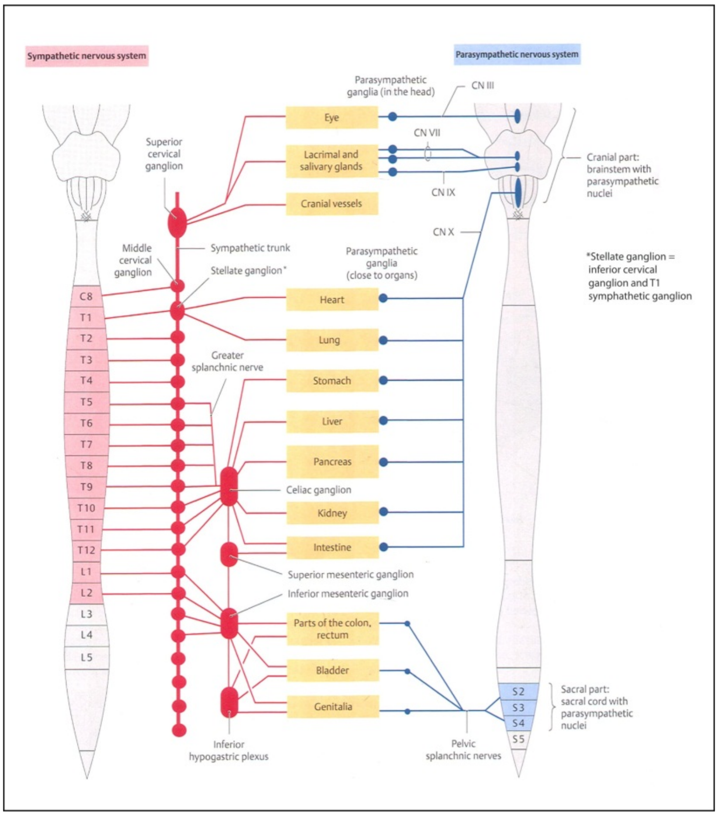
D20


Key:
Preganglionic neuron
Postganglionic neuron
Descending autonomic pathways
Hypothalamus
Superior cervical ganglion
Eye
Glands of eyes, nose, mouth
Salivary glands
Respiratory system
Cardiac plexus
Heart
Celiac ganglion
Liver
Digestive system
Adrenal gland
Superior mesenteric ganglion
Kidney
Inferior mesenteric ganglion
Prevertebral ganglia
Paravertebral ganglia (sympathetic chain)
Urinary and reproductive systems
To neck and upper extremities
To body wall
(Sweat glands, arrector pili muscles, peripheral blood vessels)
To pelvic region and lower extremities
[A]
Cranial parasympathetic nerve fibers
Superior salivatory nucleus
Inferior salivatory nucleus
Dorsal vagal nucleus
Ciliary ganglion
Pterygopalatine ganglion
Otic ganglion
Submandibular ganglion
Lacrimal and other glands
Parotid gland
Blood vessels
Sympathetic prevertebral ganglia
Terminal ganglia
Sacral parasympathetic nerve fibers
Pelvic splanchnic nerve
[B]

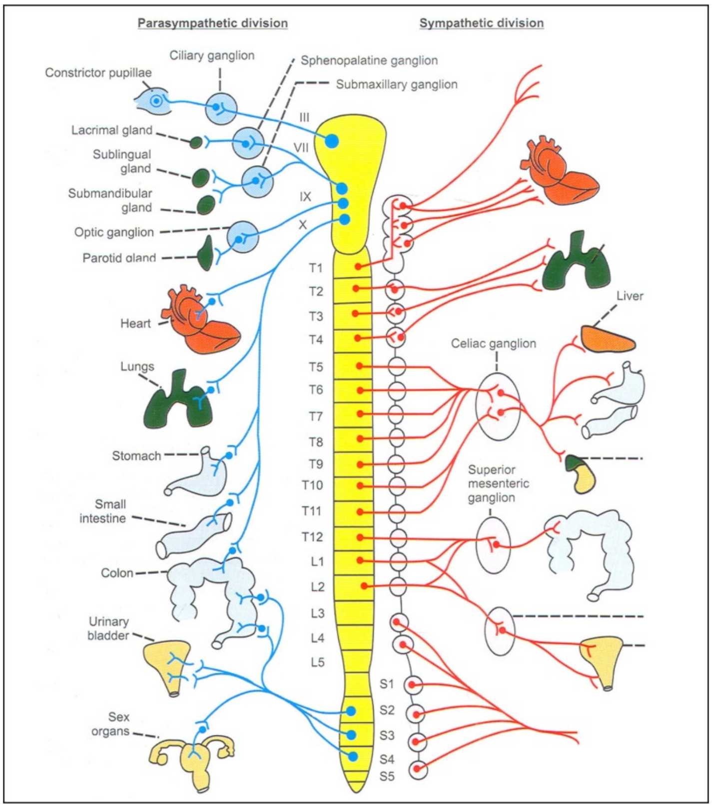
B21


Superior cervical ganglion
Internal carotid nerve and plexus
External carotid nerve and plexus
Gray rami communicantes
First thoracic ganglion
Innervation to arrector pili muscles, vascular smooth muscle, and sweat glands of skin
Lacrimal gland
Eye
Parotid gland
Sublingual gland
Submandibular gland
Larynx
Trachea
Bronchi
Lungs
Cardiac branches
Greater thoracic splanchnic nerve
Heart
Celiac ganglion
Lesser thoracic splanchnic nerve
Stomach
Aorticorenal ganglion
Liver
Gallbladder
Bile ducts
Pancreas
Least thoracic splanchnic nerve
White ramus communicans
Gray ramus communicans
Kidneys
Superior mesenteric ganglion
Intestines
Lumbar splanchnic nerves
First lumbar ganglion
Sacral splanchnic nerves
Descending colon
Inferior mesenteric ganglion
First sacral ganglion
Sigmoid colon
Rectum
Inferior hypogastric plexus
Urinary bladder
Prostate
External genitalia
Preganglionic fibers
Postganglionic fibers
Branch of oculomotor nerve (III)
Branch of facial nerve (VII)
Medulla oblongata
Branch of glossopharyngeal nerve (IX)
Otic ganglion
Submandibular ganglion
Ciliary ganglion
Pterygopalatine ganglion
Lacrimal glands
Mucous glands of nose, paranasal sinuses, palate
Parotid glands
Sublingual glands
Submandibular glands
Vagus nerve (X)
Pulmonary plexus
Superior mesenteric ganglion
Inferior hypogastric plexus
Pelvic splanchnic nerves
S2
S3
S4

A22


Sympathetic nervous system
Parasympathetic nervous system
Parasympathetic ganglia (in the head)
CN III
CN VII
CN IX
CN X
Superior cervical ganglion
Eye
Lacrimal and salivary glands
Cranial vessels
Cranial part: brainstem with parasympathetic nuclei
Middle cervical ganglion
Sympathetic trunk
Stellate ganglion*
Parasympathetic ganglia (close to organs)
*Stellate ganglion = inferior cervical ganglion and T1 symphathetic ganglion
C8
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
Heart
Lung
Greater splanchnic nerve
Stomach
Liver
Pancreas
Celiac ganglion
Kidney
Intestine
Superior mesenteric ganglion
Inferior mesenteric ganglion
Parts of the colon, rectum
Bladder
Genitalia
S2
S3
S4
S5
Sacral part: sacral cord with parasympathetic nuclei
Inferior hypogastric plexus
Pelvic splanchnic nerves

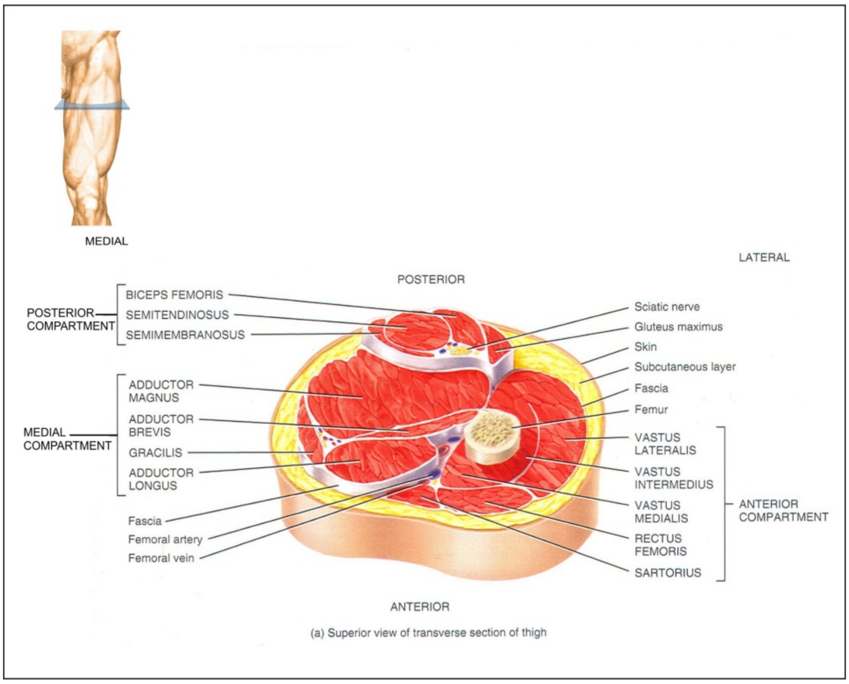
C23


Parasympathetic division
Sympathetic division
Ciliary ganglion
Sphenopalatine ganglion
Submaxillary ganglion
Constrictor pupillae
Lacrimal gland
Sublingual gland
Submandibular gland
Optic ganglion
Parotid gland
III
VII
IX
X
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
Heart
Lungs
Stomach
Small intestine
Colon
Urinary bladder
Sex organs
Liver
Celiac ganglion
Superior mesenteric ganglion

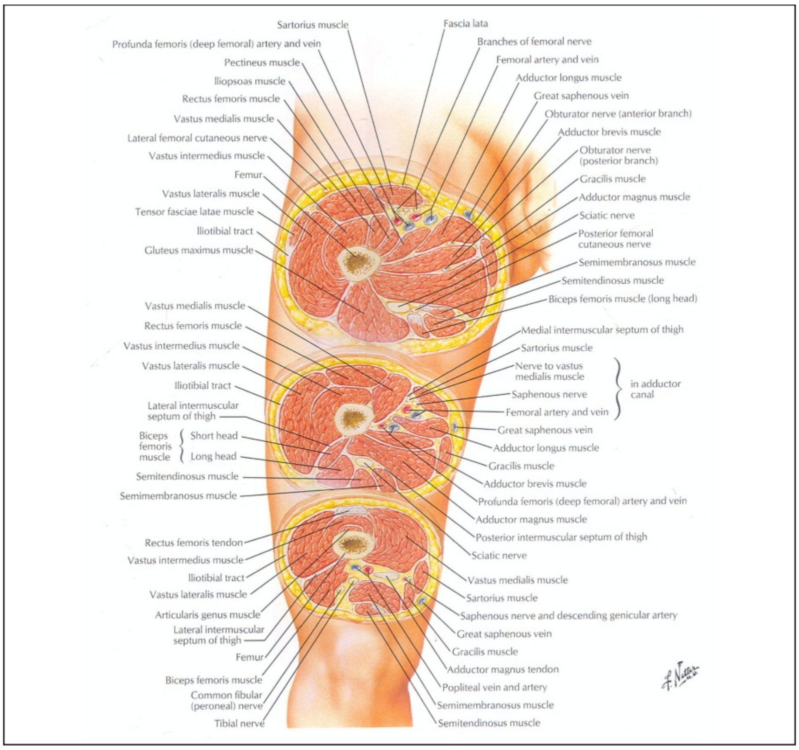
Size and depth

Present the three examples of the muscles of the leg showing cross sections. Which illustration would you prefer and understand to learn the anatomy of the leg and why? Between the other two pictures, which one do you prefer the most? Please elaborate.

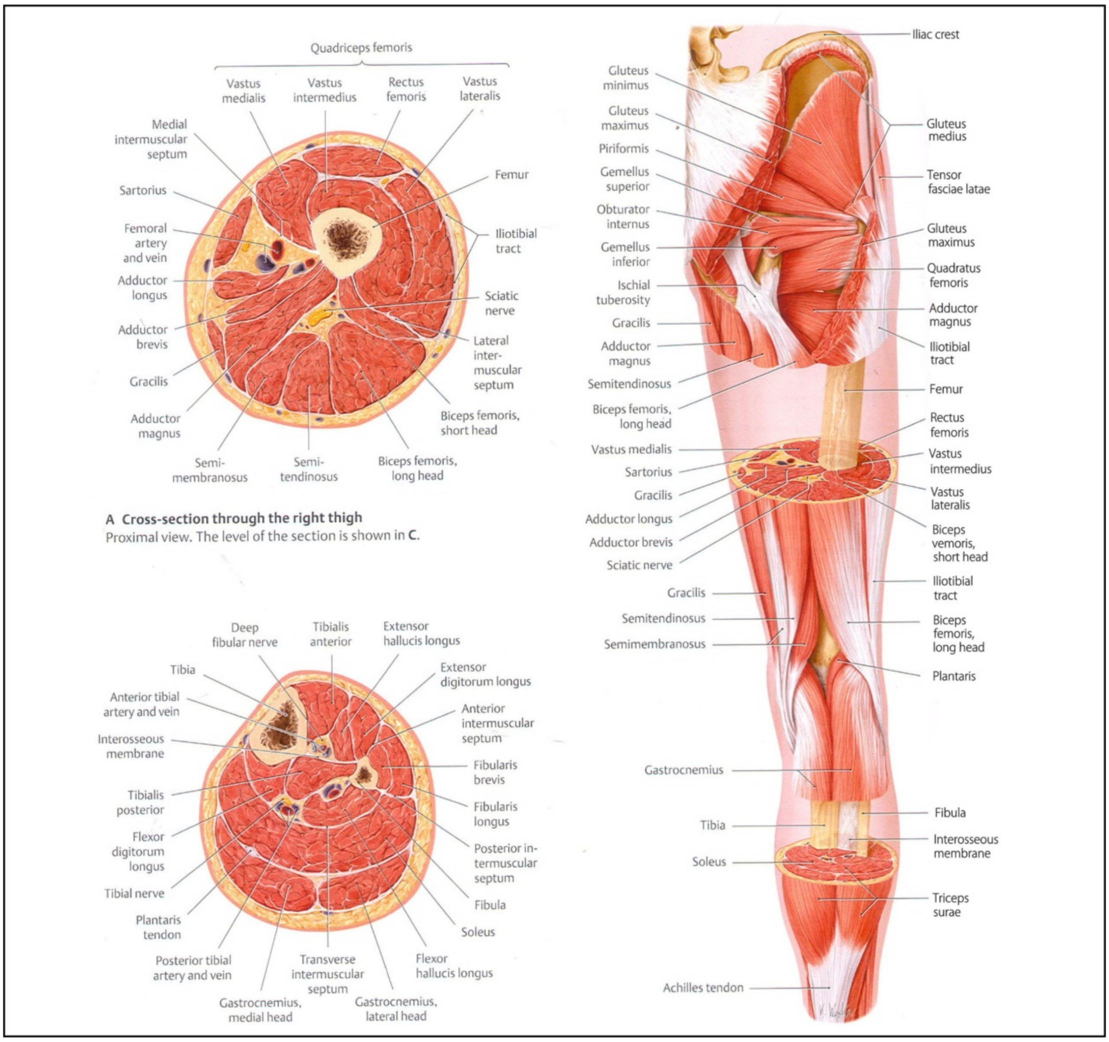
D24



B25



A26



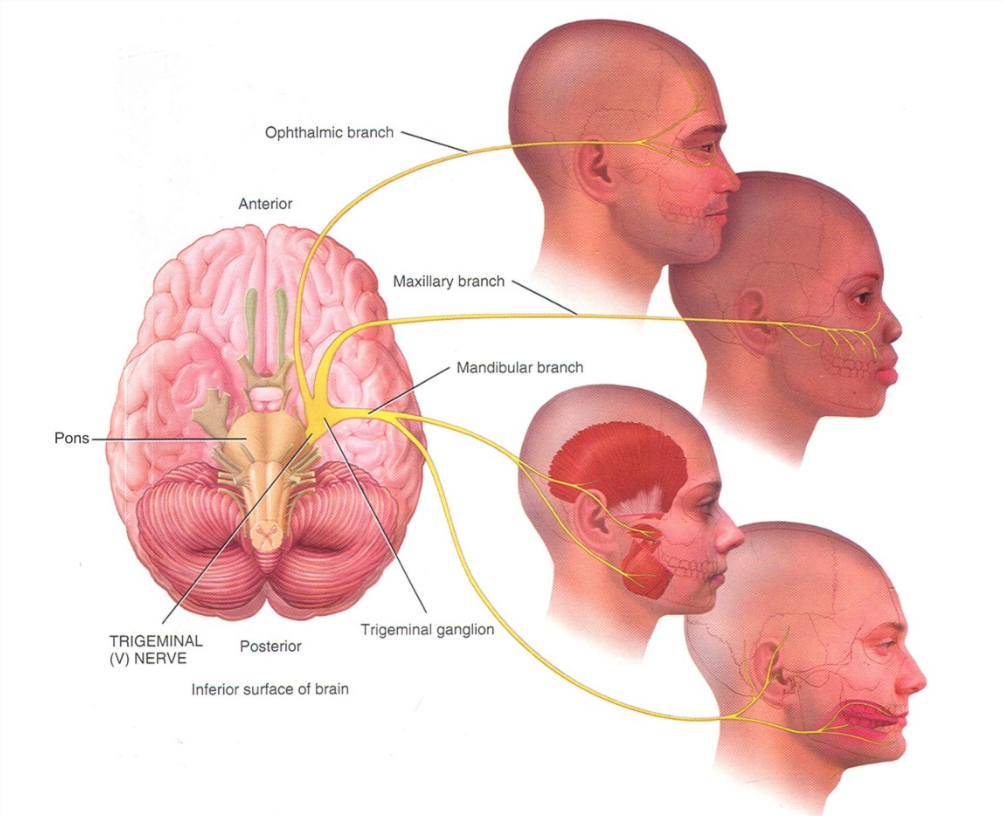
A Cross-section through the right thigh
Proximal view. The level of the section is shown in **C**.

Design principles

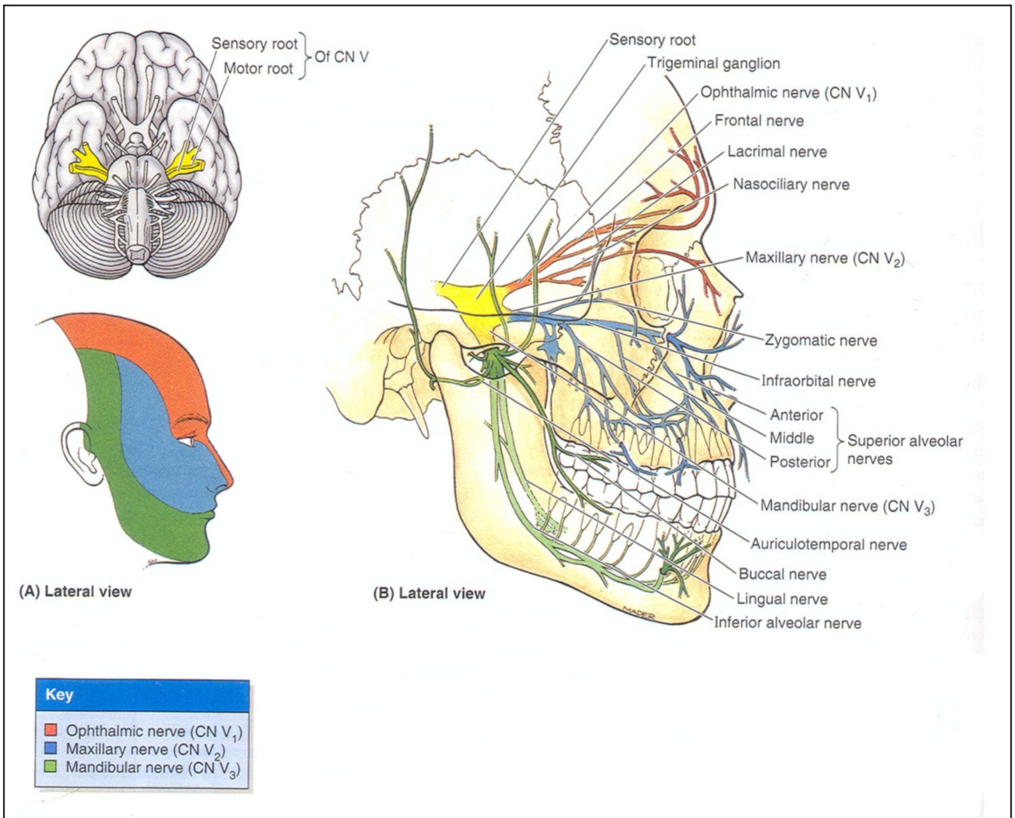
Unity and variety

Present the three examples of the pathway of the trigeminal nerve. Which illustration would you prefer and understand to learn the trigeminal nerve from and why? Between the other pictures, which one do you prefer the most? Please elaborate.

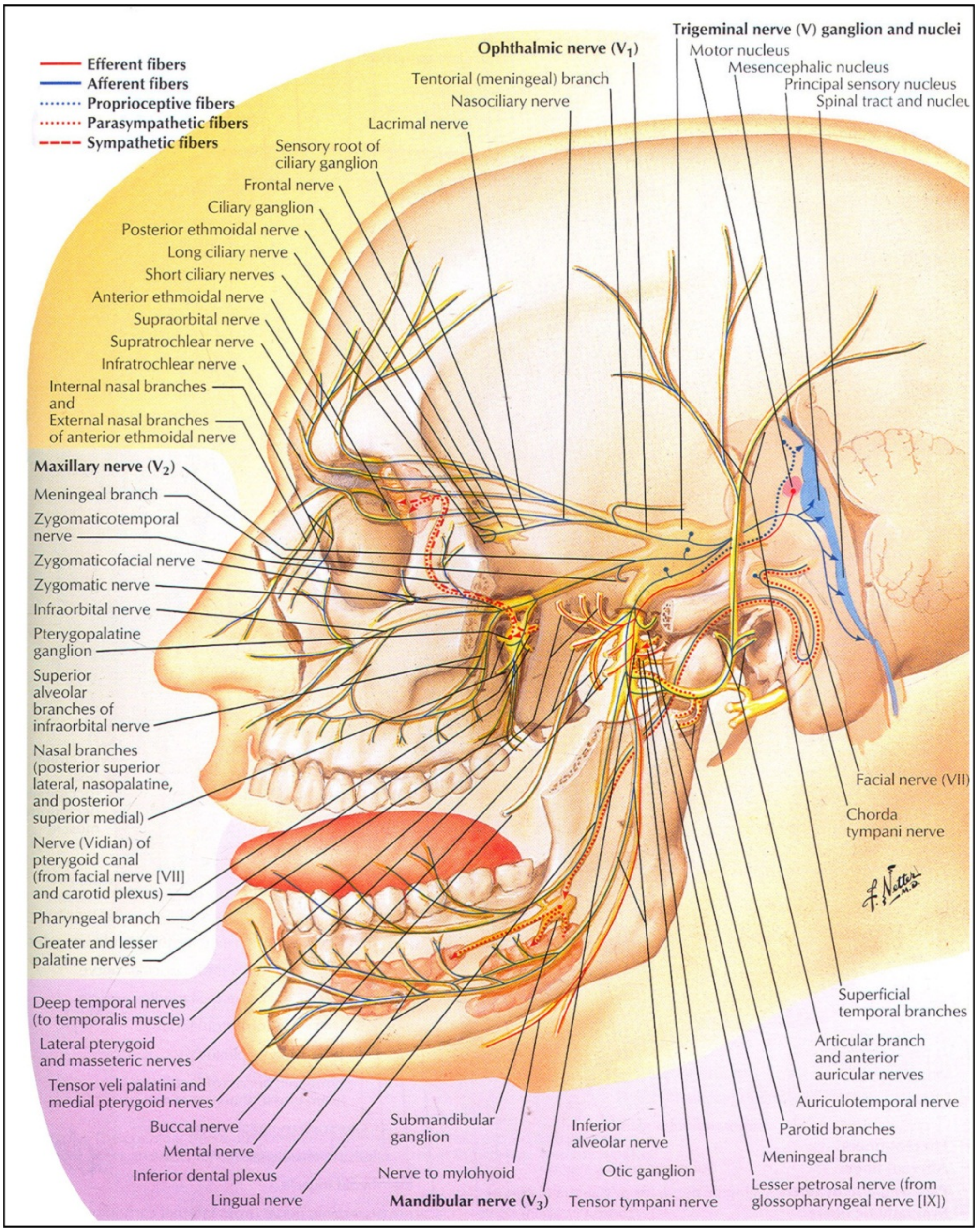
B27


Ophthalmic branch
Anterior
Maxillary branch
Mandibular branch
Pons
TRIGEMINAL
(V) NERVE
Posterior
Trigeminal ganglion
Inferior surface of brain

A28


Sensory root
Motor root
Of CN V
(A) Lateral view
Key
Ophthalmic nerve (CN V1)
Maxillary nerve (CN V2)
Mandibular nerve (CN V3)
Sensory root
Trigeminal ganglion
Ophthalmic nerve (CN V1)
Frontal nerve
Lacrimal nerve
Nasociliary nerve
Maxillary nerve (CN V2)
Zygomatic nerve
Infraorbital nerve
Anterior
Middle
Posterior
Superior alveolar nerves
Mandibular nerve (CN V3)
Auriculotemporal nerve
Buccal nerve
Lingual nerve
Inferior alveolar nerve
(B) Lateral view

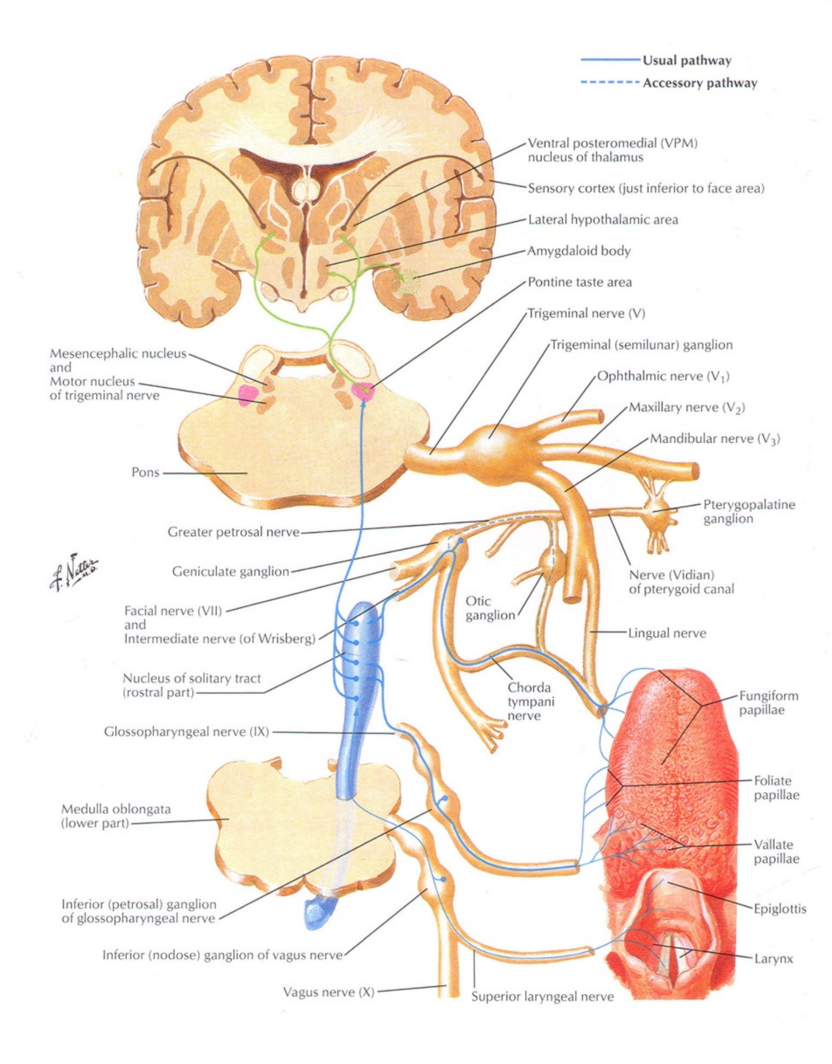
C29



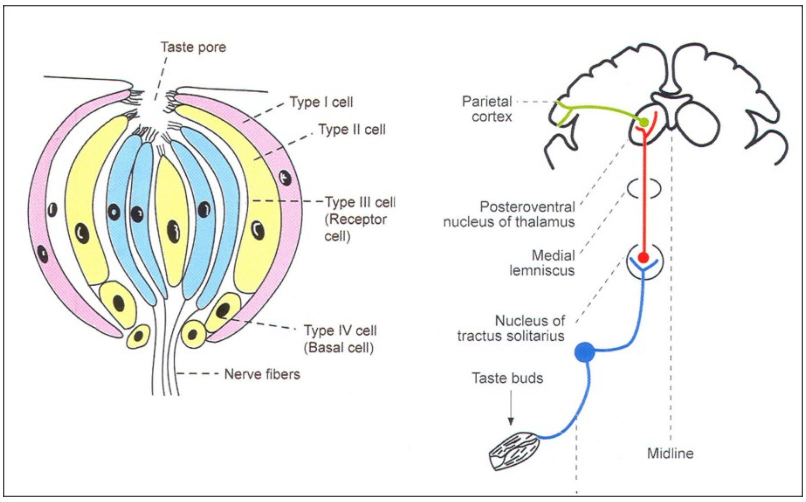
Hierarchy and dominance

Present the three examples of the pathway of taste. Which illustration would you prefer and understand to learn the pathway of taste from and why? Between the other two pictures, which one do you prefer the most? Please elaborate.

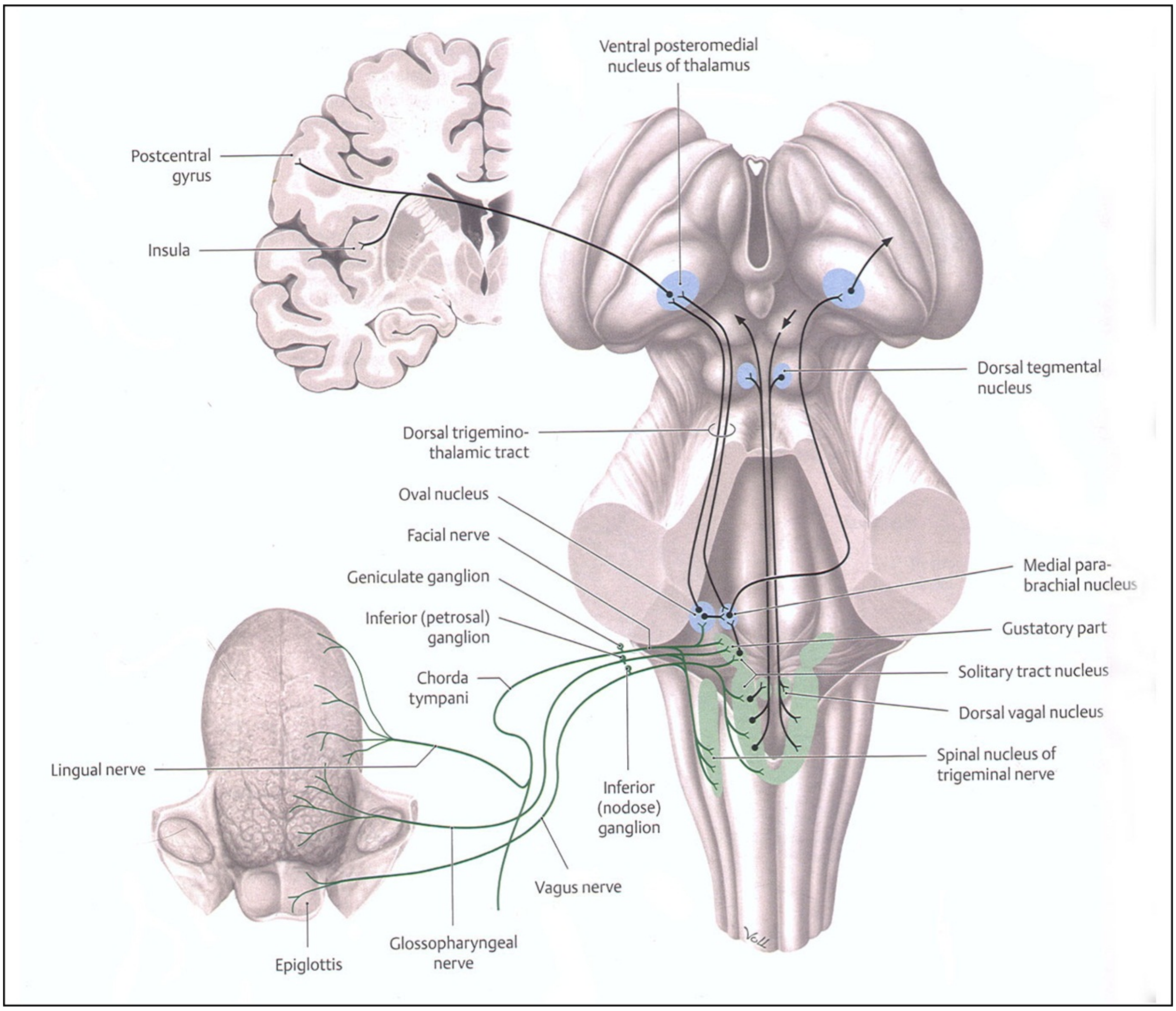
B30


Usual pathway
Accessory pathway
Ventral posteromedial (VPM) nucleus of thalamus
Sensory cortex (just inferior to face area)
Lateral hypothalamic area
Amygdaloid body
Pontine taste area
Trigeminal nerve (V)
Trigeminal (semilunar) ganglion
Ophthalmic nerve (V_1)
Maxillary nerve (V_2)
Mandibular nerve (V_3)
Pterygopalatine ganglion
Nerve (Vidian) of pterygoid canal
Lingual nerve
Fungiform papillae
Foliate papillae
Vallate papillae
Epiglottis
Larynx
Superior laryngeal nerve
Vagus nerve (X)
Inferior (nodose) ganglion of vagus nerve
Inferior (petrosal) ganglion of glossopharyngeal nerve
Medulla oblongata (lower part)
Glossopharyngeal nerve (IX)
Nucleus of solitary tract (rostral part)
Facial nerve (VII) and Intermediate nerve (of Wrisberg)
Geniculate ganglion
Greater petrosal nerve
Otic ganglion
Chorda tympani nerve
Pons
Mesencephalic nucleus and Motor nucleus of trigeminal nerve

D31


Taste pore
Type I cell
Type II cell
Type III cell (Receptor cell)
Type IV cell (Basal cell)
Nerve fibers
Parietal cortex
Posteroventral nucleus of thalamus
Medial lemniscus
Nucleus of tractus solitarius
Taste buds
Midline

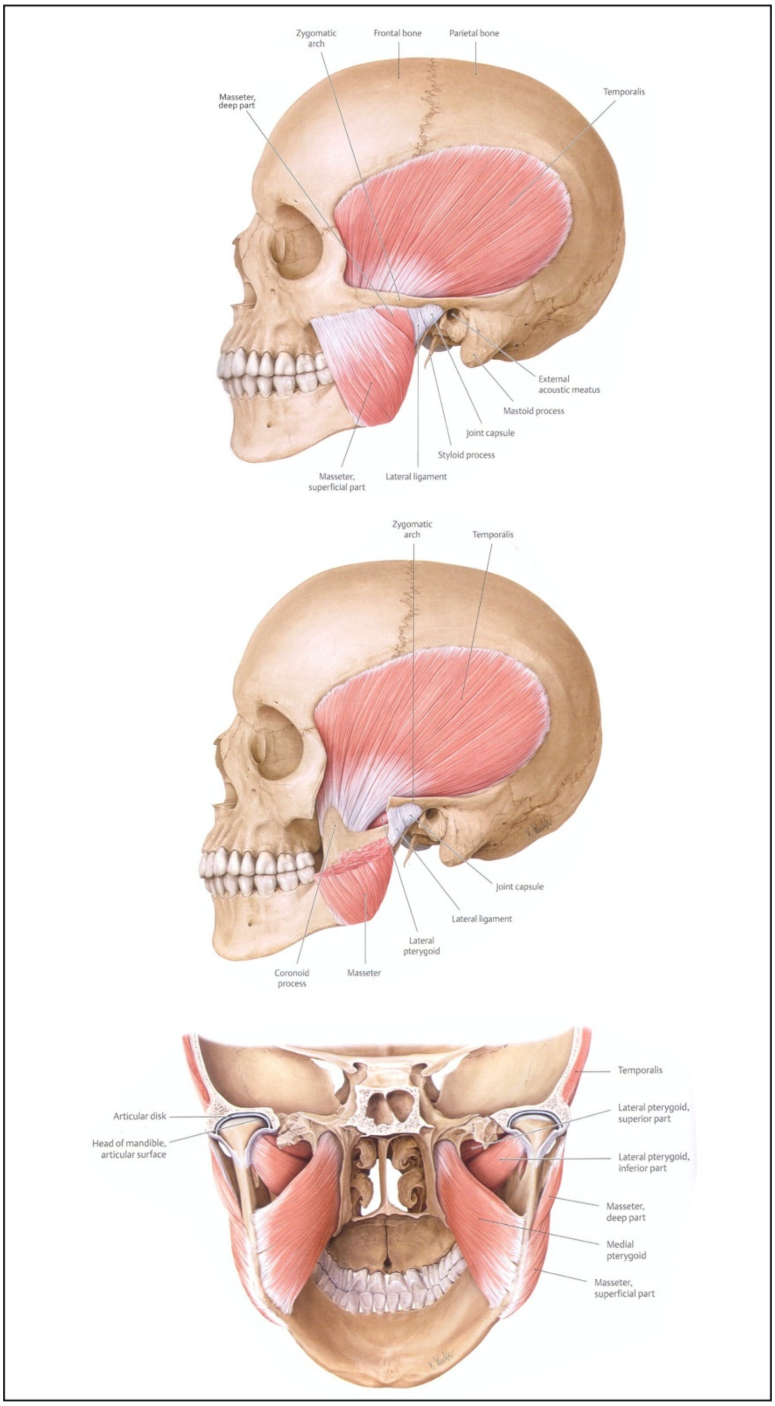
A32



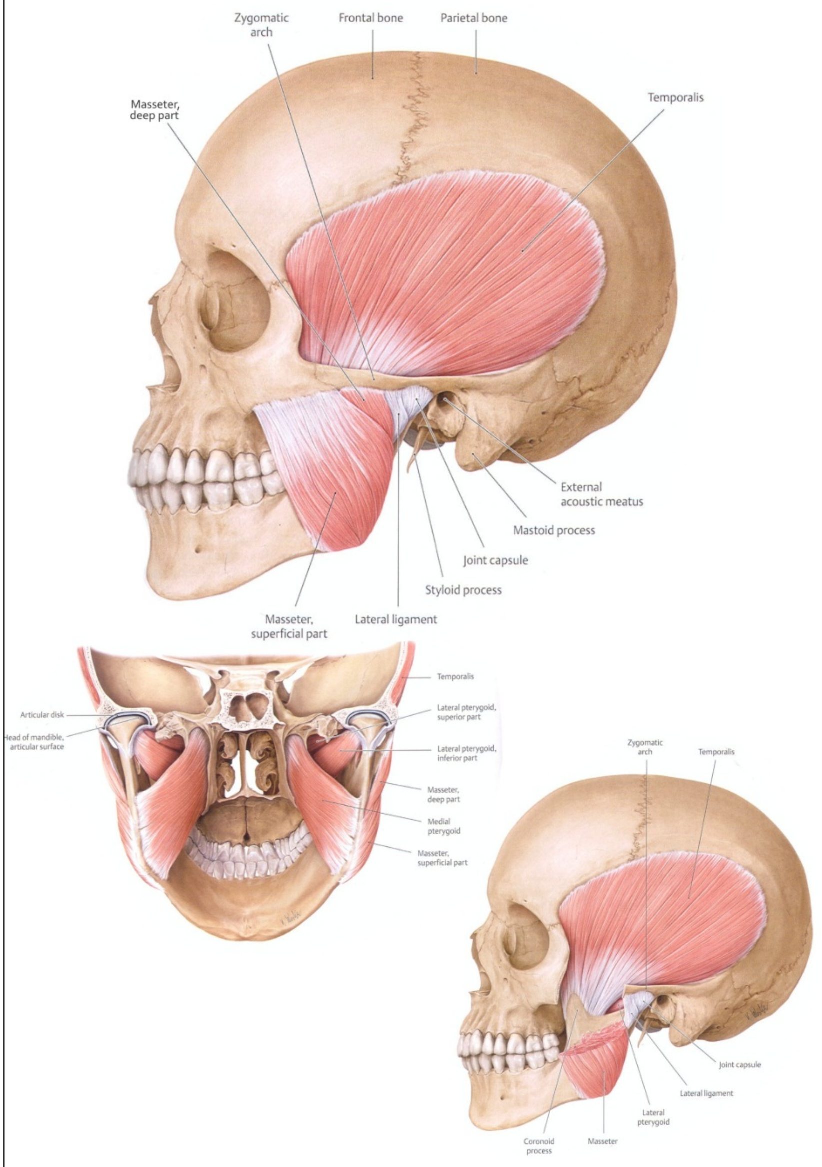
Balance

Present the three examples of the muscles of mastication. Which illustration would you prefer to learn the muscles of mastication from and why? Between the other three pictures, which one do you prefer the most? Please elaborate.

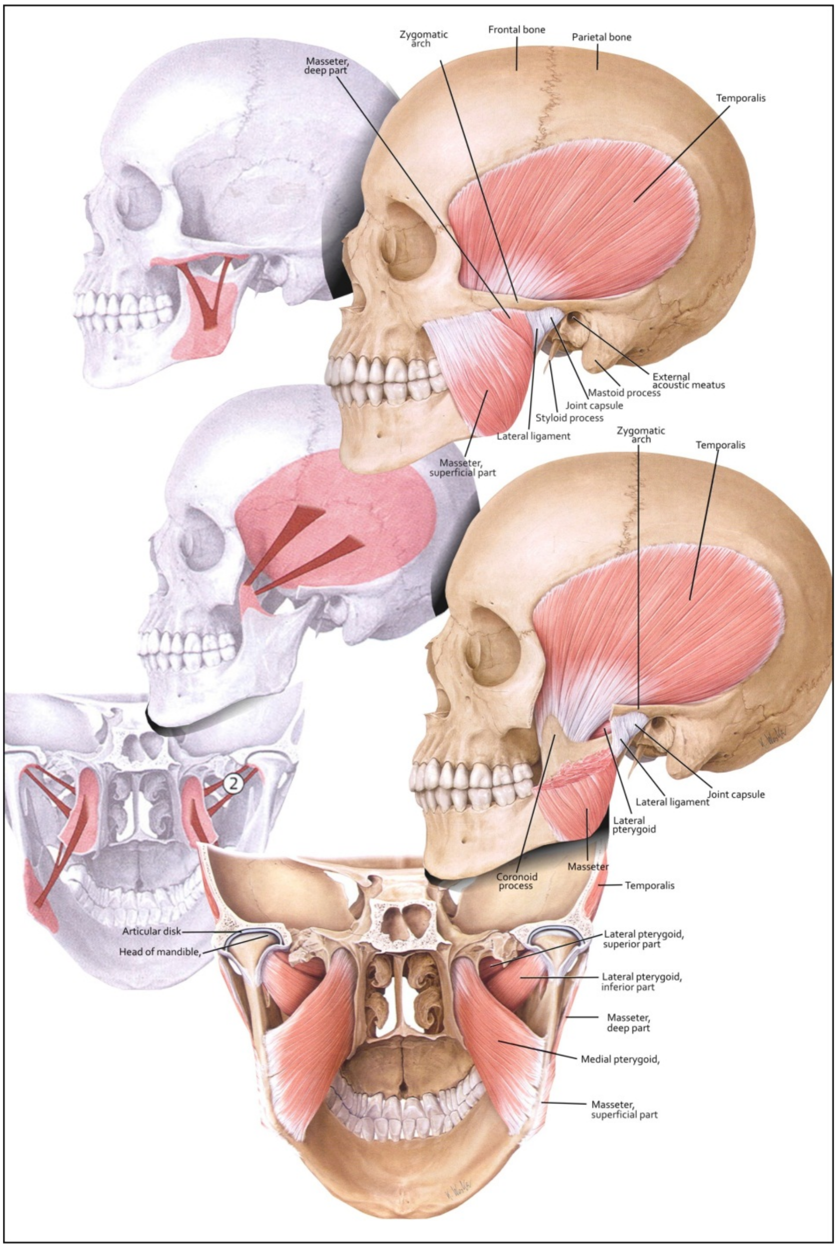
B33


Zygomatic arch
Frontal bone
Parietal bone
Masseter, deep part
Temporalis
External acoustic meatus
Mastoid process
Joint capsule
Styloid process
Masseter, superficial part
Lateral ligament
Zygomatic arch
Temporalis
Joint capsule
Lateral ligament
Lateral pterygoid
Coronoid process
Masseter
Temporalis
Articular disk
Head of mandible, articular surface
Lateral pterygoid, superior part
Lateral pterygoid, inferior part
Masseter, deep part
Medial pterygoid
Masseter, superficial part

D34


Zygomatic arch
Frontal bone
Parietal bone
Masseter, deep part
Temporalis
External acoustic meatus
Mastoid process
Joint capsule
Styloid process
Masseter, superficial part
Lateral ligament
Temporalis
Articular disk
Head of mandible, articular surface
Lateral pterygoid, superior part
Lateral pterygoid, inferior part
Masseter, deep part
Medial pterygoid
Masseter, superficial part
Zygomatic arch
Temporalis
Joint capsule
Lateral ligament
Lateral pterygoid
Coronoid process
Masseter

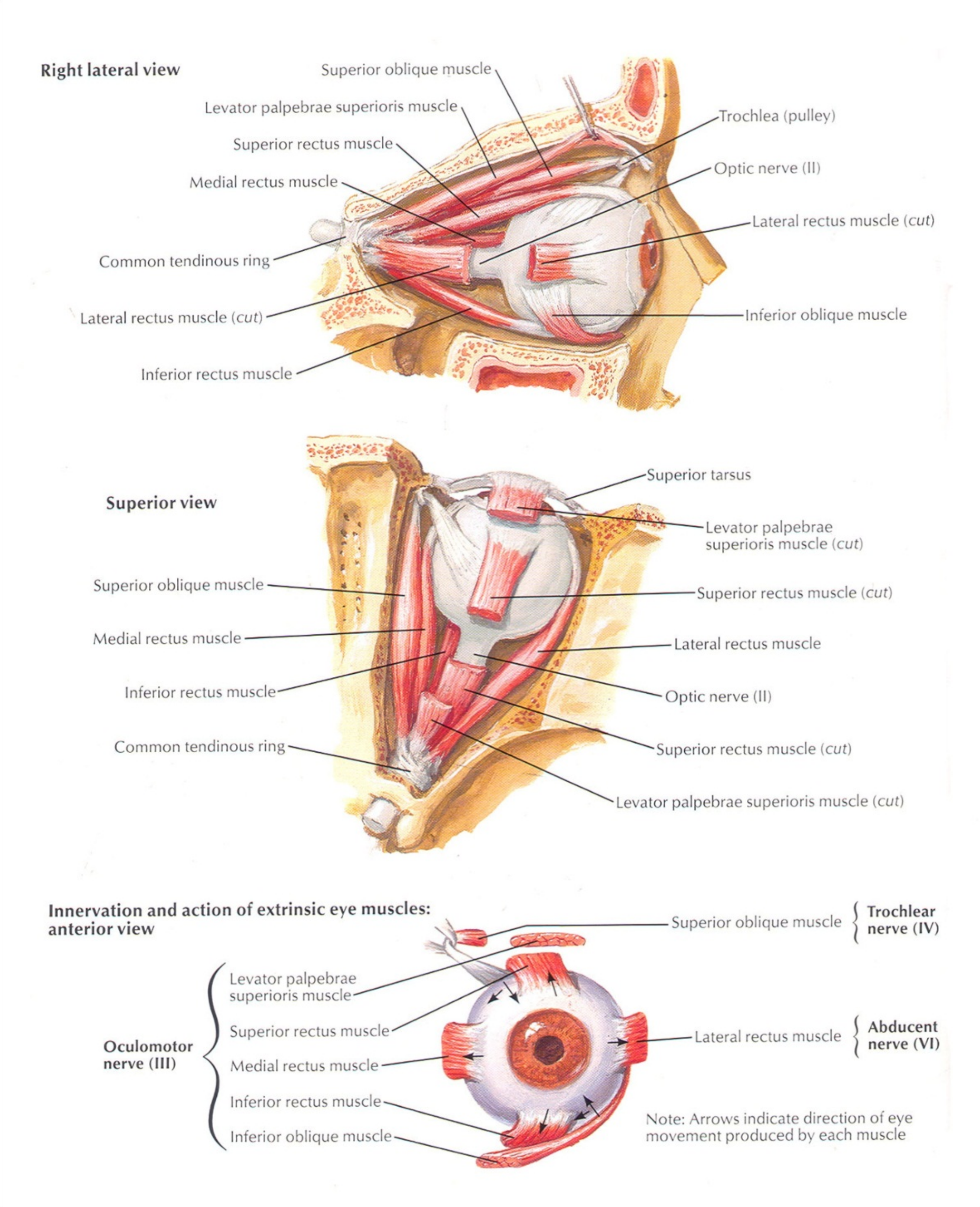
A35



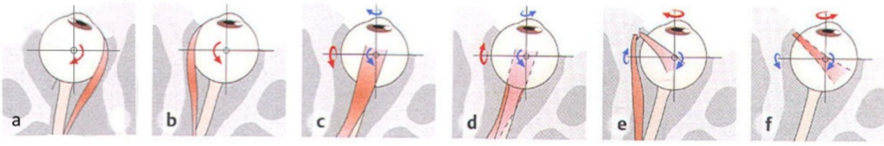
Proximity and repetition

Present the three examples of the function of eye muscles. Which illustration would you understand and prefer when learning the different muscles of the eye? Between the other three pictures, which one do you prefer the most? Please elaborate.

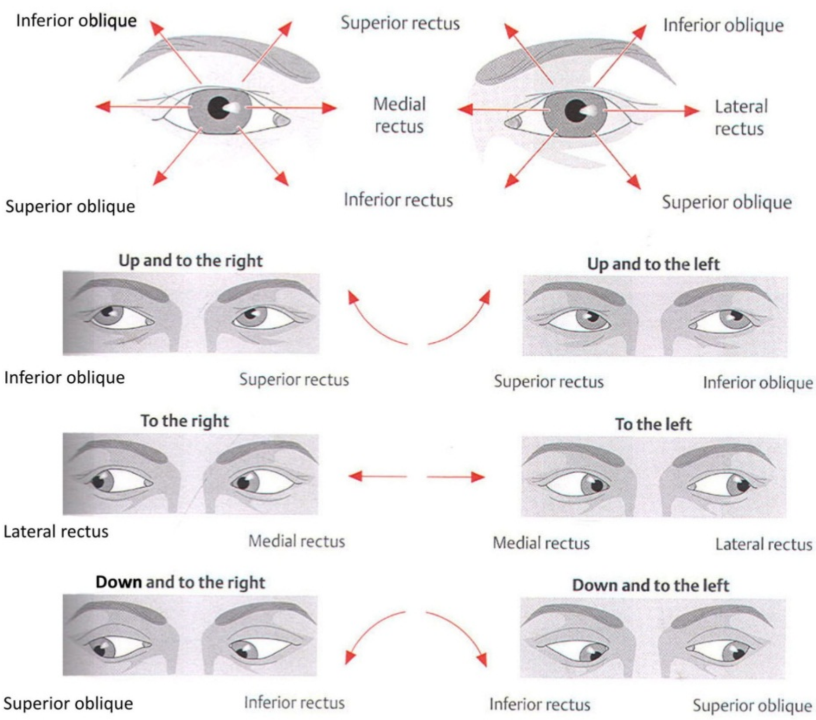
B36


Right lateral view
Superior oblique muscle
Levator palpebrae superioris muscle
Superior rectus muscle
Medial rectus muscle
Common tendinous ring
Lateral rectus muscle (cut)
Inferior rectus muscle
Trochlea (pulley)
Optic nerve (II)
Lateral rectus muscle (cut)
Inferior oblique muscle
Superior view
Superior oblique muscle
Medial rectus muscle
Inferior rectus muscle
Common tendinous ring
Superior tarsus
Levator palpebrae superioris muscle (cut)
Superior rectus muscle (cut)
Lateral rectus muscle
Optic nerve (II)
Superior rectus muscle (cut)
Levator palpebrae superioris muscle (cut)
Innervation and action of extrinsic eye muscles: anterior view
Superior oblique muscle
Trochlear nerve (IV)
Oculomotor nerve (III)
Levator palpebrae superioris muscle
Superior rectus muscle
Medial rectus muscle
Inferior rectus muscle
Inferior oblique muscle
Lateral rectus muscle
Abducent nerve (VI)
Note: Arrows indicate direction of eye movement produced by each muscle

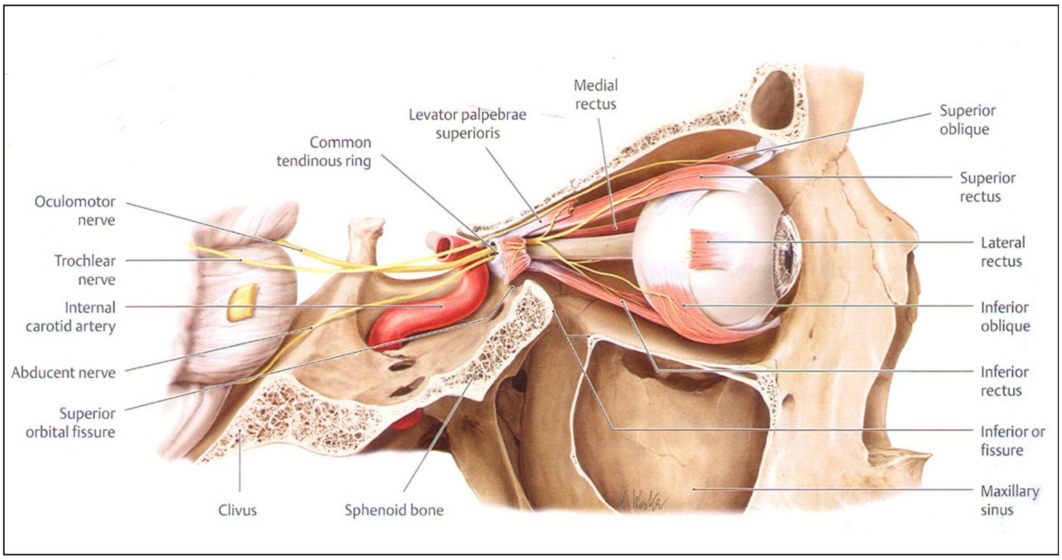
D37



Muscle	Primary action	Secondary action	Innervation
a Lateral rectus	Abduction	None	Abducent nerve (CN VI)
b Medial rectus	Adduction	None	Oculomotor nerve (CN III),inferior branch
c Superior rectus	Elevation	Adduction and medial rotation	Oculomotor nerve (CN III),superior branch
d Inferior rectus	Depression	Adduction and lateral rotation	Oculomotor nerve (CN III),inferior branch
e Superior oblique	Depression and abduction	Medial rotation	Trochlear nerve (CN IV)
f Inferior oblique	Elevation and abduction	Lateral rotation	Oculomotor nerve (CN III), inferior branch



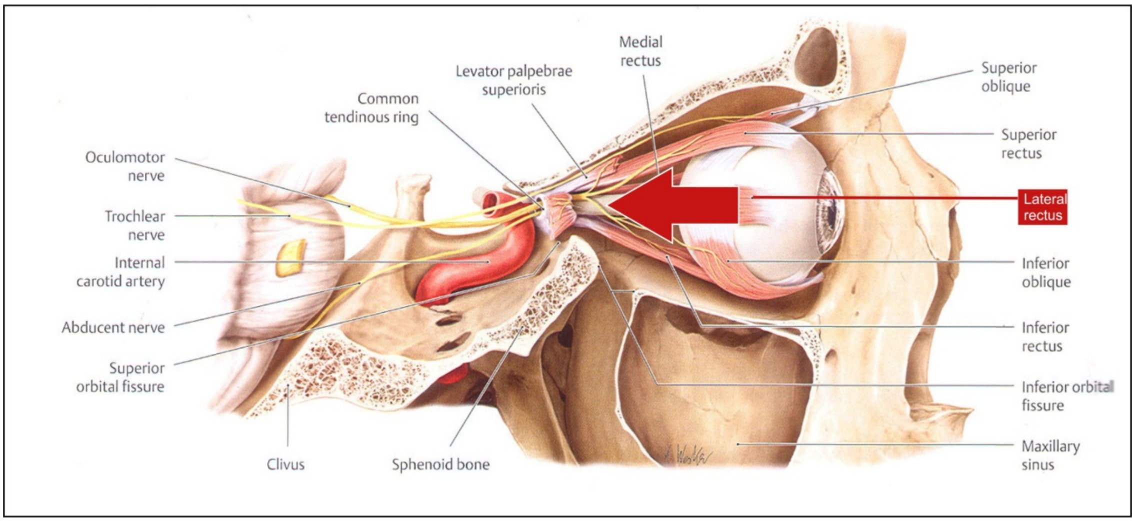
A38



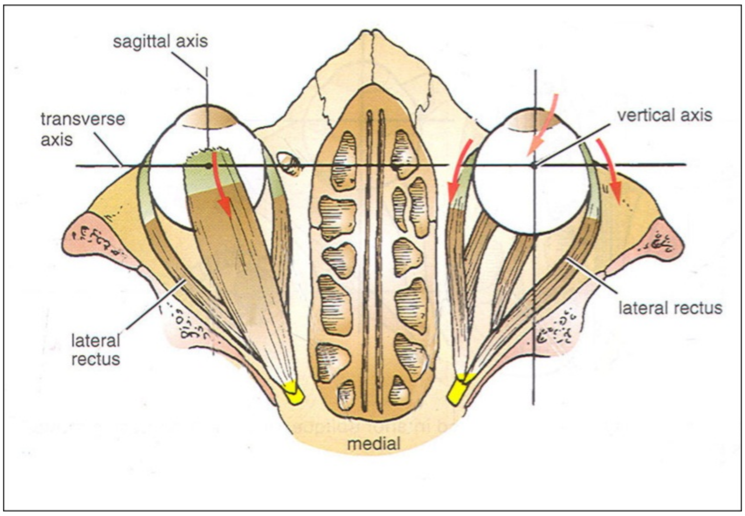
Movement

Present the five examples of the function of the lateral rectus eye muscle. Which illustrationwould you prefer and understand to learn lateral rectus eye muscle from and why? Between the other two pictures, which one do you prefer the most? Please elaborate.

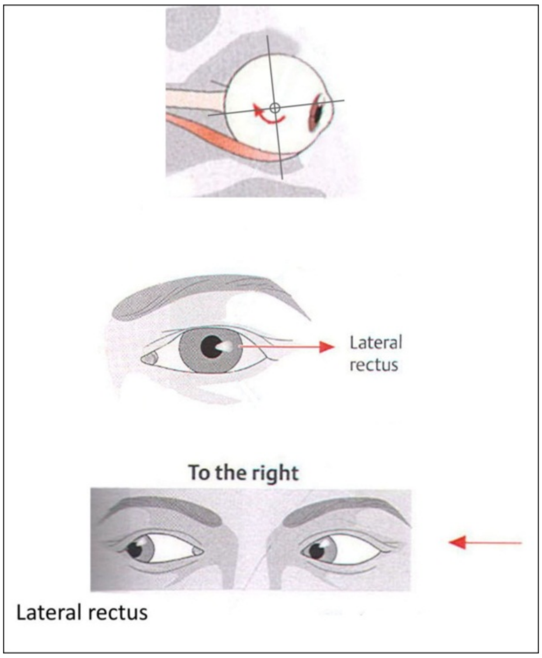
D39



B40



A41



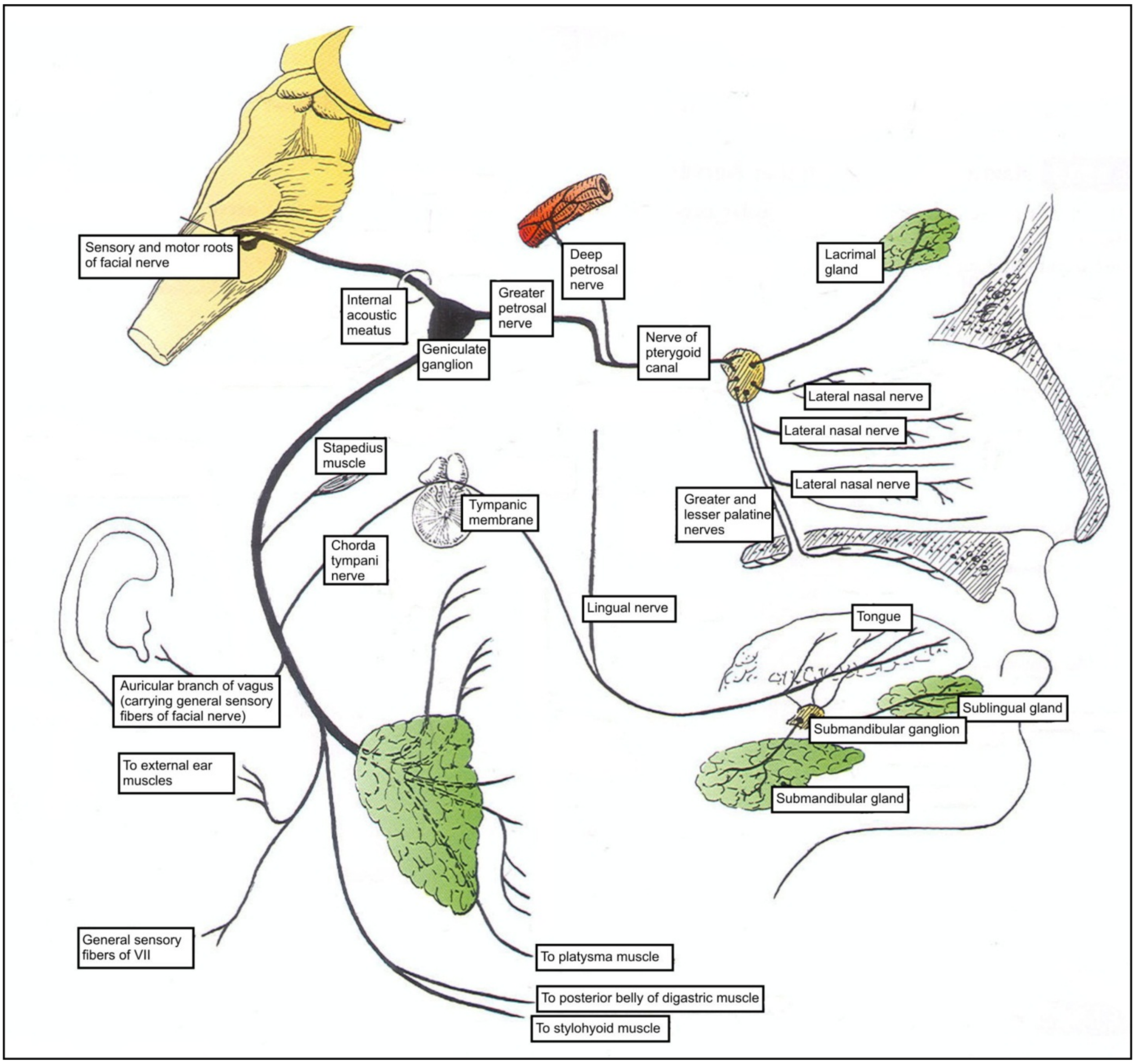
C42 E43

Show animations of the lateral rectus muscle.

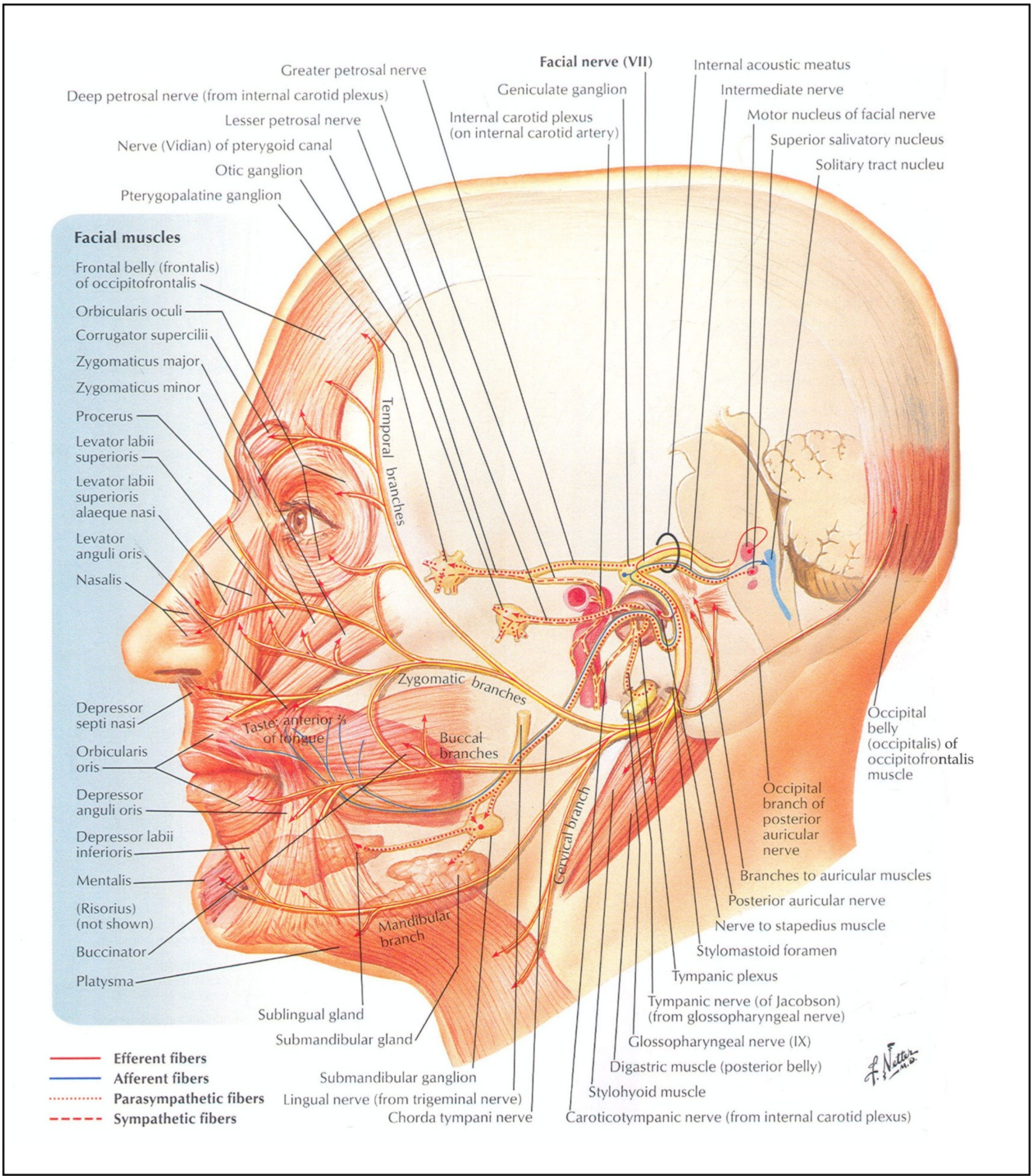
Labelling

Present the three examples of the labelling of the facial nerve. Which illustration would you prefer and understand to learn the facial nerve from and why? Between the other two pictures, which one do you prefer the most? Please elaborate.

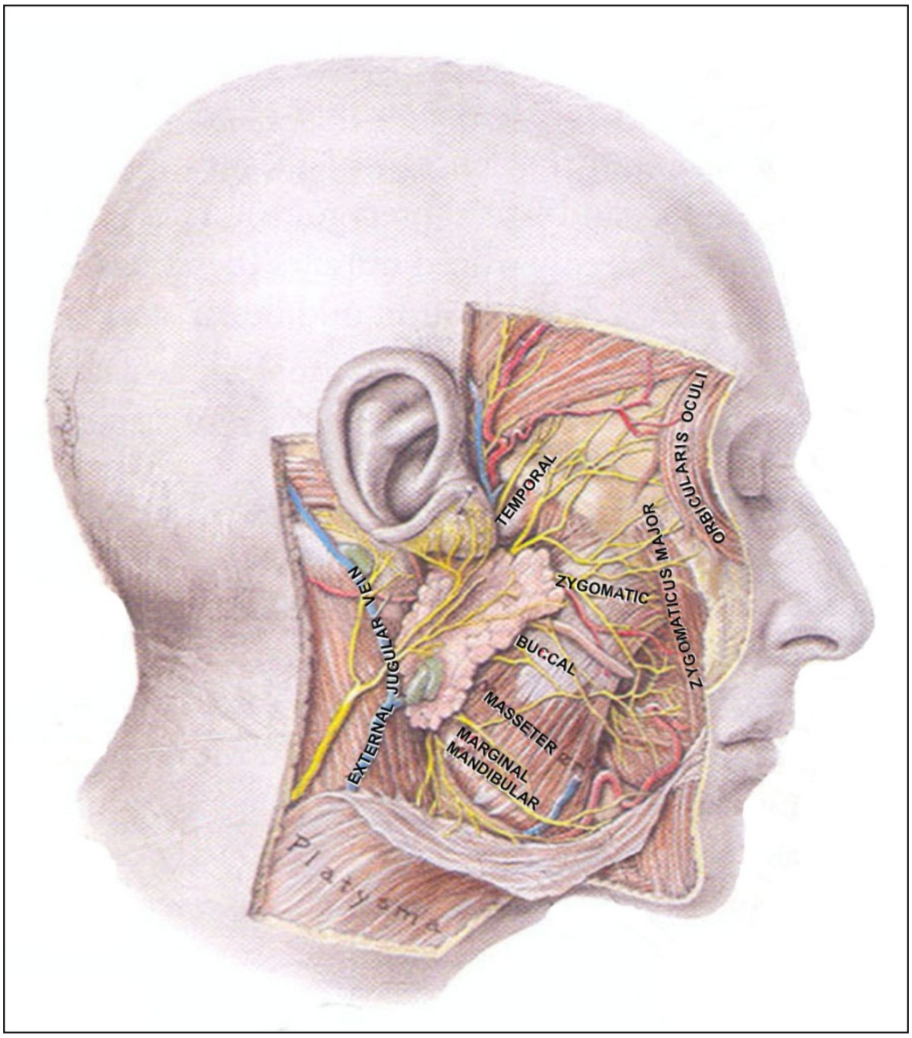
D44


Sensory and motor roots of facial nerve
Internal acoustic meatus
Geniculate ganglion
Greater petrosal nerve
Deep petrosal nerve
Nerve of pterygoid canal
Lacrimal gland
Lateral nasal nerve
Lateral nasal nerve
Lateral nasal nerve
Greater and lesser palatine nerves
Stapedius muscle
Tympanic membrane
Chorda tympani nerve
Lingual nerve
Tongue
Sublingual gland
Submandibular ganglion
Submandibular gland
Auricular branch of vagus (carrying general sensory fibers of facial nerve)
To external ear muscles
General sensory fibers of VII
To platysma muscle
To posterior belly of digastric muscle
To stylohyoid muscle

B45


Greater petrosal nerve
Deep petrosal nerve (from internal carotid plexus)
Lesser petrosal nerve
Nerve (Vidian) of pterygoid canal
Otic ganglion
Pterygopalatine ganglion
Facial nerve (VII)
Geniculate ganglion
Internal carotid plexus
(on internal carotid artery)
Internal acoustic meatus
Intermediate nerve
Motor nucleus of facial nerve
Superior salivatory nucleus
Solitary tract nucleu
Facial muscles
Frontal belly (frontalis)
of occipitofrontalis
Orbicularis oculi
Corrugator supercilii
Zygomaticus major
Zygomaticus minor
Procerus
Levator labii
superioris
Levator labii
superioris
alaeque nasi
Levator
anguli oris
Nasalis
Depressor
septi nasi
Orbicularis
oris
Depressor
anguli oris
Depressor labii
inferioris
Mentalis
(Risorius)
(not shown)
Buccinator
Platysma
Temporal branches
Zygomatic branches
Taste: anterior ⅔
of tongue
Buccal
branches
Cervical branch
Mandibular
branch
Occipital
belly
(occipitalis) of
occipitofrontalis
muscle
Occipital
branch of
posterior
auricular
nerve
Branches to auricular muscles
Posterior auricular nerve
Nerve to stapedius muscle
Stylomastoid foramen
Tympanic plexus
Tympanic nerve (of Jacobson)
(from glossopharyngeal nerve)
Glossopharyngeal nerve (IX)
Digastric muscle (posterior belly)
Stylohyoid muscle
Caroticotympanic nerve (from internal carotid plexus)
Sublingual gland
Submandibular gland
Submandibular ganglion
Lingual nerve (from trigeminal nerve)
Chorda tympani nerve
Efferent fibers
Afferent fibers
Parasympathetic fibers
Sympathetic fibers

A46



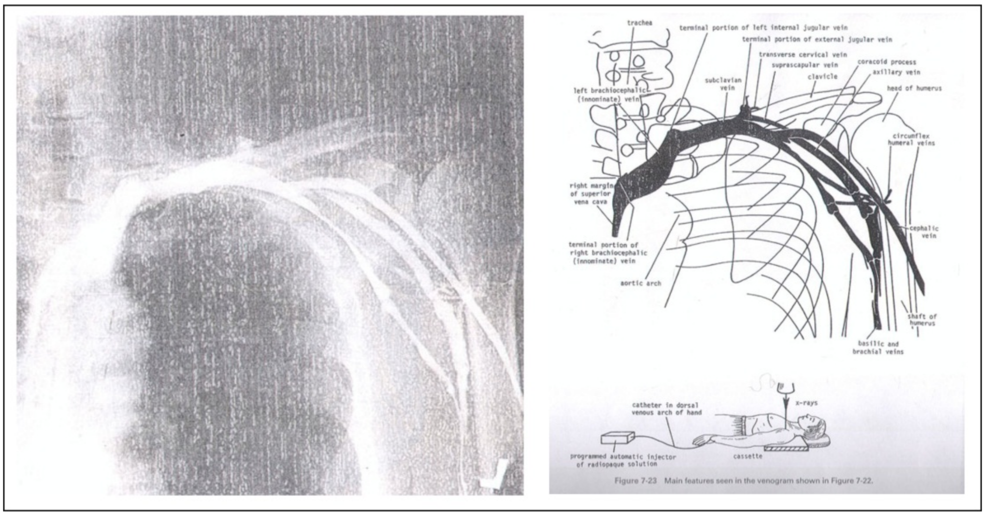
C47

Present a different example of the labelling of the facial nerve directly from the anatomy atlas. Would you prefer this illustration to learn the facial nerve from? Please elaborate.

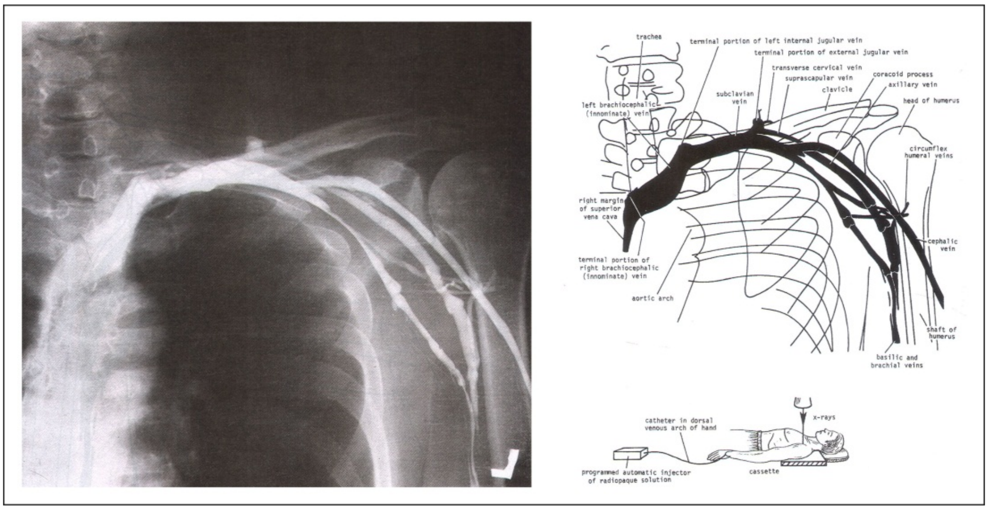
Reproduction

Present the three examples of different versions of a venogram of the subclavian artery, axillary and brachial veins in the shoulder. Does the quality of the reproduction of the three illustration inflict an influence on your learning? Please elaborate. Do you feel it is necessary to present any x-ray with an outline illustration? Please elaborate.

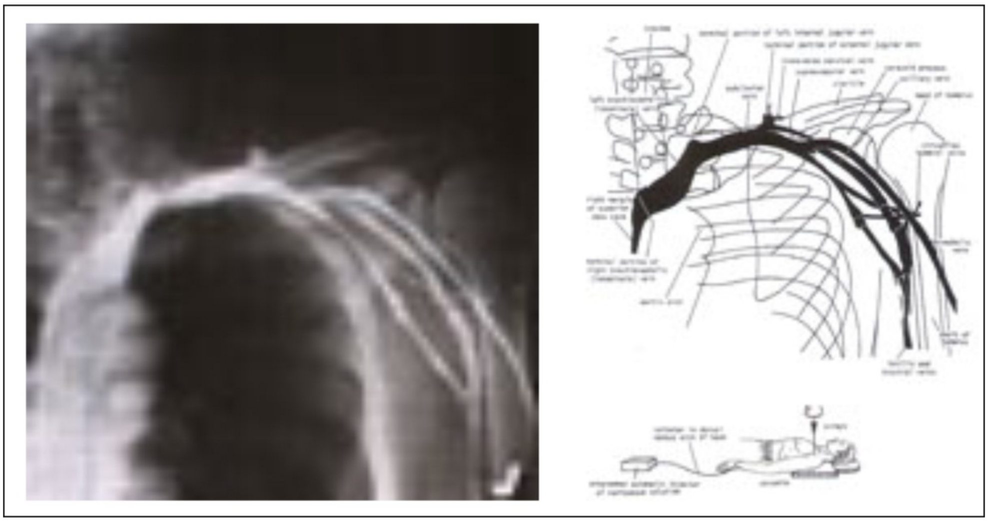
D48


trachea
terminal portion of left internal jugular vein
terminal portion of external jugular vein
transverse cervical vein
suprascapular vein
coracoid process
axillary vein
subclavian vein
clavicle
head of humerus
left brachiocephalic (innominate) vein
circumflex humeral veins
right margin of superior vena cava
cephalic vein
terminal portion of right brachiocephalic (innominate) vein
aortic arch
shaft of humerus
basilic and brachial veins
catheter in dorsal venous arch of hand
x-rays
programmed automatic injector of radiopaque solution
cassette
Figure 7-23 Main features seen in the venogram shown in Figure 7-22.

B49


trachea
terminal portion of left internal jugular vein
terminal portion of external jugular vein
transverse cervical vein
suprascapular vein
coracoid process
axillary vein
subclavian vein
clavicle
head of humerus
left brachiocephalic (innominate) vein
circumflex humeral veins
right margin of superior vena cava
cephalic vein
terminal portion of right brachiocephalic (innominate) vein
aortic arch
shaft of humerus
basilic and brachial veins
catheter in dorsal venous arch of hand
x-rays
programmed automatic injector of radiopaque solution
cassette

A50



Conclusion

For the significance of the study, the interviewer asks the participant the following questions about the use of computer and illustrations during learning namely:

Question 1: Do you have a computer at home with internet access?

The participant may answer yes or no as it will give the interviewer an indication to what extent he/she is exposed to a computer.

Question 2: Do you use the internet to look at videos and animations of anatomical structures or surgical procedures additional to learning?

The participant may answer yes or no as it will give the interviewer an indication to what extent he/she is using the internet to look at videos and animations of surgical procedures and anatomical structures to learn from.

Question 3: Do you possess extra atlases and textbooks except from prescribed materials?

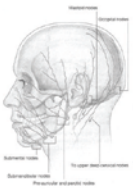
The participant may answer yes or no as it will give the interviewer an indication to what extent he/she is using additional atlases and textbooks except from prescribed materials.

Question 4: How do you prefer to use medical illustrations during learning?

This is a question provides opportunity for the participant to explain and demonstrate if necessary how he/she uses medical illustrations during learning.

The interviewer asks the respondent if he/she would like to add anything else to the discussion. The interviewer thanks the respondent for his/her time.

APPENDIX B: AN EXAMPLE OF A DATA SHEET SHOWING SECOND- AND FIFTH-YEAR MEDICAL STUDENTS' CATEGORASATION OF PREFERENCE REGARDING AN ILLUSTRATION DEMONSTRATING LYMPH DRAINAGE

Lymph drainage in the head and neck – actual lines				
Illustration D1 	**Categories:** **First preference for use and comprehension during learning:** **Constructs:** Very positively demonstrates: clarity/detail/ information/ realism/showing location and relation to structures	**Second preference for use and comprehension during learning:** Positively demonstrates: clarity/a detail/ information/ realism/showing location and relation to structures	**Third preference for use and comprehension during learning:** Negatively: demonstrates: clarity/detail/ information/ realism/showing location and relation to structures	**Fourth preference for use and comprehension during learning:** Very negatively demonstrates: clarity/detail/ information/ realism/showing location and relation to structures
Second year medical students responses:				
	Resp# 6: *Just enough labels to identify the information - **P*** **Resp# 3:** *It shows location of lymph for understanding and clinical reference best - **P***	**Resp# 8:** *Skull in background helps to detect relation of lymph (depth) - **P*** **Resp# 4:** *Not enough labels and incomplete - **N***	**Resp# 1:** *Prefers the skull in background (depth). Realistic depiction – **P/N***	**Resp# 10:** *It is pointless without any text. It doesn't focus much on the cheek area and therefore less explainable. There is not enough information - **N***
Resp# 1: White female, Resp# 3: White male, Resp# 4: Black female, Resp# 6: Black male, Resp# 8: Indian female, Resp# 10: Indian male.				
Fifth year medical student responses:				
	Resp# 9: *It is not too complex. It reveals enough detail - **P*** **Resp# 11:** *It detects depth of the nodes and vessels - **P***		**Resp# 2:** *In relation to C4 it is a better choice. It shows lymph nodes in relation to skull – **N/P*** **Resp# 7:** *It lacks contrast. She mentioned the revealing of depth after been asked about it, but still feels it is insufficient - **N*** **Resp# 12:** *It does not contain enough information. Features are not detected easily when looking at for the first time - **N***	**Resp# 5:** *There is not enough contrast and no distinction between nodes - **N***
Resp# 2: Black male, Resp# 5: White male, Resp# 7: Black female, Resp# 9: Taiwanese female, Resp# 11: Portuguese male, Resp# 12: White female.				

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APPENDIX C: AN EXAMPLE OF THE INFORMED CONSENT LETTER

Consent forms signed by all participants, together with the letters of approval to commence with this study are available at the Department of Visual Arts

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Department of Visual Arts

LETTER OF INFORMED CONSENT

Department of Visual Arts, University of Pretoria
Researcher: Marinda Pretorius
MA Student
University of Pretoria, Faculty of Humanities, Department of Visual Arts,

Dear Participant,

Re: Invitation to participate in a Design research study

I am inviting you to participate in a qualitative research study titled *"An Exploration of student's perceptions regarding medical illustrations as a learning tool"*. This study forms part of the requirements for the degree in MA Information Design, for which I am currently registered at the University of Pretoria. The aim of the study is to investigate the impressions and attitudes of medical students towards computer-based- and text book-based illustration in learning- and teaching experience during medical training.

As part of the above study, face-to-face, informal interviews will be conducted between the researcher (myself) and your, as participant. As a participant, you will be asked open-ended questions, to which you can choose to respond. These informal interviews will take place during 2011.

Information arising from these interviews may be used in the writing up of my dissertation. I do not know of any risks to you if you decide to participate in this study. The interviews are solely for research purposes, and not for any form of personal gain. There will be no financial gains for you as participant. Your participation is voluntary and you may withdraw from participation in the study at any time, without any negative consequences. The data will be destroyed if you decide to withdraw from the study. The interviews will be recorded and transcribed and the transcriptions and recordings of the interviews will be archived at the Department of Visual Arts for 15 years.

Should you wish, all information derived from these interviews can be treated as confidential. Should you not wish to have your name revealed in the thesis, anonymity will be assured. You are free to contact me at the below contact numbers should you wish to clarify any issue or should doubts arise. The interview should last approximately an hour. Regardless of whether or not you choose to participate, please let me know if you would like a summary of my findings. To receive a summary, please contact me at the address mentioned below.

The Head of the Department of Visual Arts at the University of Pretoria has approved this study, as well as the UP Ethics Committee. If you have any questions or concerns about being a participant in this study, you may contact me either by e-mail or telephone, listed below.

I shall be grateful for your co-operation in this research study.

Thank you,
Yours sincerely,

Marinda Pretorius
MA Student, Faculty of Humanities, Department of Visual Arts

Email: mpretorius@med.up.ac.za
Tel: 012 319 2432,
Fax: 012 319 2240
Cell: 082 965 2998

STATEMENTS OF CONSENT BY PARTICIPANTS

A. Consent Statement

I ____________________________, agree to participate in this research study. I am aware of the terms and conditions regarding my participation in this research study, as outlined in the letter of invitation handed to me. Accordingly, I know that I can stop the interview at any time and that the recording and notes will be destroyed in such a case. I note that the interview will be digitally recorded on audio equipment for research purposes and that it will be transcribed and archived at the Department of Visual Arts, University of Pretoria for 15 years.

B I have been told that I have the right to hear the audio recording or read the transcription before it is used. I have decided that I:

(tick whichever is applicable)

- ☐ want to hear the tapes
- ☐ do not want to hear the tapes
- ☐ want to read the transcription
- ☐ do not want to read the transcription

C I have been told that all information derived from these interviews **can** be treated as confidential and that I may remain anonymous.

(tick whichever is applicable)

- ☐ My name may be revealed in the dissertation
- ☐ I want to remain anonymous

D I have been told that the recording and transcriptions will be archived for 15 years at the University of Pretoria.

(tick whichever is applicable)

- ☐ The information may be used in other research without my permission
- ☐ The information may not be used in other research without my permission, please contact me at.. if anybody else wants to use the information.
- ☐ The information may only be used for this study.

Marinda Pretorius may use the information derived from the interview for research purposes.

The interview will be held at __________________ **on** ___________________.

________________________ ______________

Signature Date

Appendix 1 - If B was ticked.

Audio Recording/Transcription Review Statement

I____________________________, acknowledge that I have reviewed the audio recording or have read the transcription of the interview held on ______________________, in which I participated.

Comment:
____
____
____

____________________________ ________________

Signature of participant Date