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# Focused Multisensory Anatomy Observation and Drawing for Enhancing Social Learning and Three-Dimensional Spatial Understanding

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The concept that multisensory observation and drawing can be effective for enhancing anatomy learning is supported by pedagogic research and theory, and theories of drawing. A haptico-visual observation and drawing (HVOD) process has been previously introduced to support understanding of the three-dimensional (3D) spatial form of anatomical structures. The HVOD process involves exploration of 3D anatomy with the combined use of touch and sight, and the simultaneous act of making graphite marks on paper which correspond to the anatomy under observation. Findings from a previous study suggest that HVOD can increase perceptual understanding of anatomy through memorization and recall of the 3D form of observed structures. Here, additional pedagogic and cognitive underpinnings are presented to further demonstrate how and why HVOD can be effective for anatomy learning. Delivery of a HVOD workshop is described as a detailed guide for instructors, and themes arising from a phenomenological study of educator experiences of the HVOD process are presented. Findings indicate that HVOD can provide an engaging approach for the spatial exploration of anatomy within a supportive social learning environment, but also requires modification for effective curricular integration. Consequently, based on the most effective research-informed, theoretical, and logistical elements of art-based approaches in anatomy learning, including the framework provided by the observe–reflect–draw–edit–repeat (ORDER) method, an optimized “ORDER Touch” observation and drawing process has been developed. This is with the aim of providing a widely accessible resource for supporting social learning and 3D spatial understanding of anatomy, in addition to improving specific anatomical knowledge. Anat Sci Educ 0: 1–16. © 2019 American Association of Anatomists.

*Key words:* Gross anatomy education; undergraduate education; medical education; anatomical illustration; anatomical drawings; teaching of anatomy

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## INTRODUCTION

### Visual Observation and Drawing

While the technique of drawing may be commonly associated with the production of fine art, visual representations have also historically been utilized in anatomy (Calkins et al., 1999; Kemp, 2010; Ghosh, 2015). In essence, drawing is simply the act of making marks or lines on a suitable surface. Since ancient times, humans have been performing such actions using their fingers and primitive tools to make marks in clay and rock, with pencil and paper being typically used today (Dowd, 2018). In terms of anatomical drawing as a learning approach, of particular note is the work of pre-eminent 19th-century naturalist Louis Agazzis, who taught his students at Harvard University to study zoology through meticulous observation and drawing (Agassiz, 1862; Cooper, 1917; Lerner, 2007). More recently, drawing has been utilized widely within science education (Glynn, 1997; Disessa, 2004; Ainsworth et al., 2011; Katz et al., 2011), and medical and anatomy education (Phillips, 2000; Naug et al., 2011; Bell and Evans, 2014; Backhouse et al., 2017; Reid et al., 2019), as an art-based (Table 1) learning approach. Educational theories (Kolb, 1984; Ausubel, 2012) and theories of drawing (Mitchell, 1994; Perkins, 1994; Catterall, 2005; Petherbridge, 2010), in addition to educational research studies (Nayak and Kodimajalu, 2010; Naug et al., 2011; Lyon et al., 2013; Noorafshan et al., 2014; Balemans et al., 2016; Backhouse et al., 2017; Pickering, 2017; Greene, 2018; Reid et al., 2019), and findings from educational neuroscience and cognitive psychology (Guérin et al., 1999; Bouaziz and Magnan, 2007; Friedlander et al., 2011; Tyler and Likova, 2012) have provided support for the concept that the process of drawing can be valuable for learning and enhancement of student engagement through innovation and interactivity.

Visualization is an important facet of science (Gilbert, 2005) and anatomy (Pandey and Zimitat, 2007) education. Incorporating non-specific visual arts can develop deep neural integration pathways, suggesting that engagement in artistic activities could increase cognitive function and develop motor skills (Tyler and Likova, 2012). By extrapolation, the application of specific art-based practices explicitly integrated into a defined learning method could further enhance these abilities. Factors supporting a link between artistic practice and knowledge consolidation include stimulating visual cues, activating prior knowledge, improving academic grades, influencing metacognition to prompt tacit intelligence, and strengthening overall knowledge retention (Nayak and Kodimajalu, 2010; Azer, 2011; Naug et al., 2011; Balemans et al., 2016). More directly, visual observational drawing shows a strong link with memory and motor control (Chamberlain et al., 2014).

## Table 1.

**Glossary of Terms Used for the Description of Haptico-Visual Observation and Drawing Process (HVOD)**

| Term | Definition |
|---|---|
| Art-based learning | Approaches in anatomy education that utilize artistic methods including drawing, clay modeling, and body painting with the purpose of enhancing learning rather than producing art. |
| Contour drawing | Technique for representing the outline of a 3D object on a 2D surface. |
| Cross-contour drawing | Technique for representing mapping and topography of the shape and features of a 3D object with drawn lines. |
| Descriptive value | Term used to describe marks on paper, which have been constructed in combination with the form of the object, being observed and therefore reflect the form of the object. |
| Discriminative touch | Technique also known as “fine touch” which allows focus on, isolation of, and potentially identification of a given object without the requirement for visual observation. |
| Exploratory procedures | Haptic explorations or palpations that gather knowledge about an object (Lederman and Klatzky, 1987; Lederman et al., 1993). |
| Gesture drawing | Technique for producing permanent marks which represent expressive gestural movements of the hand, wrist, elbow, shoulder, and trunk. |
| Mark analysis technique (First phase) | Technique used by hapticovisual observation and drawing (HVOD) instructor and participants to interpret the marks made on paper by an observer-drawer during HVOD Stage 1. Marks are analyzed to identify if typical movements, or gestures that are directed, purposive, spontaneous, fluid, and varied were used to produce them. |
| Mark analysis technique (Second phase) | Technique used by hapticovisual observation and drawing (HVOD) instructor and participants to interpret the marks made on paper by an observer-drawer during HVOD Stage 3. The presence, location, number, and strength of marks are identified in order to determine which areas of the object the student has observed effectively, which areas need to be observed further, and therefore how well the individual understands the anatomical feature that they have been studying. |
| Modeled drawing | Technique for representing 3D volume. This involves initial creation of an outline template that is then modeled into shape by adding or removing marks or areas using, e.g., a pencil or eraser. |
| Observational drawing | Technique of creating drawings based on visual information that is gained from simultaneous observation of physical objects. |
| Observer-drawer | An individual engaged in observational drawing. When engaging in hapticovisual observation and drawing, the individual is using visual and haptic observation while making marks on paper to represent the object they are observing. |

As a three-dimensional (3D) discipline, anatomy learning requires visuospatial understanding (Keenan and ben Awadh, 2019) and there are parallels between the involvement of frontal regions of the brain and the cerebellum during drawing and visuospatial activities, suggesting similar brain regions may be involved in both processes (Makuuchi et al., 2003; Ferber et al., 2007; Miall et al., 2009; Schlegel et al., 2015). While this work and additional findings (Voss et al., 2010; Freeman et al., 2014; Markant et al., 2016) would support the implementation of active visual art-based learning approaches in general, particular focused observation and drawing techniques have also been shown to specifically enhance anatomy learning (Nayak and Kodimajalu, 2010; Naug et al., 2011; Lyon et al., 2013; Noorafshan et al., 2014; Balemans et al., 2016; Backhouse et al., 2017; Pickering, 2017; Greene, 2018; Reid et al., 2019).

Studying diagrammatic or graphical representations of anatomy that display topological and geometric information are likely to be more effective for processing, understanding and memorizing observations of 3D form than textual, sentential, or other non-diagrammatic approaches (Larkin and Simon, 1987; Stenning and Oberlander, 1995; Stern et al., 2003). A feature shared by all visuospatial learning approaches is an attempt to facilitate the interchange of two-dimensional (2D) and 3D information, a skill that is not only essential for interpreting many aspects of medical imaging, histological examination, and embryological development, but one that is also essential for relating the mostly 2D information in textbooks to authentic practical situations involving 3D living and cadaveric anatomy. With the development of sophisticated electronic modes of delivery, students must also be able to relate digitally rendered 3D anatomy with 2D cross sections and textbook images (Keenan and ben Awadh, 2019). Annotated anatomical illustrations presented within textbooks and online resources can be valuable for learning in terms of the identification and highlighting detailed anatomical structures and their relationships, for example, the course of blood vessels and nerves within the body.

Anatomical illustrations in contemporary anatomy atlases are essentially "contour" drawings (Table 1). The marks that define these illustrations predominantly show an outline of the anatomical structure from a single perspective. While digital models can be effective for appreciating the 3D form of anatomical structures, many such resources rely on visual observation of a 2D screen. Although virtual reality, augmented reality and autostereoscopy can present anatomical features in 3D (Keenan and ben Awadh, 2019), such resources have extensive financial implications and therefore are not currently widely accessible to students within all anatomy programs or medical schools, nor are they normally suitable for self-directed learning (SDL) activities outside of the anatomy laboratory. Furthermore, with the exception of 3D printed models and some physical simulations (Kinnison et al., 2009; Yeom et al., 2017), many anatomy learning technologies rely on visualization only and do not explicitly include haptic elements.

## Haptic and Multisensory Learning

The process of haptic observation is known to play an important role in learning (Klatzky et al., 1987; Lederman and Klatzky, 1993; Woods and Newell, 2004; Jones et al., 2006; Minogue and Jones, 2006; Kuschel et al., 2010; Friedlander et al., 2011; Klatzky and Lederman, 2011; Loomis et al., 2013). The fingers possess a large number of neural endings which enable both skilled motor activity and transmission of sensory information to higher centers of the brain for processing "discriminative touch" (Table 1). This results in a relatively large area of the somatosensory cortex being comprised of sensory information regarding touch from the hand (Johnson and Lamb, 1981; Hocherman and Wise, 1991; Delhaye et al., 2018), an area of the brain where spatial information is also processed (Phillips et al., 1988).

Moreover, recognition and learning is enhanced through multimodal haptic and visual observation (Woods and Newell, 2004; Minogue and Jones, 2006). Multimodal approaches can be effective in anatomy learning (Sugand et al., 2010; Naug et al., 2011; Estai and Bunt, 2016), and findings from cognitive neuroscience which support the impact of multimodal and multisensory processes on learning (Zhou and King, 1997; Zhou and Fuster, 2000; Tal and Amedi, 2009; Murray et al., 2016; Matusz et al., 2017), suggest that educational interventions that incorporate the elements of both sight and touch could enhance anatomical understanding. This may be due to the extent of integration of visual and tactile input in the creation of memory during multimodal approaches (Tal and Amedi, 2009; Murray et al., 2016; Matusz et al., 2017). The parietal region of the brain plays a crucial role in the perception of multimodal data, combining a variety of sources (e.g., visual and haptic) into a cohesive pathway (Gainotti et al., 1985). While further research is required to identify the cognitive processes responsible for the memorization of objects using multimodal visual and haptic observation combined with drawing, neuroimaging studies have identified that the parietal lobe displays increased activity during drawing tasks (Solso, 2001; Makuuchi et al., 2003; Miall et al., 2009).

## Haptico-Visual Observation and Drawing

Based on an understanding of the importance of visual and haptic aspects of learning and the value of drawing in anatomy education, it can be hypothesized that simultaneous multisensory observation and drawing of an anatomical structure may result in the acquisition of substantially more information about the 3D form of the structure over and above the use of visual resources alone. A specific method known as "observational drawing" (Kantrowitz, 2012) (Table 1) is likely to be best suited to this approach to learning. More specifically, it is postulated that combined "gestural drawing," which incorporates "cross-contour" and "modelled" observational drawing (Table 1) can enhance learning through facilitating the translation of the 3D form of an anatomical structure onto a 2D drawing surface, that is, paper.

Previous work by the authors (L.S. and G.L.) has briefly described the process of haptico-visual observation and drawing (HVOD). Students reported that HVOD was an effective approach for encouraging a deep understanding and spatial awareness of the 3D form of anatomical structures (Reid et al., 2019). While an objective experimental study of anatomy learning with HVOD has not yet been implemented, the rationale and design of HVOD is supported by this previous phenomenological study and is also supported by anecdotal observations. Furthermore, the HVOD process is underpinned by the educational value of observational drawing, and includes elements which have a basis in cognitive neuroscience and pedagogic research.

The HVOD approach (Fig. 1), involves a step-by-step process of initially preparing the hand and upper limb of the "observer-drawer" (Table 1) participants, in order to produce directed, purposive, spontaneous, fluid, and varied (DPSFV) movements (Stage 1); to encourage and develop combined multimodal

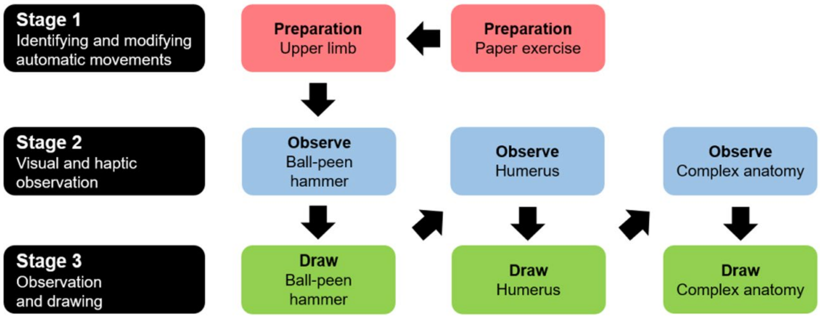



**Figure 1.**

The haptico-visual observation and drawing (HVOD) process. The HVOD method can be divided into three distinct but integrated stages of preparation: Identifying and modifying automatic movements (Stage 1); visual and haptic observation (Stage 2); observation and drawing (Stage 3). Each object or anatomical structure should be carefully observed in Stage 2. Graphite marks that represent observations of the object ("drawings") are then produced during Stage 3. The ball-peen hammer is observed and drawn in Stages 2 and 3, before repeating these activities with the humerus. Once these steps have been successfully achieved, the observer-drawer can subsequently move on to observation and drawing of more complex anatomical structures of their choosing. The observer-drawer is therefore able to focus on specific area(s) of anatomy that they may wish to understand more deeply and effectively.

visual and haptic observation of anatomy (Stage 2); and to create representations of what is being observed through making graphite marks on paper using DPSFV movements (i.e., gestural drawings), which can then be analyzed in order to identify how effectively the observer-drawer participant is conducting their observations (Stage 3). The anticipated outcome of HVOD is to develop the observational skills of observer-drawers and in doing so, to enhance their appreciation of the 3D form and spatial arrangement of anatomical structures, rather than seeking to impart specific anatomical knowledge with respect to the functional details and terminology associated with each feature. Esthetically pleasing and anatomically accurate drawings may also be produced by observer-drawers, but this outcome can be considered as a welcome but non-essential by-product of the learning process (Keenan et al., 2017; Reid et al., 2019). Indeed, focusing on the esthetic properties of a drawing may actually detract from a perceptual understanding of the data that the image is intended to represent (Kulvicki, 2006).

A detailed overview of the practical implementation of HVOD, which was not comprehensively included in the authors' previous work (Reid et al., 2019) is described here. This will serve to remind and support individuals who have previously been trained as HVOD observer-drawers and who may be seeking to utilize aspects of the approach in their own practice. This guide will also be of benefit to those who are yet to experience HVOD by introducing them to this valuable approach.

# DESCRIPTION OF HAPTICO-VISUAL OBSERVATION AND DRAWING PROCESS

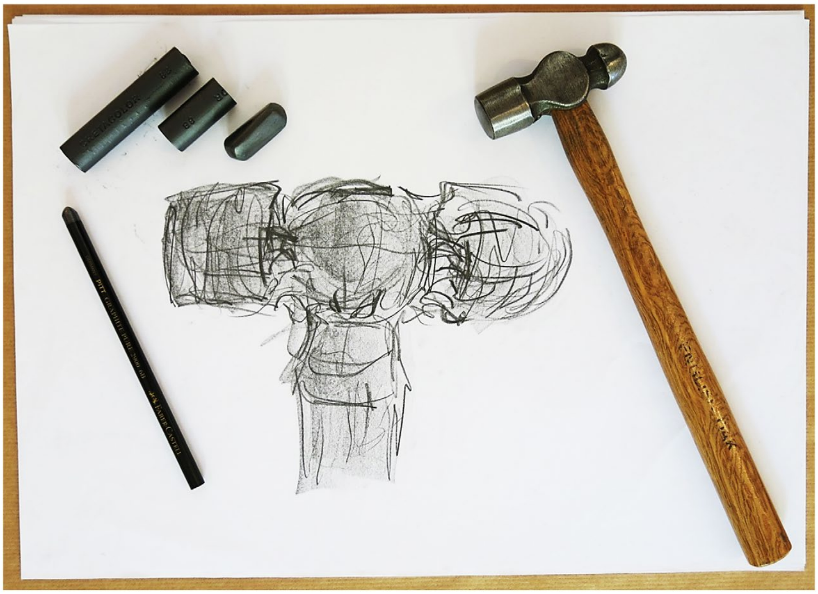
## Context and Learning Environment

Since 2014, the first author (L.S.) has designed and implemented HVOD workshops for both academics and students of anatomy in South Africa at the University of Cape Town (UCT) in addition to running a UCT certificated, continuing professional development course in HVOD for health care professionals. The ability to observe using touch and record these observations using drawing is fundamental to all such workshops. Learning spaces that can accommodate up to 20 participants and around 10 large tables in an elliptical formation have been utilized, and have included anatomy museums, laboratories, and seminar rooms, depending on the location.

One-day workshops in HVOD are also tailored for specific health-care disciplines, with the aim of developing the skills of participants in spatial orientation and appreciation of the 3D positional arrangement of anatomical structures in 2D cross-sectional diagnostic images. This includes radiation oncology planners who require improved spatial orientation skills in order to increase the accuracy of their planning, and forensic pathologists who need to develop understanding of anatomical volumes when viewing full-body low-dose X-ray images. Instruction in the application of haptic observation is also provided to orthopedic surgeons and surgical registrars in order to enhance their awareness of anatomical variation and improve laparoscopic instrument techniques for minimally invasive surgery.

The medical M.B.Ch.B. degree at UCT is a six-year program into which school leavers are accepted. The teaching and learning of clinical anatomy occur across Years 1–Year 3 of the program which is integrated into a problem-based learning curriculum and consists of whole class lectures, practical sessions using prosected specimens and models, and full-body dissection. All students take four weeks out of the regular program in order to pursue a credit-bearing Special Studies Module (SSM). This has previously been delivered in Year 2, but for 2019 was moved to Year 3. Students select the field and topic that they would like to research from a list supplied by supervisors from all departments at the Faculty. The HVOD anatomy drawing SSM is delivered by L.S. as a workshop, with students being supplied with drawing materials, paper, osteological material, and cadaveric specimens. While the HVOD process itself is delivered and learned within the first three days, the remainder of the SSM involves further applications of HVOD in the study of anatomy.

Additionally, workshops have been delivered by L.S. to postgraduate Biomedical Engineering, Fine Art, and Drama students at UCT, undergraduate medical students at Newcastle University, United Kingdom, and to students at the University of Adelaide, Australia via video. Workshops have also been held in the United Kingdom and South Africa for anatomy educators with the aim of developing their observational skills and



## Figure 2.

Haptico-visual observation and drawing (HVOD) materials. A 200g (7oz) ball-peen hammer, solid graphite sticks, preferably 6B (Faber-Castell AG, Stein, Germany) and 8B (Cretacolor, Revillier Urban & Sachs GmbH & Co KG Vienna, Austria) as shown, are the preferred medium, as graphite is soft enough to transfer and record the subtle nuances of hand gestures in the marks made. Also, graphite does not smudge as easily as charcoal. The A3 size (29.7 × 42.0 cm) 80gsm paper that is used in Stage 1(2), Stage 3(1) and Stage 3(2) is shown, while A4 (21.0 × 29.7 cm) 80gsm paper is used in Stage 1(1) for the paper exercise. An example of HVOD marks representing a ball-peen hammer that was produced using these materials is shown. Drawing is by Graham Taschner, from a HVOD workshop at the University of Cape Town in 2015 (used with permission).

3D appreciation of anatomy, while simultaneously providing examples of valuable anatomy learning techniques that may be utilized and delivered by participants to students at their own institutions. One such workshop was held within the School of Medical Education at Newcastle University in May 2017.

Prior experience of observation, drawing, or even anatomy is not pre-requisites for individuals seeking to learn about the 3D form of structures using the HVOD process. It is intended that HVOD can be transferable to any discipline in which an understanding of the form of 3D structures is required, and HVOD is therefore particularly appropriate for studying anatomy. However, previous training and expertise in artistic practice may actually serve as a barrier by reducing the receptiveness of an individual to engage and persist with a new drawing method. Students are asked to suspend their application of any prior drawing approach during the process, in order that they may most effectively learn the HVOD mark-making technique. The important, and potentially counterintuitive, concepts that HVOD drawings are simply the consequence of observation, and that observation of anatomical form is the primary aim of HVOD, are also emphasized to students.

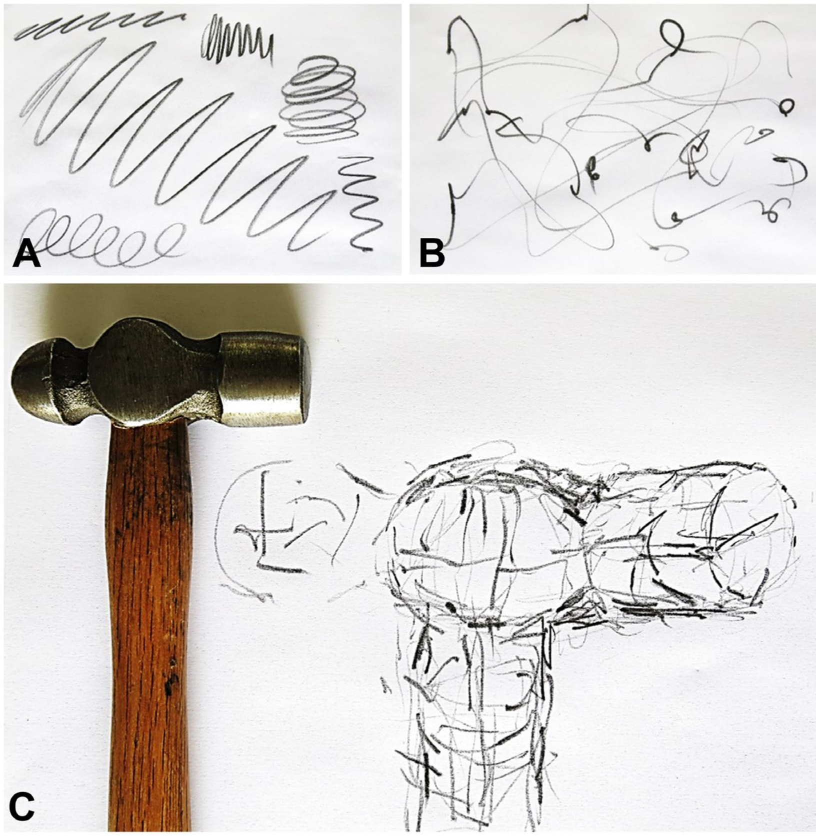
Nonetheless, anecdotally, many students and educators do not appreciate the pedagogic value of drawing, or believe that they cannot draw and that only the "gifted" can do so. Indeed, prior student and educator beliefs and perceptions of their own capabilities can strongly influence educational expectations (Thomas et al., 2001). However, it is proposed that anyone can be trained to observe an object and simultaneously compose gestural marks on paper, such that their marks correspond with what they are observing. This concept forms the basis for the HVOD process. Any observer-drawer should therefore be able to enhance their understanding of anatomy while having the opportunity to develop their drawing technique for use as a potentially valuable teaching and learning tool. Consequently, it is important to underline this idea to participants from the outset, as the class may have a range of prior drawing experiences.

Having completed each stage of the process, it is proposed that the HVOD method described here can commit the form of the object into the memory as a visual image (Reid et al., 2019). Furthermore, it is postulated that this image can be subsequently cognitively accessed and viewed from all angles in the absence of the simultaneous observation of the object. During a HVOD workshop, the observer-drawer is guided through the three distinct stages of the process by the instructor, as described in Figure 1 and below, in order to develop their ability to make marks that represent what they observe.

## Stage 1: Preparation, Identifying, and Modifying Repetitive Upper Limb Movements

Before beginning to observe and draw an object (Fig. 2), the observer-drawer should engage in a series of important incremental learning steps. This is with the intention of preparing the upper limb and hand to move in purposive and directed ways that will allow the student to record what they observe about the 3D form of the object, in pencil marks on paper. These steps are supported by engagement in two specific activities, the "paper exercise" and the "scribble exercise."

**The paper exercise.** Repetitive and predictable upper limb and hand movements are typically employed during our daily life and directly coincide with, and enable us to function within, the architecture and design of the modern environment (Lederman and Klatzky, 1993). The paper exercise guides students in the exploration of gestures that are in direct contrast to such common movements. Students are instructed




## Figure 3.

The haptico-visual observation and drawing (HVOD) mark analysis technique. The ability to produce directed, purposive, spontaneous, fluid, and varied (DPSFV) marks is developed during the paper exercise and scribble exercise in Stage 1 of HVOD. A, During the first phase of the HVOD mark analysis technique, the marks produced by observer-drawers are analyzed to identify if they are produced with repetitive and predictable upper limb and hand movements, or if they are produced with varying speed and pressure from DPSFV gestures of the upper limb and hand (as shown on panel B). During Stage 3 of HVOD, the second phase of the HVOD mark analysis technique is used to identify marks which represent the parts of a 3D object that have been effectively observed, and the parts which have not been effectively observed. Second-phase mark analysis of a HVOD drawing of a ball-peen hammer; C, shows that the ball-peen (rounded end) has not been effectively observed. This is due to the lower number and level of detail of the marks present. The other features of the hammer have been more effectively observed, as shown by a higher number of more detailed marks. This drawing can be compared and contrasted with the hammer drawing in Figure 2, the entire form of which has been drawn, and therefore observed, effectively.

to: "*Use your hands only and identify how many different things you can do to a sheet of paper*" and encouraged to use DPSFV gestures of the upper limb, hand, and digits, and metacognitively appreciate their own improvements when doing so. While appearing to be a simple exercise, anecdotally almost all students find this challenging from the outset. The difference between the first and subsequent attempts can be remarkable, with students initially acting on the paper slowly and with uncertainty. By the third and fourth attempts, using a new sheet of paper on each occasion, students are able to perform a variety of imaginative DPSFV gestures. With repetition, students become increasingly able to move their upper limb joints, particularly radiocarpal and intercarpal joints and joints of the digits, in a DPSFV fashion so that each hand movement flows seamlessly from the previous one. This provides them with an awareness of the contrast between their typical actions and their DPSFV movements.

**The scribble exercise.** Students are instructed to simply "*scribble on the paper*" in order that the instructor can implement the first phase of the "mark analysis technique" (Table 1) to identify those marks which are produced by repetitive and predictable movements (Fig. 3A), and those which are DPSFV marks (Fig. 3B). Similar approaches for the analysis of drawings and visual communication have been previously employed to identify learning and areas of incomplete student conceptual understanding (Thomas et al., 2001; Köse, 2008; Tversky, 2014). The progress of individual observer-drawers is monitored by the instructor, and each student is supported accordingly. The instructor provides specific and individualized practical guidance in order to address the challenges experienced by each participant. This stage also extends DPSFV movements to include the upper limb, pelvis, and lower limbs. These actions are optimized through standing, rather than sitting, while drawing. This allows movements of the entire body to be reflected as nuanced gestures through fine motor control, which consequently supports the production of similarly nuanced descriptive marks. The instructor ensures that the shoulder, elbow, and wrist of each student is relaxed and that the drawing marks therefore reflect the movement of the entire body. In order to encourage the production of DPSFV marks exclusively, the instructor presents a number of tasks that introduce varied pencil pressure, speed of pencil movement, and movement across the paper in multiple directions while using varying pressure. It is important that the observer-drawer

## Table 2.

**Exploratory Procedures of Haptic Analysis Performed by the Observer-Drawer During the Haptico-Visual Observation and Drawing Process**

| Procedure | Aspect of Object Being Explored |
|---|---|
| Lateral motion | Texture |
| Unsupported holding | Weight |
| Pressure | Hardness |
| Enclosure | Global shape, volume |
| Static contact | Temperature |
| Contour following | Global shape, exact shape |
| Function test | Specific function of object |
| Part-motion test | Movement of specific component |

Exploratory procedures are used when palpating the ball-peen hammer, humerus, or anatomical structure being observed and drawn. Table is modified from and based upon previous work (Lederman and Klatzky, 1987, 1993).

becomes aware of their propensity to make repetitive and predictable movements so that they can actively begin to move their upper limb using DPSFV gestures to produce DPSFV marks on paper. These DPSFV marks possess a “descriptive value” (Table 1) that will be required in subsequent stages, once students have learned to haptically observe the object. It is proposed that learning occurs during individual and collaborative reflection upon these drawing marks.

## Stage 2: Visual and Haptic Observation

This stage is crucial in understanding the 3D form of an object under observation and the important physical nuances that comprise it. The acquisition of haptic information about the object builds on student learning achieved through visual observation. The activity is performed by applying exploratory procedures (EPs) (Tables 1 and 2) (Lederman and Klatzky, 1987; Lederman et al., 1993) to a ball-peen hammer. The EPs of “lateral motion,” “contour following,” and “grasping” are used in particular for the extraction of 3D object properties. A hammer is used as an introductory object for palpation and haptic exploration, as it is comprised of a variety of different geometric volumes and surfaces and is small enough and light enough to hold comfortably in one hand (Fig. 2).

This stage is achieved by first palpating in combination with visual observation and then haptically only, with the eyes closed. The hammer is viewed and simultaneously palpated from various perspectives after which the eyes are closed. EPs continue so that students can gather both visual and haptic data regarding the 3D form of the hammer. Upper limb and hand DPSFV movements trace the contours of the 3D form, in multiple directions. The DPSFV movements are reflected by similar movements of the drawing hand. In Stage 3, these movements will consequently describe with pencil marks, the 3D form under observation, via haptic exploration of the sensing hand.

## Stage 3: Observation and Drawing

**Making marks on paper and representing the object being observed.** The student begins to haptically and visually observe the ball-peen hammer and simultaneously draw it using DPSFV movements based on what they have learned in Stages 1 and 2. A non-anatomical object is initially drawn in order to mitigate any anxiety that the student may have toward drawing an anatomical structure. This is with the intention that any perceived expectation of drawing in a style typical of published anatomical illustrations found in educational resources and popular anatomical artwork will be removed. In an analogy to anatomical variation, these objects also possess minute variations that make the haptic exploration of each individual hammer a unique experience. After discovering their ability to observe and draw an anatomically neutral object, it is proposed that the student will transition into observing and drawing anatomical structures with greater confidence. While gesture drawings may appear haphazard in their esthetic, the marks that comprise them are a representation of what has been haptically and visually observed. At this point, it is important to emphasize to students that the primary purpose of observing and making marks is not to render an esthetically agreeable drawing but to gather 3D information that will lead to a more closely observed understanding of the object (Keenan et al., 2017; Reid et al., 2019).

When a 3D object such as a hammer, humerus or heart is visually observed, the object is seen in its entirety and not as an object broken into component parts, as the brain constructs a 3D representation from observed 2D images on the retina (Lawson et al., 1994; Tarr and Bülthoff, 1998). While a metal hammer is cast in one solid piece of metal, it possesses features that might be named, for example, head, face, eye, and peen. In order to appreciate the combined structures that make up the entire 3D form of an object, it is proposed that it is important to describe the object globally using a series of continuous, cross-contour gestures (Table 1). This can be accomplished via the seamless element of DPSFV movements. While contour following is applied to the object with one hand yielding sensory input, a cross-contour drawing is produced from the motor output and represents what is being haptically observed.

Encouraging the observer-drawer to describe the object using a very swift drawing action is effective for supporting them in observing the object in its entirety and drawing it as a single entity. This is in contrast to observing and drawing the object in terms of separate and semantically defined component parts. Consequently, HVOD requires visual and haptic observation of the object to be followed by the making of marks that reflect it as a unitary 3D entity. The observer-drawer tends to perform this activity by making a mark that represents one area of the object, before rapidly moving on to another distant point, then quickly moving on to draw another part, and so on until the marks made define the object in all three dimensions. This combined observation and rapid mark-making action continues until the form of the object is represented in 3D by a myriad of marks on the paper, a 2D surface, and may reflect the simultaneous cognitive processing of the observer-drawer (Kantrowitz, 2012). Such HVOD outputs may therefore serve as more faithful representations of the observer-drawer’s understanding of all surfaces of the 3D object than would a fixed-perspective, photo-realistic drawing.

Throughout Stage 3, the instructor uses the second phase of the mark analysis technique (Table 1) to advise students where necessary, based on an analysis of their visible upper limb movements, and the pencil marks that result from these exercises (Fig. 3C). Observer-drawers are also trained to interpret their own marks and those of their peers using this technique. Peer learning exercises where students evaluate and provide feedback on each other's marks can then be introduced. Anecdotally, participating non-practiced observer-drawers have been able to identify the extent of observation achieved by their peers. Such activities can serve as an indication to learners when they need to explore and observe the anatomy further in order that they may more effectively understand it. Evidence can be interpreted from the detectable marks made with graphite on paper, by movements of the body. These gesture and cross-contour marks are visual records of upper limb gestures that reflect what has been observed through the senses (Ashwin, 1984; Ashwin, 2016). For example, if the gestural cross-contour marks representing the 3D form of the striking face of the hammer are prominently drawn in terms of the strength and number of marks (relative to the marks representing the head, eye, middle and opposing ball-peen ends of the hammer), the striking face can be considered to be the area that has been scrutinized in the most detail by the student. In effect, the drawing that emerges is testimony to the extent to which the object or anatomical structure has been effectively observed. Having assimilated this constructive critical feedback, the student is then able to repeat the process by re-observing those features that were initially not well observed, while redrawing the object. Having been introduced to second-phase mark analysis when using the hammer, this level of scrutiny can subsequently be extended to the observation and drawing of anatomical features.

**Drawing an anatomical structure.** Having drawn the ball-peen hammer, the student then haptically and visually observes and draws a humerus, before selecting an anatomical structure with a more complex 3D form such as the skull or heart. The student is guided through exercises, such as turning the humerus through 360° in approximately 20° increments, pausing the rotation while observing and drawing the visible anatomical structures, before continuing with the next 20° rotation. The student will draw the structures that they observe at each rotation *in the same place* on the piece of paper. This exercise enables the student to explore and observe the many structures of the anatomical structure in all of its dimensions. Through this process, the observer-drawer will have gathered data about the 3D form of the object through visual and haptic observation.

It is proposed that this stored information is now accessible to the student, so that the 3D structure of the object can then be realized during drawing. During all subsequent steps, the student continues to palpate anatomical structures using EPs. It is also useful to palpate the object with the eyes closed. Temporarily eliminating the sense of sight while palpating allows the observer-drawer to focus more acutely on haptic observation (Klatzky et al., 1987). Furthermore, and as described above, it is postulated that both visual and haptic observation may enhance 3D understanding of the object under observation and may also facilitate differing perceptions of the same data (Klatzky et al., 1987).

Having completed this task, it is proposed that the student should be able to close their eyes and view the object in their mind as a visual image (Reid et al., 2019). It is therefore important to emphasize the distinction between the internal and external representations of anatomical form in the context of the 3D spatial anatomy addressed by HVOD. This is both in terms of the observational process and the drawings which are produced (Scaife and Rogers, 1996). The tangible product of HVOD superficially appears to be a 2D drawing on a flat surface (i.e., paper). On closer inspection, the implicit output acquired from engaging in the process is the external representation of 3D form on a 2D paper surface using DPSFV marks. Perhaps most importantly, the internal representation of 3D anatomy that is produced during HVOD may provide a tacit understanding and appreciation of that structure.

### Phenomenological Study of Educator Perceptions

Previous work has identified that Year 2 medical students at UCT perceived that HVOD could facilitate their ability to create a mental picture of the anatomy under observation through memorization and deep 3D observation. Students also reported that despite the process requiring a significant investment of time, this was offset by the learning gains achieved (Reid et al., 2019). Further to these findings, it was also important to explore the perspectives of anatomy educators regarding HVOD, with a view to supporting wider integration of the approach. As such, educator views were sought with respect to the pedagogic value, curricular implementation, and accessibility of the HVOD process, and how HVOD may influence their teaching practice and impact the learning and experience of their students.

## MATERIAL AND METHODS

Educators ($n$ = 9) affiliated to higher education institutions across the United Kingdom attended a three-day HVOD workshop facilitated by the first author (L.S.) and held at Newcastle University School of Medical Education in United Kingdom. Authors (I.K. and K.B.) attended the workshop as observer-drawers but did not participated in research activities. A post-workshop focus group approach was developed and implemented based on established principles of focus group design (Greenbaum, 1998; Stewart and Shamdasani, 2014) in order to identify educator perceptions of HVOD.

The majority of workshop attendees consented to participate in the focus group ($n$ = 5). Participants indicated that they utilized either practical dissection or prosection in their teaching practice in addition to lecture-based instruction. Participants also reported that they primarily attended the workshop with the aim of experiencing a new learning approach, to develop their own skills and to increase the variety of learning approaches they could deliver to their students. The focus group comprised a semi-structured design, whereby broad topics of effective anatomy teaching methods, and the value, logistics, benefits, and limitations of HVOD were raised by the facilitator (K.B.) for open discussion. Participants were encouraged to actively take part and account for their views. Video and audio recordings of the focus group were transcribed into text format. Transcripts were then analyzed using double-coded (K.D. and I.K.) thematic content analysis, based on principles described elsewhere (Onwuegbuzie et al., 2009; Stewart and Shamdasani, 2014).

A post-workshop questionnaire including the free-text items described below was also administered to participants.

1. Please comment on the potential impact of the workshop your teaching
2. Please comment on the potential value of the hapticovisual observation and drawing method for your teaching and for your students' learning

3. Please comment on any barriers to using haptico-visual observation and drawing in your teaching and for your students' learning
4. Please comment on what you consider to be the most effective features of the haptico-visual observation and drawing method
5. Please comment on what you consider to be the least effective features of the haptico-visual observation and drawing method

Participant responses ($n = 5$) to these items were reviewed post hoc, and comments that reflected themes arising from the focus group were identified.

The Newcastle University School of Medical Education Research Management Group approved implementation of the study in January 2017. The Newcastle University Faculty of Medical Sciences Ethics Committee granted approval for this project 11900/2016 to progress in February 2017. Focus group participants (denoted here as participants A, B, C, D, and E) gave informed written consent to anonymously participate in the research.

# RESULTS

## Focus Group

Three themes were identified from analysis of the focus group transcript. Examples of participant comments, followed by supporting questionnaire comments, are provided under each theme.

### Theme 1: Spatial Exploration of Form and Holistic Understanding

*"I found it very illuminating to take my knowledge of structures away from the anatomical, and clinical to a more innate understanding of structures. Developing an understanding that I couldn't really express in any other way than drawing, I think it did supplement [my] anatomical knowledge."* [Participant A]

*"Trying to get students properly engaged with the [anatomy content], not on the superficial level and really thinking about form and function can be quite challenging. They're under a lot of pressure to learn for exams so it's quite easy for them to want to know facts. To engage in something in a deep way and in a holistic way of the whole body, is maybe what they should be aspiring to do and we struggle to get them there. A technique [like HVOD] that can make them engage more fully is what I would want."* [Participant B]

*"If I was teaching the skull, I do feel that you do handle the skull but not in the way that we did [in the HVOD workshop] and I would encourage [students] to do that more, to explore the space in more depth, how big the space is and think about what fits in there."* [Participant C]

*"[Anatomy learning] has to be haptic, [students] have to handle things, turn it around, turn it upside down, pull things, tug things, move it around, look at it through another view, to really understand the anatomy. And understanding the space, for instance like a pelvis, is about understanding space, more than the contents, and unless you have it in your hands I don't think you can understand the pelvis."* [Participant C]

*"So the humerus, I'm fairly certain will be embedded in my mind permanently because I've examined it so minutely. If I struggled with something like the foot and if I spent that much time on the foot, I'd have permanent knowledge, I think."* [Participant D]

Responses to free-text questionnaire items 2, 4, and 6 also reflected this theme:

*"I think it helped to understand space rather well, for example the skull, and translating feel of an object onto paper helps to affirm those relationships. A more accurate appreciation of form and space, and being able to capture that on paper helps to reinforce the memory of those relationships."* [Participant C]

*"Using the hand is a surprisingly effective way of remembering something like shape, especially when combined with observation. It forms longer lasting memories and a better sense of proportion."* [Participant D]

*"I think it is a valuable tool to familiarize yourself with the spaces. I have appreciated things about the skull [during the workshop] that I have not before."* [Participant E]

### Theme 2: Modifications Required for Curricular Integration

*"I'd like to modify [HVOD] a little bit, still using the same techniques and the same order, in terms of the weighting I'd emphasize on using a more obvious application. I think it is fine, but as a teacher I have a tendency to keep bringing it back to anatomy."* [Participant A]

*"I think a modified method would be a 'win-win' … I would modify it to say, 'That looks pretty good like a skull, why don't you add a few foramina' or 'Why don't you start thinking about where muscles attach.'"* [Participant B]

*"The time that it takes to really develop skills and benefit from [HVOD] is incompatible with the curriculum and the timetable. It could be an adjunct, but it would be really difficult to incorporate it as a formal teaching session. Maybe in postgraduate teaching it would be different."* [Participant C]

*"I think [HVOD] is far too labor and time intensive except for those difficult structures, in which case I think it would be useful. You could go down to the lab and ask for a heart, ask for a pelvis and try sketching it."* [Participant D]

*"If we were looking at this as a teaching method it would be one of those opt-in Wednesday afternoons or lunch time things … I think if you offered it, I can see some medical students wanting to do it."* [Participant E]

Responses to free-text questionnaire items 1 and 3 also reflected this theme:

*"I feel the practicalities of integrating this method within the medical curriculum might limit how much I could use it. I am hoping to introduce elements as a supplement to conventional teaching, for example encourage haptico-visual assessment during dissection. Full benefit requires a certain level of time and emotional investment."* [Participant A]

*"[Potential barriers are] timetable constraints and student confidence and desire to draw."* [Participant B]

*"I would like to try this approach but time to do this in our curriculum is very limited. It is unlikely I will spend time using this as a teaching method, but I would use it in a special interest group for anatomy. Students perceptions of this as a valuable activity in their learning [is a potential barrier because] they won't have curriculum time to invest to overcome those perceptual barriers."* [Participant C]

*"The main barrier will be time- getting it into the medical curriculum would be almost impossible although I may try it next year to introduce [students] to an organ. It will always be an added extra but I shall certainly use it for my own study."* [Participant E]

### Theme 3: Engagement in Learning within a Social Environment

*"Teaching over a number of sessions, in the same environment, in the same set up, it creates a safe space. I suppose the question is, "how do you get [students] to remember [what they've learned] away from [the safe space]?" Hopefully over the length of the course it sticks with them. This course does things that'll stick with me I'm sure."* [Participant A]

*"To make [students] feel safe to ask questions, you have to create an environment that's conducive to people wanting to be uninhibited to opening themselves up, I think that's a good thing to try to take into teaching for sure."* [Participant A]

*"I really appreciated the [collegiate environment] of being with fellow [workshop participants], but think how different that experience would've been if it was either you watching Leonard on a YouTube video at home, or even if it was just you and Leonard."* [Participant B]

*"[There were] lots of shared experiences coming from different directions and that's almost what I would encourage my students to do if they're struggling. It's not necessarily their relationship with the tutor it's their relationship with their fellow students and how can they help each other, support each other."* [Participant B]

*"I could see how you could have a bony pelvis or a pelvic dissection and have a student, kind of feel those outlines and margins and have them explain it to someone else."* [Participant C]

Response to the free-text questionnaire item 4 also reflected this theme:

*"Leonard's energy and effort to create an environment conducive to uninhibited drawing seemed vital to allow people to "loosen up" and engage with the process."* [Participant A]

*"Quick exercises and scribbling made drawing feel less precious, this allowed us to be less inhibited in our mark making and less worried about making mistakes."* [Participant B]

## DISCUSSION

Having presented a detailed description of an innovative observation and drawing approach that has been designed for delivery to anatomy educators, students and health care professionals, it has been important to investigate the value of this approach in order to provide a scholarly basis for its implementation. Further to the proposed value of HVOD as a multisensory art-based learning method that incorporates combined visual and haptic techniques with observational drawing, and which can enhance cognitive memorization of anatomical structures (Reid et al., 2019), findings presented here indicate that there is additional value in the process above and beyond these elements, particularly with respect to student engagement in spatial and holistic anatomy learning within a supportive social learning environment. However, a predominant educator perspective was that the integration of HVOD within program curricula could be problematic.

### Spatial and Holistic Anatomy Learning

Educators who had experienced HVOD perceived that a particularly important aspect of the process concerned their deeper and more detailed appreciation of not only the entire 3D form of the structures they had observed and drawn, but also a greater understanding of space and anatomical relationships, which they anticipated would be of benefit for their students. The importance of haptic observation alongside visual observation in supporting these elements of spatial anatomy learning was also noted by focus group participants.

The human body is evidently 3D and therefore, according to the modality appropriateness hypothesis (Lodge et al., 2016) and studies in object perception (Klatzky et al., 1993; Klatzky and Lederman, 2011), visual and haptic 3D approaches should be utilized in order to most effectively deliver gross anatomy learning. While cadaveric specimens, 3D printed and plastic models supplemented by digital resources can fulfill this requirement to some extent (Keenan and ben Awadh, 2019), educator perceptions described here indicate that HVOD provides specific guidance for building upon the traditional usage of these 3D approaches in order to provide the necessary time and focus on detailed visual and haptic examination of 3D anatomical form.

When considering the use of 3D approaches for enhancing spatial anatomy learning, it is important to note that increases in cognitive load have been identified in students with low visuospatial ability when learning with such resources (Huk, 2006). As previously described (Keenan and ben Awadh, 2019), there is a strong evidence that spatial ability is a crucial element of both sucessful anatomy learning (Rochford, 1985; Guillot et al., 2007; Fernandez et al., 2011; Lufler et al., 2012; Nguyen et al., 2012; Nguyen et al., 2014; Sweeney et al., 2014) and surgical skill performance (Wanzel et al., 2002; Suozzi et al., 2013). Indeed, the learning of anatomy can actually enhance spatial ability (Vorstenbosch et al., 2013), which in turn can itself improve anatomy learning (Langlois et al., 2017). This suggests that an approach such as HVOD, which focuses specifically on 3D spatial form, can support this proposed positive feedback loop for the enhancement of anatomical knowledge, skills, and attributes in student cohorts who are likely to initially present with a range of spatial abilities. Furthermore, the inclusion of haptic elements may negate the requirement for high levels of intrinsic visuospatial ability for learning with

HVOD, due to cognitive differences in the properties (Loomis et al., 2013) and recognition (Matusz et al., 2017) of visual and haptic spatial images.

As noted during the focus group, students of anatomy are perhaps more likely to focus on facts rather than form. The HVOD process may therefore benefit from a greater focus on the identification of distinct anatomical features. Student motivation and engagement in education as a means to an end with respect to course progression is often described anecdotally as the idea that "assessment drives learning," a concept which also has empirical support (Larsen et al., 2008; Wood, 2009; Wormald et al., 2009). With respect to assessed learning outcomes in anatomy education, there is a requirement for students to acquire and retain knowledge of specified anatomical terms in order to successfully negotiate examinations (Choudhury and Freemont, 2017). Although attempts have been made to encourage assessment of a broader, practical understanding of anatomy (Rowland et al., 2011; Smith and McManus, 2015), and references to anatomical form and spatial relationships have been included when constructing anatomy learning outcomes (Smith et al., 2016), undergraduate assessment of anatomy is often limited to the identification of named and often clinically relevant anatomical structures (Choudhury and Freemont, 2017).

An appreciation of holistic 3D aspects of anatomy learning within the ordered sequence of HVOD is likely to provide a framework around which specific knowledge can be constructed (Leach and Scott, 2002), as has been previously demonstrated in surface anatomy education (Bergman et al., 2013). Nonetheless, the holistic elements of 3D spatial anatomy supported by HVOD are unlikely to be directly assessed, in turn may not be explicitly delivered by anatomy educators, and are consequently unlikely to be specifically addressed by their students. Therefore, in order to provide a multifaceted learning approach which can be effectively integrated within objective-driven anatomy curricula, and to achieve necessary student motivation with respect to assessed outcomes, it is recommended that all anatomy learning approaches, including any future versions of the HVOD process, should include reference to specific and detailed named anatomical structures alongside an emphasis on the understanding of 3D spatial form.

## Curricular Integration of Art-Based Anatomy Learning Approaches

Further to proposed future modifications relating to specific anatomical knowledge, findings here and in the authors' previous work (Reid et al., 2019) have indicated that there are limitations regarding the integration of HVOD into curricula, which raises concerns relating to the equitable accessibility of the process to all students. Even if a learning approach possesses embedded pedagogic value, to reach all students and deliver these gains within a medical or anatomy program, any process must be successfully integrated within the established curriculum. While educator participants identified positive educational attributes of HVOD, they also identified that the time required to deliver the process would limit their own usage of the approach with their students. This appears to be due to the schedule and timescale required for implementation of HVOD not necessarily being conducive to successful integration into assessment and learning outcome-based anatomy teaching within already congested medical programs.

A new medical curriculum was recently introduced at Newcastle University, United Kingdom, with a cohort of 287 students experiencing this curriculum for the first time in academic year 2017/2018, followed by an increase in cohort size to 335 in 2018/2019 and 345 in 2019/2020. Delivery of anatomy teaching at Newcastle University has been previously described (Backhouse et al., 2017) and these learning approaches have been largely continued within the new curriculum. However, while anatomy laboratory group sizes have been reduced from 18 to 8 students per demonstrator in the new curriculum, practical contact time for individual students has reduced from 57 to 28 hours. These changes reflect the challenges and time pressures experienced by anatomy educators when planning the introduction of novel teaching approaches, and is supported by previous work which has identified the widespread reduction (Dyer and Thorndike, 2000; Aziz et al., 2002), and importance (Bergman et al., 2008; Sugand et al., 2010) of curricular time for anatomy learning. With a view to this, the provision of non-timetabled, SDL activities is a key area into which educators are able to expand their anatomy learning interventions.

Technology-enhanced learning (TEL) is an effective medium for supporting the delivery of SDL approaches (Trelease, 2016; Keenan and ben Awadh, 2019), and can be used to deliver drawing activities that can enhance anatomy knowledge (Pickering, 2015; Backhouse et al., 2017; Pickering, 2017; Greene, 2018). Furthermore, HVOD workshops are designed with the intention of delivery within small-group teaching environments. While providing optional extracurricular or student-selected classes is possible, catering to an entire cohort of medical students would present significant logistical challenges. Moreover, the ability to deliver HVOD has thus far been entirely dependent on L.S., thereby limiting the number of anatomy educators and students who are able to experience it. Notwithstanding concerns identified with respect to remote delivery of HVOD regarding the importance of L.S. being physically present, the development of a TEL-based SDL approach with opportunities for peer assistance in addition to instructor support may serve to overcome some of the logistical challenges identified in this study.

## Engagement in Observation and Drawing within a Social Learning Environment

While engagement is often considered to be a vital component of anatomy learning (Janssen et al., 2015; Pizzimenti and Axelson, 2015; Brown et al., 2018; Green et al., 2018), it is additionally important to identify and define the nature of engagement as either behavioral, emotional, or cognitive (Pickering and Swinnerton, 2018). Findings presented here suggest that HVOD is likely to address each of these aspects of engagement. The descriptive guide for HVOD usage outlined above emphasizes the importance of behavioral engagement of observer-drawers for the critical haptic and visual observation of objects coordinated with simultaneous and deliberate mark-making. This focused concentration is required in order that they may successfully achieve each step within HVOD Stages 2 and 3. In addition to improving observational processes and subject-specific knowledge acquisition (Alsaid and Bertrand, 2016; Balemans et al., 2016; Backhouse et al., 2017), drawing has been identified as stimulating student motivation, engagement, well-being, and cognition (Van Meter and Garner, 2005; James et al., 2017). The art-based elements of HVOD are therefore likely to be particularly relevant to the cognitive and emotional engagement of learners, supporting their broad and profound understanding of 3D anatomical form. Finally, participants indicated that engagement, again likely both emotional and cognitive, was achieved through their shared experiences within the social learning environment of the HVOD workshop.

The positive environment described here by HVOD participants is underpinned by theories of social constructivism, which advocate the value of collective learning with and from others (Bandura and Walters, 1963; Bandura, 1977; Vygotsky, 1978; Bandura, 2001). Furthermore, collaborative learning (Bergman et al., 2013), the social context of dissection (Kerby et al., 2011) and social media usage (Hennessy et al., 2016) have been identified as important for enhancing anatomy learning. Findings here indicate that HVOD can provide an additionally valuable social learning experience. Furthermore, the delivery of HVOD as a sequence of instructor-led and instructor-assisted activities in observation and drawing, followed by student-led application of these concepts, can support the construction of an effective social learning environment (Leach and Scott, 2002). Additionally, focus group participants alluded to peer learning activities when describing the value of students supporting and explaining their observations to each other within the social HVOD learning environment. Peer learning is an approach that has been expounded and successfully integrated into anatomy education (Brueckner and MacPherson, 2004; Duran et al., 2012; Hall et al., 2013; Border et al., 2017), and which could be explicitly introduced into future iterations of HVOD.

## A Collaboratively Optimized Observation and Drawing Approach

In order to address the limitations of curriculum integration alongside the need to include named anatomical structures, the effective theoretical and pedagogical aspects of HVOD can be modified and enhanced in order to produce an optimized focused drawing technique for flexible anatomy learning. With a view to this, a collaboration between authors I.K. and L.S. has led to two art-based observation and drawing approaches that were originally developed independently, in the United Kingdom and South Africa, respectively, to be combined into a single enhanced method.

Previous work by author I.K., working with student partners at Newcastle University, United Kingdom, has described the design and evaluation of an observe–reflect–draw–edit–repeat (ORDER) learning approach (Fig. 4, top right) (Backhouse et al., 2017). The ORDER cycle was developed based on an understanding of the value of visualization, observation, and drawing in medical and anatomy education (Pandey and Zimitat, 2007; Nayak and Kodimajalu, 2010; Lyon et al., 2013), with a view to applying drawing as a tool to address the complex landscape of modern anatomy education through the delivery of an innovative, engaging, and cost-effective approach. This is achieved through the delivery of an explicit, step by step protocol of collaborative observation, reflection, drawing, and modification which is repeated in cycles. This structure encourages students to build on their prior knowledge while enabling the complexity of the anatomy under observation to be increased (Backhouse et al., 2017). The ORDER process fulfills logistical curricular requirements in terms of a focus on assessed learning outcomes, without the need for significant technological or cadaveric resources, and has subsequently been successfully integrated as a supplementary activity within anatomy classes at Newcastle University (Keenan and Shapiro, 2017). The inherent flexibility of the process allows the "draw" step in ORDER to be substituted with "do" when an alternative activity (e.g., multisensory observation) is required. The theoretical underpinnings (Kolb, 1984; Ausubel, 2012), research-informed design (Nayak and Kodimajalu, 2010; Naug et al., 2011; Tyler and Likova, 2012; Lyon et al., 2013; Noorafshan et al., 2014; Balemans et al., 2016) and cyclical structure of ORDER can therefore provide a framework around which the HVOD process can be constructed into effective and universally achievable steps to produce a novel "ORDER Touch" approach (Fig. 4).

Furthermore, online ORDER activities have been shown to enhance student performance to a significantly greater extent than non-ORDER online resources (Backhouse et al., 2017). In a similar fashion, an optimized HVOD process could also potentially be delivered flexibly as a remotely accessed and SDL approach via TEL means, while attempting to maintain the positive and collaborative HVOD learning environment and learning gains reported here and in previous work (Reid et al., 2019). Such an approach could incorporate remote instruction in HVOD by L.S. and could therefore allow a wider audience to experience the approach. A massive open online course (MOOC), a format which has been previously utilized in anatomy education (Pickering et al., 2017; Swinnerton et al., 2017) may provide a platform for such adaptable and remote delivery. Discussion forums and peer–peer learning and feedback activities can also be integrated within a MOOC, in an attempt to recreate the supportive social learning environment of a face-to-face HVOD workshop.

## Limitations

**Study limitations.** While there are already practical, theoretical, evidence-based underpinnings and direct interpretivist support for HVOD in anatomy learning (Reid et al., 2019), it will be important to demonstrate the value of HVOD, ORDER Touch and any optimized focused observation and drawing process for anatomy learning. Due to the relatively small population of workshop participants available to the authors, it has not been possible to collect valid post-positivist experimental or survey data regarding the impact on learning and perceived value of HVOD thus far. A future study incorporating pre–post-testing of participant observer-drawers with respect to their visual and haptic observational skills and their 3D spatial understanding of anatomical form is planned in the event that HVOD or ORDER Touch can be delivered to a larger sample size of both student and educator participants, potentially via online means. As this study was restricted to UK anatomy educators, their views may not necessarily be transferable to educators in other countries and contexts, who may for example, have more flexibility in terms of the curricula they deliver. These aspects, and the value of spatial, holistic, and social learning with HVOD, can also be more comprehensively explored experimentally and quantitatively. If the detailed delivery and identification of named anatomical features within the HVOD process were to be included within ORDER Touch, alongside the existing emphasis on 3D form and spatial understanding, this would also allow the possibility of

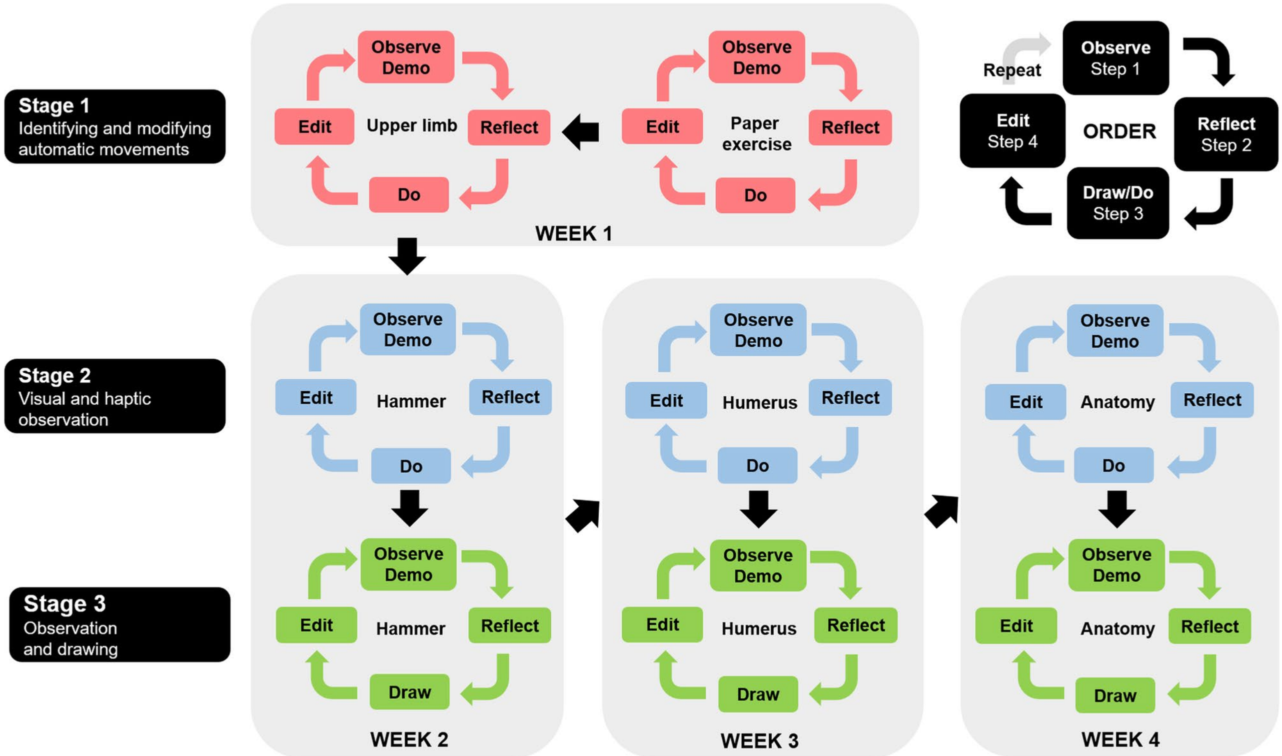



**Figure 4.**

Proposed design of an optimized haptico-visual observation and drawing (HVOD) process for anatomy learning. The observe–reflect–draw–do–edit–repeat (ORDER) cycle (Backhouse et al., 2017) is shown (top right), and is the framework around which each stage of the HVOD process can be constructed to produce a novel ORDER Touch approach. It is proposed that the experiential learning cycles of ORDER Touch can be delivered within a massive open online course (MOOC) platform, as flexible self-directed learning activities that completed are over the period of a week, with the whole course being delivered over four weeks. For example, students will be asked to watch a video in which an instructor will encourage them to perform a particular HVOD exercise. The activity will be explained and an example will be demonstrated in the video (Observe Demo). Students will then have the opportunity to consider the activity through re-watching the video and adding their thoughts to the MOOC discussion forum (Reflect). Students will subsequently perform the activity themselves (Do) and contribute a brief description of their findings to the forum. Participants will upload their drawings for instructor and peer feedback. They will then be given the opportunity to make changes based on this feedback and to resubmit their work (Edit). This process can then be replicated for subsequent steps within the MOOC.

implementing post-positivist research studies which included pre–post-anatomy knowledge testing.

**Limitations of the a haptico-visual observation and drawing process.** While the specific nature of the processes of visual and haptic observation in HVOD may enhance student understanding of anatomical structures, it is also important to note that participants have spent a significant period of time actively studying objects during the HVOD process, which will lead to the creation of memories (Markant et al., 2016). Active and collaborative approaches are also known to be important for learning (Hake, 1998; Laal and Ghodsi, 2012; Freeman et al., 2014) and so actively engaging with and drawing anatomical structures in a shared environment is likely to be more effective for learners than passively observing these objects when alone, whether this is using a focused technique like HVOD or any other active approach. Additionally, focus group responses indicated that some participants felt that the amount of time that they spent studying objects was important for their learning. It may be that observing the same objects in a non-HVOD fashion over the same period may result in equivalent gains, due to the significant influence on learning of increased time on task (Chickering and Gamson, 1987; Fasel et al., 2005; Gibbs, 2010). Furthermore, experiencing intense emotions is also known to impact upon memory and learning (Tyng et al., 2017). Based on the authors' and participants experiences, engagement in an HVOD workshop is likely to evoke such feelings, while similar reactions may also be elicited from pursuing other active and collaborative art-based learning activities such as body painting (McMenamin, 2008; Finn and McLachlan, 2010; Nanjundaiah and Chowdapurkar, 2012). It will therefore be important to test these hypotheses experimentally in future work in order to identify the specific value of these aspects of the HVOD and ORDER Touch approaches.

## CONCLUSIONS

The HVOD process is a practically deliverable and universally achievable anatomy learning approach that is valuable for anatomy educators and their students. The multisensory visual and haptic observation and drawing process provided by HVOD is effective for enhanced holistic understanding of 3D spatial anatomy, and delivery of this approach provides an engaging and supportive social learning environment. Accordingly, it is proposed that a greater emphasis on the observational and spatial aspects of anatomy learning should be embraced by educators in order that they may deliver progressively beneficial approaches for anatomy learning to their students. Construction of a refined and collaboratively developed ORDER Touch process, integrating specific anatomy knowledge alongside observation and spatial learning within a remotely accessible TEL resource is planned. Such a method may provide educators with an engaging and effective approach for achieving integrated holistic, spatial, and knowledge-based anatomy learning, and may also address logistical concerns with respect to the curricular implementation of art-based approaches. Successful development of an ORDER Touch MOOC may therefore have implications for modern anatomy education in terms of the pedagogic value of learning resources combined with flexible delivery, accessibility, and global reach.

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