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EDUCATION

The sonographic OODA loop: Proposing a beginner's model for learning point-of-care ultrasound

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Abstract

Unlike practitioners of formal diagnostic sonography, point-of-care ultrasound users must often acquire basic ultrasound skills in far shorter time frames, with less time dedicated to obtaining mastery; therefore, they often rely on conceptual models to achieve this. There is currently no introductory model which point-of-care ultrasound users might adopt to describe the cognitive processes involved in acquiring a basic ultrasound image, and in learning point-of-care ultrasonography. We propose the 'sonographic OODA loop' in reference to Boyd's observe–orient–decide–act (OODA) decision loop, as a model which can be used initially by ultrasound-naive clinicians to understand the cognitive and motor processes that occur when they acquire ultrasound images, and hopefully achieve greater insight into their early practice.

Keywords
POCUS; cognitive; education; visuospatial; psychomotor; OODA loop

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INTRODUCTION

Ultrasound is a medical technique which enables clinicians to acquire images of anatomical structures to assist in diagnosis of underlying pathologies. This image acquisition is done through a handheld transducer, or probe, which is placed over the relevant surface anatomy of the patient and allows transmission of a two-dimensional (2D) image to a linked display monitor. Point-of-care ultrasound (POCUS) has many practical and logistical advantages over more complex medical imaging techniques, such as portability, compactness, speed of image acquisition, and relatively low cost; this means it is often used as a diagnostic tool by clinicians who are not sonography experts.(1)

Operator competency with the transducer is a crucial component of accurate and effective image acquisition, and the subsequent diagnostic efficacy of the technique. Competent POCUS requires a unique combination of cognitive and motor skills, including visuospatial, perceptual, and attentional processing, motor coordination, and psychomotor integration, in order to move the transducer in such a way as to produce a coherent 2D image of the three-dimensional (3D) anatomical structures.(2) Ultrasonography skills are regularly taught in healthcare institutions across the world and yet there is an absence of a unifying model to describe the cognitive and motor processes involved in learning how to accurately acquire and interpret an ultrasound image for POCUS users. This theoretical gap is particularly apparent when reviewing the existing tools available for use as a basis for teaching ultrasound skills to new practitioners. Common approaches tend to focus on medical physics or image interpretation as their foundation (3,4), rather than understanding the perceptual and cognitive skills inherent in obtaining an image, which are in fact the critical factors in determining operator competency. One suggested model of teaching psychomotor skills to healthcare practitioners proposes an 11-stage instructional process to enable learners to develop such expertise over their training (5), however this model does not accommodate learners for whom the skill is not a regular aspect of their practice, and who will not have the time to regularly revisit the learning stages suggested. As such, there is a need for a simplified conceptual model for POCUS users which can be easily understood in a very short length of time and be immediately implementable in a manner that can improve their practice. Therefore, this paper sets out a pragmatic model that can be used to understand the sequence of cognitive and perceptual processes that occur when an ultrasound-naive clinician acquires ultrasound images.

The 'sonographic OODA loop' (Figure 1 and Table 1) has been selected in reference to Boyd's observe-orient-decide-act decision (OODA) loop.(6,7) The sonographic OODA loop is an introductory model describing a continuous cycle involving visuoperceptual, visuospatial, visuomotor and psychomotor processes

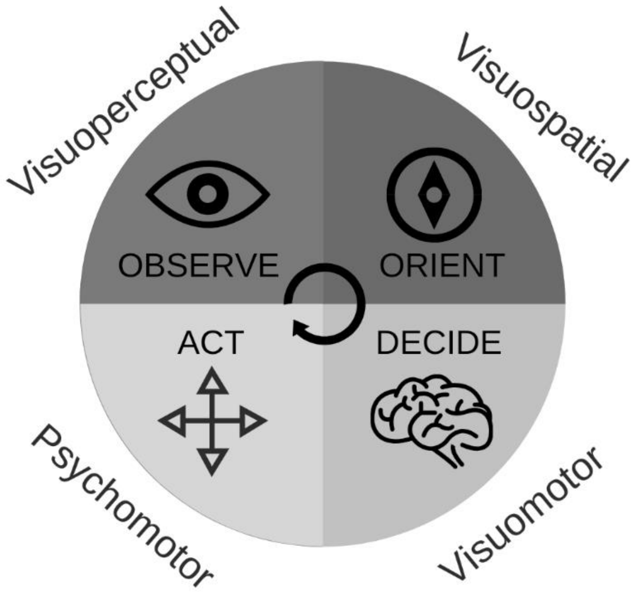

Figure 1. Sonographic OODA loop domains

which can be used by POCUS learners to understand the acquisition and interpretation of ultrasound images. It is not intended as a comprehensive representation of the multiple complexities of ultrasound image acquisition and interpretation, but rather serves as an initial model for POCUS users to begin identifying gross flaws in their image acquisition and interpretation. In this regard, the sonographic OODA loop describes a framework which assigns the complex process to four discrete steps in order to begin assisting learners in gaining insight into their automatic performance.

The four steps begin with visuoperceptual processing being used to observe the image being acquired, followed by visuospatial processing, which aids orientation of the image in relation to the 3D anatomic whole-structures being scanned, and in spatial relation with the clinician. Next, visuomotor abilities are used to plan the transducer manipulation required to obtain and optimise the intended ultrasound images, after which the actual action of transducer manipulation is governed by psychomotor performance. In his far more complex model, Boyd describes how fighter pilots make rapid decisions in mid-aerial combat using a system of multiple observation, orientation, decision and action loops.(6,8) A distillation of Boyd's OODA loop was felt to reflect a similar process to the desired one in this model and was therefore selected for its ease of recall and its current use within emergency medicine.(9)

BACKGROUND

When observing first-time POCUS users there is a common anecdote of learners being completely focussed on the screen before them, whilst the transducer slips further and further away from the location of the intended anatomical structure. Dieden, Carlson and Gudmundsson (10) report that learners felt 'disorientated', especially when trying to direct the transducer at the same time as attempting to take measurements and ascertain clinical significance of the images. When reflecting on this common phenomenon, it became apparent that the attentional capacity (11,12) of learners was likely completely dedicated to attempting to orient themselves on the screen, without having developed a mental map of the structures being scanned. As such there was a disassociation between the images on the screen, and the anatomy of the patient before them, and therefore, the lack of a reference for visuospatial orientation. It is possible that learners become unable to orient themselves, and so quickly flounder, lost in a grey fuzz of uninterpretable anatomy, which then affects their performance. By directing the learner's attention to the position of the transducer on the patient's body and prompting them to visualise in their mind the anatomical structures below, learners are often able to rapidly re-orient themselves, re-position the transducer and resume scanning, successfully locating a target structure. Similar conclusions are evident in the educational literature on the process of skill acquisition in sonography, with key factors such as learner confidence, proficiency at visualising the anatomical structures being insonated, as well as increased levels of simulated practice opportunities, all leading to increased competency.(13–15)

The process of learning ultrasound image acquisition bears a resemblance to the way in which children learn to integrate visual and motor skills in order to orient themselves to their surrounding 3D world and interact purposefully with it. It is widely accepted that the developing visual system is able to process shape representation to support two separate visual functions: vision for perception (object recognition) and vision for action (visuomotor control).(16,17) These separate processes have been shown to develop at different rates, with functional magnetic resonance imaging (fMRI) data indicating that four-year-old children already show adult like patterns of neural activation in visuomotor control tasks (18), whereas developmental differences are observed between children and adults in visual perception tasks.(17) At roughly six months of

Table 1. Processes and stages of the sonographic OODA loop

Instruction for learner	OODA stage	Domain/ Process
Look at the transducer on the patient's body and look at the ultrasound screen	Observation	Visuoperceptual
Understand the image on the screen in relation to the anatomy being scanned	Orientation	Visuospatial
Plan the desired route of movement	Decision	Visuomotor
Move the transducer to achieve this	Action	Psychomotor
Re-loop		
Re-assess the image on the screen (and the placement of the transducer on the patient's body)	Observation	Visuoperceptual

OODA: observe-orient-decide-act

age an ability is gained by the infantile brain, known as object completion.(19) This ability allows the mind to make sense of 2D shapes from a single viewpoint as being representative of volumetric 3D structures. The term arises from understanding how the mind uses limited information (2D surfaces) to complete the mental model of the 3D object. A closely related concept is that of exploratory manipulation. Whilst Soska and Johnson in 2008 (19) defined object completion during experiments involving infant children, earlier work by Eppler in 1995 (20) informed how infants also began a process whereby they not only grasped an object and placed it in their mouths, but actually played with the object by rotating it and exploring its multiple surfaces and axes, gaining awareness of its volumetric 3D structure, termed exploratory manipulation.(21)

Furthermore, James and Kersey (18) propose that when learning a complex motor skill, adults are more likely to show dorsal pathway activation (known to be crucial in spatial processing) similar to that seen in younger children, as opposed to ventral stream activation (which underpins object identification and recognition) displayed in simple motor action paradigms. This suggests that when learning a new, complex visuospatial skill, such as POCUS, the neurocognitive processes required reflect those of the developing brain whereby consolidation of perception and action is slower and more effortful. This suggests that focussed strategies may be required to help integrate an individual's visuoperceptual information-processing skills with their visuomotor control output.(22) We therefore pursued the development of an easily understood and basic framework or model which early-stage learners could use to give structure to their approach to image acquisition and skill performance.

The model

Observe: Observe the image on the screen and attempt to recognise the shapes presented.

Orient: Using knowledge of the anatomy, create a mental map which orients the structure with one's transducer, and the image on the screen.

Decide: Plan a route from the current location to a new location which will improve visualisation of the structure by adding information to complete an imagined 3D topographic map.

Act: Move the transducer in the intended route.

The sonographic OODA loop comprises four steps, which guide an integrate image acquisition and interpretation for a novice operator: (1) visuoperceptual processing, (2) visuospatial processing, (3) visuomotor integration and (4) psychomotor output.

Nicholls, Sweet and Hyett (2) describe image acquisition as requiring a synthesis of complex and multidimensional visuospatial, visuomotor and psychomotor abilities. Following this work, we suggest that when an individual begins learning ultrasonography for the first time, their brain undergoes a new and more complex process of perceptual and spatial integration, including both forwards and reverse object completion. This occurs during their manipulatory exploration of the 3D volumetric structures that are viewed through 2D planar surfaces using ultrasonography. In the first stage of the model, visuoperceptual processing, we propose that in order to achieve successful image acquisition of a target structure, the learner needs to observe the screen and recognise shapes and structures. Following the initial visuoperceptual processing, we suggest that learners should then view the image on the screen (representing their current planar location) and correlate this with a spatial position relative to the whole structure being scanned. This visuospatial processing component is crucial to allow the learner to understand the image on the screen in relation to the anatomy being insonated. The learner therefore creates a 3D topographic mental map of the target and surrounding structures using 2D images, and can then deconstruct this 3D mental map through multi-planar perspectives and select an intended plane for further examination. This stage also allows for the integration of knowledge regarding sonographic artefacts such as anisotropy, posterior acoustic enhancement and acoustic shadowing, which rely on an appreciation of spatial orientation. Similar visuoperceptual processing strategies have been documented in the learning of other clinical contexts that rely on demanding perceptual, spatial and motor integration, such as surgery. Wanzel et al. (23) demonstrated that visuospatial ability, specifically mental rotation of 3D objects, was related to initial competency in a spatially complex, novel surgical procedure, and that, as spatial complexity of the surgical procedure increased, so did correlations with these higher-level visuospatial test scores. This indicates that, as in POCUS, the ability to transpose 2D images into 3D representations and to spatially manipulate these representations may be necessary in gaining new complex motor skills.

The learner may then engage in visuomotor processing to plan their psychomotor manipulation of the ultrasound transducer. Visuomotor processing has an important function in the learning cycle, as it is the point at which the learner can detect whether their integration of perceptual and spatial understanding will result in a useful motor output. Here error can be potentially corrected before it occurs, saving the learner time from re-orienting after making erroneous movements, which risk losing the anatomical reference points previously gained.

Once performing the actual movement (the psychomotor action step), the learner will be encouraged to slowly change the planar perspective through which they are exploring the whole structure. As they move the transducer and the image changes, a continuous observation of the image demands reinterpretation of one's location and spatial relationship to the target of the structures being scanned. This cycling of visuospatial and proprioceptive feedback will loop in a continuous manner until the learner is competent at undirected insonation of structures and can make clinically meaningful diagnoses using the images they obtain. We propose that adopting the OODA loop model of teaching might enable POCUS trainees to sequence the component processes involved in acquiring the skill of ultrasound, and might enable a more refined process of error detection and correction, which places the individual at the centre of the learning.

CONCLUSION

Ultrasonography involves the complex and unconscious cycling of visuoperceptual, visuospatial, visuomotor and psychomotor feedback loops in order to associate the imagined construction of 3D topographic maps of anatomical structures, with the 2D planar perspective displayed on an ultrasound screen, and the spatial orientation of the transducer on the patient's body, in order to successfully acquire images of a target structure. The proposed concept of the sonographic OODA loop provides early-stage learners of POCUS with a basic model which they can use to target gross deficits in their process of image acquisition.

Further investigation is needed to explore and validate this proposed model and might begin with observational trials comparing skill acquisition between learners who have pre-scanning exposure to teaching based on the sonographic OODA loop versus controls in early-stage learners. This model is intended as an educational aide and is not representative of the complexity of the processes underpinning the performance of ultrasound.

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COMPETING INTERESTS

The authors declare no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement.

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