USING EYE-TRACKING TO OPTIMIZE SKIN SELF-EXAMINATION TRAINING

by

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ABSTRACT

Using eye-tracking technology to capture the visual scanpaths of a sample of laypersons (*N* = 92), the current study employed a 2 (training condition: ABCDE vs. Ugly Duckling Sign) × 2 (visual condition: photorealistic images vs. illustrations) factorial design to assess whether SSE training succeeds or fails in facilitating increases in sensitivity and specificity. Self-efficacy and perceived importance were tested as moderators, and eye-tracking fixation metrics as mediators, within the framework of Visual Skill Acquisition Theory (VSAT).

For sensitivity, results indicated a significant main effect for visual condition, $F(1,88) = 7.102$, $p = .009$, wherein illustrations ($M = .524$, $SD = .197$) resulted in greater sensitivity than photos ($M = .425$, $SD = .159$, $d = .55$). For specificity, the main effect for training was not significant, $F(1,88) = 2.120$, $p = .149$; however, results indicated a significant main effect for visual condition, $F(1,88) = 4.079$, $p = .046$, wherein photos ($M = .821$, $SD = .108$) resulted in greater specificity than illustrations ($M = .770$, $SD = .137$, $d = .41$). The interaction for training × visual condition, $F(1,88) = 3.554$, $p = .063$, was significant within a 90% confidence interval, such that those within the UDS Photo condition displayed greater specificity than all other combinations of training and visual condition. No significant moderated mediation manifested for sensitivity, but for specificity, the model was significant, $r = .59$, $R^2 = .34$, $F(9,82) = 4.7783$, $p = .001$, with Percent of Time in Lookzone serving as a significant mediator, and both self-efficacy and visual condition significantly moderating the mediation. For those in the photo condition with very high self-efficacy, UDS increased specificity directly. For those in the photo condition with self-efficacy levels at the mean or lower, there was a conditional indirect effect through Percent of Time in Lookzone—which is to say that these individuals spent a larger amount of their viewing time on target (observing the atypical nevi)—and time on target is positively related to specificity.

Findings suggest that existing SSE training techniques may be enhanced by maximizing visual processing efficiency.

For my dad.

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CHAPTER ONE

INTRODUCTION

Evaluation of nevi in a clinical setting, and the subsequent assignment of atypical or common status, relies upon individuals who have undergone extensive training. These individuals are often physicians or dermatologists, and their training comes in the form of medical school coursework, time spent in residency, and subsequent years of practical experience. The sum of these factors is assumed to yield expertise or proficiency in the identification of critical visual features indicative of atypical nevi. The progression from experience to expertise, while illustrative in this case, is not limited to this context, and similar progressions are seen in a variety of other literature (see examples in Chen, Pizzolato, & Cesari, 2013; Collins & Evans, 2002; Plomin, Shakeshaft, McMillan, & Trzaskowski, 2014; Prietula, & Simon, 1989; Ribeiro, 2013).

While physicians and dermatologists may be uniquely qualified for the job of nevi classification, they are often not the first ones to detect atypical nevi. One study showed that only 25.3% of melanomas were initially discovered by physicians (inclusive of a variety of disciplines); with 44% discovered by patients, 18.6% by partners of patients, and 12.1% by other nonexperts (McPherson et al., 2006). Summing across these categories, 74.7% of initial melanoma identifications were performed by laypersons, or those lacking formal training.

One could assume that training laypersons would increase diagnosis rates, but developing skill into expertise takes time (Beam, Conant, & Sickles, 2003; Jaimes et al., 2013), and the situation is more complicated than such a direct solution assumes. First, multiple training techniques exist, focusing on different approaches to nevi identification (Grob & Bonerandi, 1998; Luttrell, McClenahan, Hofmann-Wellenhof, Fink-Puches, & Soyer, 2012; Rigel, Friedman, Kopf, & Polski, 2005; Robinson & Turrisi, 2006; Yagerman & Marghoob, 2013). Second, contention exists as to how training messages should be presented to maximize effectiveness—e.g., the debate between photorealistic vs. illustrated portrayals of atypical nevi features (Ahissar & Hochstein, 2004; Fillippatou & Pumfrey, 1996; Hegarty, 2011; Moll, 1986; Readance & Moore, 1981). Third, current research suggests that, even after training, laypersons may only experience moderate gains in accuracy, if any at all (Buettner & Garbe, 2000; Carli et al., 2002; Goodson & Grossman, 2009; Hamidi, Peng, & Cockburn, 2010).

Each of these issues points to a central problem: training techniques for laypersons have yet to be optimized, and it is therefore unclear what message features serve as the most efficient proxies for experience; ultimately enabling laypersons to develop skill in identifying the critical visual indicators of atypical nevi. Additional research is needed to ascertain which training methods and message features prompt the greatest increases in diagnostic accuracy among laypersons, and to inform the development of impactful training materials moving forward.

The current study calls for a closer examination of eye-tracking technology and the answers that it can provide to questions about SSE training effectiveness, and to the discipline of dermatology as a whole. Eye-tracking technology provides the capability of quantifying visual search patterns, allowing for the analysis of visual attention, and inferences about cognition to be made. In application to dermatology, eye-tracking technology affords access to data that have henceforth been uncapturable in the analysis of atypical nevi, and provides a means of measuring the impact of training on visual processes (e.g., why training works). Other disciplines, including psychiatry, radiology, and surgery, have already used this technology to capture this type of data, and a suitable introduction to eye-tracking dermatological applications should consider the benefits observed within other medical disciplines. As such, what follows is a review of eye-tracking applications in the disciplines of psychiatry, radiology, and surgery, culminating in a primer for further discussion on dermatological applications later in Chapter Two.

Eye-Tracking Applications in Psychiatry, Radiology, Surgery, and Dermatology

Eye-tracking technology has been used within a multitude of disciplines to provide data that link subject visual patterns to a variety of stimuli. Considering medical applications in particular, eye-tracking technology has been used extensively within the fields of psychiatry and radiology—with the former typically attempting to explore the visual patterns of patients with various diseases and neurological conditions (e.g., depression, schizophrenia, autism, Parkinson's disease, etc.), and the latter using eye-tracking technology to examine how physicians visually process output from magnetic resonance imaging (MRI), ultrasound, computed tomography (CT), and other imaging machines. Outside of these, other medical disciplines have also utilized eye-tracking technology, though to a lesser degree than those noted above—as in the surgical discipline's use of eye-tracking for skills training and assessment, and pathology's use of the technology to identify visual scanning patterns in the assessment of lesions. Despite the benefits provided by eye-tracking in allowing for the identification and quantification of subject visual attention, the discipline of dermatology, surprisingly, has yet to see broad application of the technology.

Notwithstanding dermatology's heavy reliance upon visual patterns and cues to discriminate between common and atypical nevi, literature that applies eye-tracking technology to the study of dermatology is sparse; and literature specific to patient-initiated behaviors, such as skin self-examination (SSE), is virtually nonexistent. This leaves a number of different questions about the potential impact of eye-tracking technology on the discipline unanswered, and warrants further examination, in the face of successful applications of eye-tracking in other medical contexts.

What follows is brief introduction to eye-tracking methodology, followed by a review of eye-tracking research in the disciplines of psychiatry, radiology, surgery, and other selected fields—culminating in a discussion of current applications and advantages of eye-tracking technology for dermatology research. Specific attention will be paid to addressing how eye-tracking technology has been used and what benefits it has yielded, with concluding discussion of barriers and future opportunities as pertaining to dermatology.

Eye-tracking functionality. Visual attention is a primary means of gathering information about one's environment. It serves an orienting role and, through both active and passive processing of visual information, allows for perception and action to be linked (Bridgeman & Tseng, 2011; Hommel, Müsseler, Aschersleben, & Prinz, 2001).

While visual attention and gaze are not necessarily eternally connected (see Velichkovsky, Dornhoefer, Pannasch, & Unema, 2000), the ability to track where an individual is looking is a strong indicator of where his/her focus may lie (Liversedge & Findlay, 2000; Rayner, 1998)—especially in scenarios where one is directed to perform a specific task (Hayhoe, Bensinger, & Ballard, 1998; Smeets, Hayhoe, & Ballard, 1996).

Eye-tracking technology refers to any of a multitude of devices designed to quantify the visual attention of subjects across a stimulus. The most commonly used measures in eye-tracking research are *fixations*, or points where the subject's eye has stopped in order to process information (see Goldberg & Kotval, 1999; Jacob & Karn, 2003; Just & Carpenter, 1976), and *saccades*, the short visual shifts that exist between fixations, and during which information encoding is suspended (see Rayner & Pollatsek, 1989). The majority of eye-tracking devices now available rely on a corneal-reflection/pupil-center method (Goldberg & Wichansky, 2003); which is to say that they utilize an infrared camera and infrared light to illuminate the subject's eye, providing a clear reflection of the pupil and the cornea for the infrared camera to register. With both of these reflections accounted for, subjects can then be calibrated by looking at pre-determined points within the tracking environment. In addition, the presence of both a pupil and corneal reflection allows for eye movements to be tracked distinctly from head movements (Duchowski, 2003; Jacob & Karn, 2003). Other devices such as accelerometers and facial recognition software can further separate eye and head movement. Once calibrated, subjects are then ready to be tracked, either via stimuli presented on a computer screen, or by interacting with stimuli in real space, in the case of untethered or portable systems.

Comprehensive reviews of the history and functionality of eye-tracking technology are available in the literature courtesy of Duchowski (2002), Kowler (2011), Rayner (1992, 1998), Rayner and Pollatsek (1989), and Schütz, Braun, and Gegenfurtner (2011). For the purposes of this review, focus will be maintained on the application-specific benefits that eye-tracking technology provides in medical applications. Just like in nonmedical applications, where eye-tracking technology has been used to understand everything from financial reports (Grigg & Griffin, 2014) and advertising (Albert, 2002; Lohse, 1997), to pilot visual patterns (Anders, 2001; Kasarskis, Stehwien, Hickox, Aretz, & Wickens, 2001), distracted driving (Land & Horwood, 1995; Sodhi et al., 2002; Velichkovsky et al., 2000), and usability testing (Cowen, Ball, & Delin, 2002; Goldberg, Stimson, Lewenstein, Scott, & Wichansky, 2002; Poole & Ball, 2006)—applications of eye-tracking in medical settings have been similarly varied, providing context in areas that would otherwise remain unquantifiable.

Applications of eye-tracking in psychiatry. Within the discipline of psychiatry, eye-tracking technology has been used extensively to study various neurological conditions and diseases, including depression, autism, and schizophrenia, among others.

Depression. Researchers studying depression have used eye-tracking technology to look for differences in visual processing between depressed and nondepressed samples. Results have determined that, while no significant differences in initial gaze patterns exist between depressed and nondepressed individuals, there are significant differences in fixation time—in that depressed individuals tend to spend more time fixating on negative images, compared to neutral images, than nondepressed individuals (Caseras, Garner, Bradley, & Mogg, 2007; Eizenman et al., 2003; Kellough, Beevers, Ellis, & Wells, 2008). When considering positive images, however, conflicting results exist. Kellough et al. (2008) concluded that depressed individuals ultimately spent less time looking at positive images than their nondepressed counterparts, while Eizenman et al. (2003) found no significant difference. However, there is strong evidence in the eye-tracking/depression literature supporting the claim by Kellough et al. (2008) that depression does result in an overall reduction in positivity (see meta-analysis by Armstrong & Olatunji, 2012). Further studies in depression and eye-tracking have highlighted differences between individuals who are clinically depressed, and those whose depression is not severe enough to be considered clinical—a condition known as dysphoria. In these cases, dysphoric individuals have been reported to spend less time observing positive images than nondysphoric ones (Matthews & Antes, 1992; Sears, Newman, Ference, & Thomas, 2011). These findings are also supported when imagery is replaced by other stimuli, in that dysphoric individuals spend less time fixating on positive words (Ellis, Beevers, & Wells, 2011) and faces (Leyman, De Raedt, Vaeyens, & Philippaerts, 2011), than their nondysphoric counterparts—the latter of which also holds true for clinically depressed individuals (Isaac, Vrijsen, Rinck, Speckens, & Becker, 2014).

Autism. For researchers studying autism, eye-tracking technology has provided a means of quantifying how children and adults visually process facial features, based on findings that autism spectrum disorders have the potential to impede identification of emotions in others (Ashwin, Chapman, Colle, & Baron-Cohen, 2006; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Celani, Battacchi, & Arcidiacono, 1999; Sawyer, Williamson, & Young, 2012). Current findings in eye-tracking-based studies are conflicted, with some researchers concluding that autistic individuals spend less time fixating on the eyes when looking at a face (Boraston, Corden, Miles, Skuse, & Blakemore, 2008; Dalton et al., 2005; Pelphrey et al., 2002; Sterling et al., 2008), and others finding no significant difference between autistic and nonautistic fixation times (Dapretto et al., 2006; Neumann, Spezio, Piven, & Adolphs, 2006; Rutherford & Towns, 2008; Speer, Cook, McMahon, & Clark, 2007; Van Der Geest, Kemner, Verbaten, & Van Engeland, 2002). Interestingly, when expanding the area of interest beyond the eyes, to include other primary features of the face (e.g., the nose and mouth), both autistic and nonautistic samples spend similar percentages of their total viewing time on each of these regions—with eyes consistently receiving the largest portion of time (Boraston et al., 2008; Dalton et al., 2005; Rutherford & Towns, 2008; Sterling et al., 2008).

While deficiencies in emotional processing capability cannot be fully explained via eye-tracking technology alone, pairing eye-tracking with other physiological measures, such as those possible through functional magnetic resonance imaging (fMRI), electroencephalography (EEG), electrocardiography (EKG), and electromyography (EMG), allows for a more thorough understanding of the link between processes and behavior—creating alignment between the disciplines of psychiatry, clinical neuroscience, and psychology. Research by Wagner, Hirsch, Vogel-Farley, Redcay, and Nelson (2013) exemplifies this well by combining eye-tracking and event-related potentials (ERPs) to further understand the neurological mechanisms driving the link between autism and processing of facial features. ERPs are electrical fields that are activated within the brain, detectable on the surface of the scalp, and indicative of large groups of neurons reacting to a stimulus or event (see Nelson & McLeery, 2008). While

Wagner and colleagues' (2013) eye-tracking results indicated similar patterns between autistic and nonautistic subjects when visually scanning faces, significant differences in the ERP data showed that autistic individuals exhibited atypical processing of facial emotions, "…with reduced neural differentiation between emotions and a reduced relationship between gaze behavior and neural processing of faces" (p. 188). In other words, while the visual scanning patterns of both groups looked similar on the surface, the underlying neural processing was quite different, helping both to reconcile the competing findings currently present in autism literature employing eye-tracking, and to provide an example of how eye-tracking can work to complement other physiological measures.

Schizophrenia. In schizophrenia research, the most common application of eye-tracking technology has been to examine how visual patterns differ between schizophrenic and nonschizophrenic individuals. Specifically, the greatest variance between these two groups lies in what are called "smooth pursuit" tasks, or those that require the subject to follow a moving object with their eyes. Smooth pursuit abnormalities are one of the most reliable and consistent physiological indicators of schizophrenia (Levy, Holzman, Matthysse, & Mendell, 1993), lending itself to a broad base of literature studying the phenomenon.

When attempting to follow a moving target with one's eyes, nonschizophrenic individuals will employ a neuronal "smooth pursuit system," which allows them to keep the center of their visual attention (the *fovea*) smoothly locked onto the target (Tregallas et al., 2004). In schizophrenic individuals, however, this smooth pursuit system competes with an uninhibited saccade system, which causes the subject's eyes to either jump ahead of the target during the exercise (Hommer, Clem, Litman, & Pickar, 1991; Rosenberg et al., 1997; Ross et al., 2002; Ross, Olincy, & Radant, 1999), or to lag behind, resulting in saccades employed to catch up with the target (Clementz, Reid, McDowell, & Cadenhead, 1995; Sweeney et al., 1994; Sweeney et al., 1998). The underlying cause for these differences, according to Chen, Nakayama, Levy, Matthysse, and Holzman (1999), is that schizophrenic individuals (and their first-degree relatives) have reduced capability to determine how quickly an intermediate speed visual target is actually moving, due to central nervous systems correlates typical to their condition. These findings were further explored by Tregallas et al. (2004), using eye-tracking paired with fMRI equipment to confirm that schizophrenic subjects exhibited reduced inhibitory function in the hippocampus, and dysfunction in the posterior cerebellum; the latter of which may be the cause of the saccadic inconsistencies observed in schizophrenic subjects (p. 320; Ross et al., 1998).

Overall, eye-tracking technology has provided psychiatry researchers of various foci with a means of both quantifying visual behaviors, and placing them within the context of known neurological conditions. This is advantageous because it opens the door for visual indicators of these conditions to be identified, categorized, and used to aid in future treatments or diagnoses. Additionally, eye-tracking technology does not rely on subject self-report in measuring visual behavior, so it allows for a more accurate determination of what was actually observed, and for how long.

While discussion of eye-tracking technology in psychiatry serves as an excellent backdrop to introduce the capabilities and potential of the hardware, other medical applications have integrated the technology into research programs that more closely resemble situations encountered in dermatology. For example, applications of eye-tracking in the discipline of radiology are, arguably, more directly comparable to dermatology than psychiatric applications—due to the former two disciplines' similar reliance on expertise and visual proficiency to drive diagnosis. A sample of these studies follows.

Applications of eye-tracking in radiology. As radiologists review medical imagery, there is always the chance of diagnostic error. Regardless of specialization, errors in diagnosis are acknowledged and documented (FitzGerald, 2005; Hertzberg et al., 1999; Janjua, Sugrue, & Deane, 1998; Jensen et al., 2006; Quekel, Kessels, Goei, & Van Engelshoven, 1999; Shah et al. 2003; Sickles, Wolverton, & Dee, 2002; Van Rijn et al., 2005), even if the underlying causes are not entirely understood (Berlin, 2007; Pescarini & Inches, 2006). Reportedly, errors in diagnosis occur during one of two stages: the visual perception stage (e.g., a radiologist inspecting an image) or the cognition stage (e.g., the thought processes that ultimately leads the radiologist to a diagnosis) (Krupinski, 1996, 2010; Manning, Ethell, & Donovan, 2004; Mugglestone, Gale, Cowley, & Wilson, 1996; Nodine, Kundel, Lauver, & Toto, 1996; Samuel, Kundel, Nodine, & Toto, 1995; Voison, Pinto, Morin-Ducuot, Hudson, & Tourassi, 2013). Both of these stages have been thoroughly explored in the literature, and eye-tracking technology has made a unique contribution to research in the inspection stage—allowing it to be broken down further into failures of search, and failures of recognition (Phillips et al., 2013).

Eye-tracking equipment has been used in a variety of radiology applications, including the examination of radiographs for fractures (Hu, Kundel, Nodine, Krupinski,

& Toto, 1994) or chest nodules (Kundel, Nodine, and Krupinski, 1989; Manning et al., 2004; Manning, Ethell, Donovan, & Crawford, 2006), training of radiologists (Kundel, Nodine, & Krupinski, 1990), and the analysis of breast lesions in mammograms (Krupinski, 1996; Lång et al., 2011), among others. In each of these capacities, eye-tracking technology has been used to analyze visual search patterns of radiologists, and to differentiate individuals based on experience level. In one such study, Leong, Nicolaou, Emery, Darzi, and Yang (2007) discovered that, when examining skeletal radiograph images, experienced radiologists not only had greater true-positive detections than less-experienced radiologists, but they also consistently reached diagnosis with significantly shorter dwell times indicative of an inverse relationship between expertise and time to diagnosis. In another study, Kundel et al. (1990) found that radiologists in training, when provided eye-tracking feedback during instruction, scored higher on accuracy measures than other radiologists who received no eye-tracking feedback.

Phillips et al. (2013) also examined the role of expertise in the interpretation of three-dimensional CT colonography examinations. The researchers remarked that, as imaging technology has progressed, radiologists are increasingly gaining access to volumetric and three-dimensional imaging technology. This technology, while providing new methods of examining data, is also more visually demanding (Phillips et al., 2013). The concern, in this case, is that increased visual demand comes with increased risk of perceptual errors and increased cognitive burden for viewers. These are not the first concerns raised about burden, as Niimi et al. (1997) were concerned with mitigating visual fatigue through various formats of presentation using static imagery on CRT displays. However, the use of moving stimuli is problematic from an eye-tracking hardware perspective, because tracking gaze over static stimuli is inherently easier than tracking gaze over moving stimuli. Ultimately, Phillips et al. (2013) developed metrics to distinguish gaze and attention when viewing moving stimuli like CT colonography fly-throughs, which can aid in future research demanding the tracking of three-dimensional imagery. Furthermore, they confirmed during this process that recognition-type errors occurred more frequently in less-experienced radiologists, when viewing moving, three-dimensional imagery (Phillips et al., 2013, p. 931).

Looking forward, recent eye-tracking research in radiology has increasingly utilized machine learning algorithms and other technologies to explore the link between medical imagery and the perceptual and cognitive behaviors exhibited by radiologists during review and diagnosis (Tourassi, Mazurowski, Harrawood, & Krupinski, 2010; Tourassi, Voisin, Paquit, & Krupinski, 2013; Voisin et al., 2013). In one such study, Tourassi et al. (2010) looked at computer-assisted detection (CADe) systems, which serve as support for radiologists during mammography screening, and what happens when these systems are made context-sensitive through integration with eye-tracking technology. Radiologists in the study wore eye-tracking equipment to provide context to the CADe system during examination, which resulted in a significant increase in machine accuracy, and near-significant increases in accuracy for less-experienced and experienced radiologists (Tourassi et al., 2010, p.5734). In turn, with greater support from context-sensitive CADe systems, perceptual and cognitive errors in interpretation can potentially be reduced during the screening process.

Overall, applications of eye-tracking to the discipline of radiology have yielded insight into the visual scan patterns of radiologists during review of medical stimuli in various formats. Specifically, eye-tracking has provided the capability to examine the correlation between gaze duration and correct diagnosis (Krupinski, 1996), how to predict diagnosis through spatial frequency representation (Mello-Thoms, Dunn, Nodine, Kundel, & Weinstein, 2002), how conspicuous lesions impact search patterns in mammography (Mello-Thoms, 2006), and the correlation between detection and lesion subtlety (Krupinski, 2005). In application to training, eye-tracking technology provides feedback for trainers and trainees in isolating perceptual and cognitive problems. For example, in a hypothetical situation where two radiologists-in-training reach the same incorrect conclusion, the underlying cause could be very different (e.g., one perceptual, one cognitive). Eye-tracking allows these differences to be identified and addressed at the point of instruction. Furthermore, posttraining, eye-tracking allows continued skill development and discrimination between experts and nonexperts.

Applications of eye-tracking in surgery. Applications of eye-tracking technology in the surgical discipline, while not as wide-spread as those in psychiatry or radiology, nonetheless offer insight into the potential benefits that exist when applying the technology in an instructional/training capacity. Chetwood et al. (2012) point to the contributions that eye-tracking has made in the aircraft industry (Sadasivan, Greenstein, Gramopadhye, & Duchowski, 2005) and radiology (Kundel et al.,1990), advocating for use of the technology in minimally invasive surgeries (laparoscopy, in this case). Developing custom software designed to overlay an instructor's gaze on a screen during training, Chetwood et al. (2012) instructed 28 subjects of varying experience levels either verbally, with a screen indicating the instructor's gaze, or both. Results indicated that subjects who received both verbal instruction and exposure to the screen indicating the instructor's gaze accomplished faster completion times, committed fewer errors, and had their focus time on targets (latency) reduced significantly.

Tomizawa, Aoki, Suzuki, Matayoshi, and Yozu (2012), in a pilot study, used mobile eye-tracking units to record extracorporeal circulation (ECC) tasks performed during cardiovascular surgery. Tracking the gaze of four perfusionists (with 2, 8, 15+, and 26+ years of experience), Tomizawa et al. (2012) discovered that the subject with the most experience spread his attention more widely across all key areas of information than his less-experienced counterparts did during the surgery. While the data in this case are limited, they portend similar types of discrimination between experts and nonexperts mentioned previously in radiologic eye-tracking applications.

Beyond training applications, Zheng et al. (2012) used eye-tracking technology to measure blinks among surgeons, and then correlated these items with the National Aeronautics and Space Administration Task Load Index (NASA TLX). Combining these two measurements provides a means of determine how high and low workload, and high and low frustration, manifest physiologically through the eyes. Subjects (N = 46) were divided into two groups based on blink frequency (infrequent = 6 blinks or less per minute, frequent = more than 6 blinks per minute), and then evaluated. While no difference existed in surgical performance, results indicated that surgeons who blinked infrequently reported higher levels of frustration and higher overall workload—providing support for eye-tracking as a possible measure of cognitive workload.

Another innovative application of eye-tracking to surgery comes from Kim et al. (2011), who applied the technology to the evaluation of breast morphology following surgery. Specifically, the researchers highlight the difficulty in quantifying aesthetics postsurgery, and proposed using eye-tracking as a means of describing how plastic surgeons evaluate breast morphology and surgical outcomes using photographs. While this study only included three subjects, results indicated that these surgeons spent the majority of their time reviewing anterior-posterior (front and back) photographs of patients, as opposed to lateral or oblique photographs, to assess initial impressions, symmetry of size, symmetry of shape, aesthetic shape, and natural shape. Generalization of this data is limited, but Kim et al. (2011) state that eye-tracking is an effective means of quantifying breast morphology in evaluating surgical outcomes. Furthermore, the researchers advocate for future use of eye-tracking in breast morphology, including among samples of breast cancer survivors, and with the aid of additional existing assessment instruments.

Use of eye-tracking technology in the field of surgery is still growing. Early applications have shown potential for the technology to contribute in training procedures (Chetwood et al., 2012), process efficiency and expert discrimination (Tomizawa et al., 2012), outcomes (Kim et al., 2011), evaluation of workload (Zheng et al., 2012), and (increasingly) integration with surgical robotics (Ahmidi et al., 2010; Noonan, Mylonas, Darzi, & Yang, 2008; Stoyanov, Mylonas, & Yang, 2008; Vine et al., 2014). Future applications will undoubtedly expand upon these areas, and help to strengthen the foundation being built by current research.

Eye-tracking and potential applications in dermatology. For the discipline of dermatology, there are lessons to be learned from reviewing eye-tracking applications in psychiatry, radiology, and surgery. Notably, each of these disciplines has benefitted from using the technology, and new lines of research have been opened. Eye-tracking research in psychiatry has helped to establish a link between visual behavior and cognition—moving beyond self-report to determine visual areas of interest. Eye-tracking research in radiology has shown the potential for visual patterns to be tracked during review and diagnosis—allowing for optimum scanning procedures to be operationalized, and expert traits to be identified and emulated. Eye-tracking research in surgery has shown how the technology can be used in training applications, as a means of clarifying areas of visual interest, skills assessment, and evaluating stress and fatigue.

These lessons have direct application to dermatology because, above all, dermatology still relies primarily on the human eye and the human brain to render judgment on atypical lesions. Diagnosis may increasingly be aided by dermoscopes (Argenziano & Soyer, 2001; Massone, Di Stefani, Soyer, 2005; Soyer, 2009), computers (Abbas, Celebi, Serrano, Fondón García, & Ma, 2013; Fikrle & Pizinger, 2007; Garnavi, Aldeen, & Bailey, 2012; Razmjooy, Mousavi, Soleymani, & Khotbesara, 2013; Ruiz, Berenguer, Soriano, & Sánchez, 2011) and other imaging tools, but the final decision to excise or ignore is a human one, based on visual indicators. Through the application of eye-tracking technology to dermatology, these visual indicators can be identified, quantified, codified, and applied for future practice. Furthermore, training of new dermatologists can be aided by eye-tracking, allowing for visual scan patterns to be presented and corrected early on.

Current applications of eye-tracking to dermatology are very limited—notably two studies (Dreiseitl, Pivec, & Binder, 2012; Krupinski, Chao, Hofmann-Wellenhof, Morrison, & Curiel-Lewandrowski, 2014) have pioneered the work. A full review of their research can be found in Chapter Two, but the goal of the current study is to join these early adopters in determining how visual patterns can be captured and used to enhance skill acquisition for laypersons in the identification of atypical nevi. In the current design, skill acquisition will be quantified via diagnostic accuracy measures and various fixation-based metrics available through eye-tracking technology, perceptual learning and eye-tracking research will be synthesized, and distinguishing features of novice and expert visual scanning patterns will be discussed. All of these will support a theory of visual skill acquisition—for which the current study serves as a framework.

CHAPTER TWO

LITERATURE REVIEW

Throughout the past 30 years, the incidence rate of melanoma within the United States has increased steadily (Siegel, Naishadham, & Jemal, 2012). Overall, the current lifetime risk of developing melanoma is 1/55 (Ries et al., 2008), which eclipses both the 1/120 rate from 1987, and the 1/1500 rate from 1935 (Rigel, 1996; Rigel, Russak, & Friedman, 2010). Currently, new cases of melanoma have outpaced all other types of cancer domestically (Linos, Swetter, Cockburn, Colditz, & Clarke, 2009), and worldwide deaths from melanoma top nearly 50,000 annually (Geller et al., 2013). Given these drastic increases in incidence rate and mortality, many researchers have concluded that we currently face a melanoma epidemic (Beddingfield, 2003; Dennis, 1999; Flórez & Cruces, 2004; Lamberg, 2002; Levell, Beattie, Shuster, & Greenberg, 2009; Rigel, Friedman, & Kopf, 1996; Rigel, Friedman, Robinson, Amonette, & Kopf, 1997; Schaffer, Rigel, Kopf, & Bolognia, 2004). However, this view is not shared universally, with critics citing increased surveillance, overdiagnosis, and discrepancies between historical incidence and mortality rates as the driving forces behind the "epidemic" (Swerlick & Chen, 1996; Swerlick & Chen, 1997a; Swerlick & Chen, 1997b; Weyers, 2012). Regardless of the factors driving the increased incidence—whether from surveillance, diagnosis, or other variables—mortality rates are best combated by the accurate, early detection of melanoma.

Melanoma is most easily treatable in its earliest, *in situ* stages. If left unchecked, however, melanoma can begin to penetrate down into the skin, becoming more difficult to treat and increasingly deadly (Rigel et al., 2010). Melanoma depth has been shown to correlate inversely with prognosis (Balch et al., 2001; Clark et al., 1989; Rigel & Carucci, 2000), and this infiltration into the skin can occur very quickly (Goodson & Grossman, 2009). Therefore, effective detection strategies for melanoma will rely on consistent monitoring of the skin to identify nevi of particular concern in their earliest stages.

Routine clinical examinations are an effective tool for the early detection and elimination of atypical nevi (Goulart, Malvehy, Puig, Martin, & Marghoob, 2011). This is not surprising, as clinical diagnoses are driven by trained physicians, and typically result in the discovery of thinner (and more treatable) melanomas (Epstein, Lange, Gruber, Mofid, & Koch, 1999). Tools like dermoscopes have been shown to provide further benefit to clinical diagnoses (Bafounta, Beauchet, Aegerter, & Saiag, 2001; Vestergaard, Macaskill, Holt, & Menzies, 2008). Despite these benefits, however, such routine visits are not always possible for every individual (e.g., those living in rural areas, those without access to a dermatologist, or lower income individuals [see Aneja, Aneja, & Bordeaux, 2012]). For these individuals and others, skin self-examination (SSE), a patient-initiated activity in which an individual routinely examines his/her body for atypical nevi (Goodson & Grossman, 2009), is intended to lead toward clinical examination, but two problems undermine its utility: first, people rarely engage in SSE (Hamidi et al., 2010; Miller et al., 1996). Second, research into the accuracy of SSE has revealed that the practice is largely ineffective at identifying atypical nevi, even after patients receive training in state-of-the-science techniques such as the ABCDEs or Ugly Duckling Sign (UDS) (Buettner & Garbe, 2000; Carli et al., 2002; Goodson & Grossman, 2009; Hamidi et al., 2010).

Given these limitations, the U.S. Preventive Services Task Force, the Canadian Task Force on Preventive Health Care, and the Institute of Medicine have labeled SSE as a stopgap measure that needs to be improved or replaced (Feightner, 1994; U. S. Preventive Services Task Force, 2009). Unfortunately, literature on the necessary ingredients for effective SSE is sparse, suggesting a need for further research to both establish the accuracy of current SSE practices, and to identify effective mechanisms to inform future SSE best practices. Even though SSE is largely ineffective, past research does suggest a few positive directions for continued investigation. For instance, research into SSE performance has shown that SSEs are most effective and accurate when individuals are taught the basic surface criteria of melanomas, such as the ABCDEs of (A)symmetry, (B)order Irregularity, (C)olor, (D)iameter, and (E)volving features; or the UDS technique of comparing abnormal nevi to others on their body (Grob & Bonerandi, 1998). Other research has shown that individual accuracy can be increased through general training and experience, irrespective of a specific training regimen (Binder et al., 1997; Pagnanelli et al., 2003; Piccolo et al., 2002). Additionally, showing individuals magnified images of nevi to model and identify problematic features has been shown to increase accuracy of melanoma identification (Robinson & Turrisi, 2006).

Visual Patterns and SSE

The effectiveness of SSE techniques hinges primarily on the capability of individuals to detect the visual cues that may or may not exist in a particular nevus of interest. Within the literature, consensus definitions have been assigned to certain visual features of atypical nevi to aid physicians in diagnoses, but these descriptors are not provided or well known to laypersons (Argenziano, et al., 2003). Additionally, very limited research has been performed thus far that tracks and explores visual gaze patterns of individuals (both experts and laypersons) attempting to diagnose nevi. Perhaps this research has not been explored because the eye-tracking technology used to capture such data has seen limited application within the field of dermatology. Other medical fields, such as radiology, have used eye-tracking equipment in concert with imaging media to examine how physicians discover suspicious masses on mammogram imagery (Krupinski, 1996; Kundel, Nodine, Krupinski, & Mello-Thoms, 2008) or chest X-rays, along with applications in CT/MRI scans and endoscopy (Cavaro-Ménard, Tanguy, & Le Callet, 2010; Cooper, Gale, Darker, Toms, & Saada, 2009; Lång et al., 2011; Meining, Atasoy, Chung, Navab, & Yang, 2010).

With dermatology's reliance on visual processes to identify atypical nevi, application of eye-tracking to the discipline is a natural fit. However, thus far, only two studies have utilized eye-tracking technology to examine visual patterns used in the diagnosis of nevi. One such study was performed by Dreiseitl et al. (2012), wherein the researchers grouped a small sample of 16 participants by diagnostic experience, and presented them individually with a series of pigmented skin lesion images to diagnose. Their gaze patterns throughout the process were tracked and, as variables of interest, the researchers measured visual coordinates, gaze track length, total time to diagnosis, fixation duration (summed time spent focused on particular elements), and total number of fixations. Results indicated that, on average, experts arrived at a diagnosis 70% quicker than novices. Additionally, both total fixation time and total number of fixations were 50% lower for experts compared to novices. This means that experts spent less time looking at the nevi, and required less overall fixation points, to come to a diagnosis, compared to novices (Dreiseitl et al., 2012, p. 204).

These conclusions were supported by a second study, performed by Krupinski et al. (2014). In this study, the researchers used eye-tracking technology to measure the success of an online dermoscopic training program—with the hope of using dermatologist search patterns to improve similar training programs in the future. In particular, the researchers presented the subjects with 20 cases of pigmented skin lesions (PSLs) that were either malignant melanoma (MM) (n = 10), or common lesions with characteristics of MM (n = 10) that were later determined to be common. In each case, subjects viewed both a standard photo of the lesion, centered and surrounded by normal skin, and a dermoscopic image of the same lesion for comparison. Lesions were rated on a scale from 1-10, with 1-5 considered common and 6-10 considered atypical. The sample consisted of four individuals, two Board-certified dermatologists and two dermatology residents, and these individuals repeated their assessment three months after the initial assessment. Results indicated that the two dermatologists had more efficient search patterns than their resident counterparts, evidenced by lower numbers of total fixations and shorter dwell times. Furthermore, in instances where decisions changed between the photograph and the dermoscopic image, total fixations and dwell times were observed to be significantly higher across all subjects, indicative of increased cognitive processing driving these decisions. It is worth noting that the findings linking expertise to shorter fixation times are consistent not only between Dreiseitl et al. (2012) and Krupinski et al. (2014), but also with findings observed in radiology and pathology (Krupinski, 1996; Krupinski, 2005; Kundel, Nodine, & Carmody, 1978; Kundel et al., 1989; Lesgold et al., 1988; Nodine et al., 1996; Nodine & Mello-Thoms, 2010; Nodine, Mello-Thoms, Kundel, & Weinstein, 2002). In other words, individuals with greater expertise consistently arrive at more accurate diagnostic decisions, while relying on fewer fixations and shorter dwell times.

But how do these findings translate to laypersons—those actually expected to perform SSE? Both Dreiseitl et al. (2012) and Krupinski et al. (2014) relied upon expert (or near-expert) samples to gather data. No dermatology study to date has used eye-tracking equipment to explore the visual patterns of trained laypersons, whose exposure to atypical nevi may be quite limited outside of the training experience itself. It is currently unclear whether proficiency, in this case, will dictate fixation count and duration among laypersons in a similar manner as it has for experts. To better understand the link between experience and expertise, it bears discussing the nature of visual learning, both to explore the mechanisms driving visual skill acquisition, and to establish a framework to test the link between training and proficiency among laypersons.

Perceptual Learning and Eye-Tracking: Identifying Expertise

One line of research that has thoroughly explored the links between various types of training and proficiency is that of perceptual learning. *Perceptual learning* describes the acquisition or improvement of skill through sensory training (Fahle, 2005). This training can focus on auditory (Polley, Steingerg, & Merzenich, 2006; Tremblay, Kraus, & McGee, 1998; Watson, 1979), tactile (Fahle, 2005; Karni & Bertini, 1997), olfactory (McCollum et al., 1991; Moreno et al., 2009; Wilson & Stevenson, 2003), visual (Ahissar & Hochstein, 1997; Li, Piëch, & Gilbert, 2004; Schwartz, Maquet, & Frith, 2002), or other sensory tasks, and seeks to determine the methods whereby individuals develop sensitivity to certain types of information (Goldstone, 1998). The moniker of s*ignal-to-noise ratio* is often used in perceptual learning literature to describe one's ability to discriminate between relevant and superfluous signals (Fahle, 2004; Gold, Bennett, & Sekuler, 1999). For example, experts in radiology are capable of discerning micro-fractures from radiographs by homing in on known trouble spots (relying on a greater quantity of prior exposure to images and relevant signals), while less-experienced individuals may find their visual attention less focused (or influenced by noise), due to reduced familiarity with the location or appearance of fractures. Noise can be internal (to the subject) or external (residing in the stimulus or channel) (Dosher & Lu, 1998), but either serves to distract the subject from the desired search task. Ultimately, it is the signal that is strengthened through training, as opposed to a reduction in internal or external noise (Gold et al., 1999), and experts are those who have become proficient at recognizing—and thus, exhibiting greater sensitivity to—critical signals.

In visual tasks like the radiology example above, or any other scenario wherein an individual is required to visually discern relevant signals from irrelevant noise, research in perceptual learning attempts to explicate what is going on cognitively during visual scanning. It had previously been assumed that visual perceptual learning was the result of conscious effort exerted by subjects during the training process (Ahissar & Hochstein, 1993; Shiu & Pashler, 1992). However, recent studies seemingly contradict these findings; placing a greater role on implicit processing (absent of conscious effort), and placing the locus of effect in higher-level cognitive processes—moving beyond mere visual processing, and into more decision-oriented areas of the brain (Carrasco, Rosenbaum, & Giordano, 2008; Chowdhury & DeAngelis, 2008; Gutnisky, Hansen, Iliescu, & Dragoi, 2009; Law & Gold, 2008; Skrandies & Fahle, 1994). This is not to say that all perceptual learning proceeds down a single cognitive path, however. Sasaki, Nanez, and Watanabe (2010) presented a model which suggests that visual perceptual learning "…may include both conscious processing, such as focused attention to a task-relevant feature, and reinforcement processing that includes implicit components" (p. 9). Looking at conscious and implicit processing as complementary pathways, in context of both attention and reinforcement, underscores the interconnectedness of the cognitive processes driving perceptual learning. This connected view of perceptual learning makes sense, considering research from Yu, Klein, and Levi (2004), which showed that skill gained through perceptual learning is not limited to similar stimuli alone, but can also transfer to other, seemingly unrelated, tasks (see also Green & Bavelier, 2003). This skill migration is possible due to the interconnectedness of neurons engaged during both tasks—not necessarily whether the tasks are similar or different in their actual performance.

Experts in visual perceptual skill are those who have an established cognitive framework optimized for specific tasks. Fahle (2005) summarized perceptual learning by stating that it "…occurs at different processing levels, with different speeds, and is subject to top-down influences" (p. 155). The multilevel nature of visual perceptual processing has already been discussed, and speed is a key discriminator between experts and novices (Ahissar & Hochstein, 2004). The reason behind this discrimination lies in the third item from Fahle's (2005) summary statement: top-down influences. In short, *top-down processing* refers to the human tendency to use existing knowledge of larger concepts to inform and gain understanding of newfound or unfamiliar concepts (Ahissar & Hochstein, 2004). This enables those with prior knowledge to draw on their experience, and place new stimuli within the context of the known. Experts possess well-developed higher level processes, and "…are those whose higher level representations have been modified by adding weight to appropriate inputs and pruning uninformative inputs (for the trained task)" (Ahissar & Hochstein, 2004, p. 462). Additionally, experts become proficient at *chunking*, or the ability to conceptually view relevant ecological elements as a single perceptual entity (further speeding up processing) (Ahissar & Hochstein, 2004; Barfield, 1986; Egan & Schwartz, 1979; Geeves, McIlwain, Sutton, & Christensen, 2013; Gobet et al., 2001; Gobet & Simon, 1998; Wickelgren, 1979). The difference between experts and novices, then, lies in three factors: prior exposure to stimuli, knowledge to determine what elements of that stimuli are relevant and which are not, and overall speed of processing.

The take-away from research in visual perceptual learning is that experts possess optimized processing tendencies in terms of both neural pathways and speed; with prior experience solidifying the cognitive advantage experts have over their less-experienced peers. The only way to develop a novice into an expert is through exposure to stimuli and/or specific training, in order to increase their range of experience (thus supporting higher-level processing) and to optimize neural pathways. Focusing purely on cognitive processes and neural pathways, however, leaves to question what is happening at the visual level.

Eye-tracking research has explored the visual differences between experts and novices, and provides key insight into the quantifiable discriminators between these two groups. Specifically, numerous eye-tracking studies in the disciplines of radiology and surgery have shown evidence of inverse relationships between expertise and measures of fixation time and total number of fixations (Leong et al., 2007; Tomizawa et al., 2012), as well as measures of accuracy and time to diagnosis (Kundel, Nodine, & Krupinski, 1990; Phillips et al., 2013; Tourassi et al., 2013). As established earlier, experts are able to come to a more accurate diagnosis more quickly, and they require less fixations overall before arriving at a decision. This is consistent with the discussion on visual perceptual learning, and the increased processing speed that experts enjoy through optimized neural processing.

The previously cited research by Dreiseitl et al. (2012) and Krupinski et al. (2014) also supported the notion that differences in skill level and processing speed are discernable through eye-tracking, reporting a clear distinction between higher and lower levels of nevi identification expertise. Neither of these studies, however, focused on true laypersons. A layperson, in application to nevus identification, is an individual who has had no formal training in the identification of atypical nevi, and who may know little to nothing about skin cancer. These are the individuals who are expected to perform SSE, and they are heretofore absent in dermatology eye-tracking research.

Given the dearth of eye-tracking research exploring nevi identification among laypersons, many initial questions need to be addressed. Namely, how do different training methods (instilling knowledge and serving as proxies for experience) impact accuracy outcomes? What role do observable fixation- and saccade-based eye-tracking metrics play in the progression from novice to expert? Will trained novices begin to exhibit a shift toward expert-like visual patterns? How much training is required to drive significant skill acquisition? To test these questions and others, a theory of visual skill acquisition is needed in order to clearly explicate the anticipated pathway from knowledge and experience to skill acquisition. This pathway is illustrated in Figure 1.

Visual Skill Acquisition Theory: An Overview

Visual skill acquisition theory (VSAT) is a framework that portrays the progression of subjects, via knowledge and experience, to the point of processing efficiency and skill in a given visual task. VSAT posits that knowledge and experience co-exist within a synergistic pattern—with each variable contributing to the development of the other. This is consistent with the earlier review of top-down processing, which states that prior knowledge allows for the weighting, pruning, and chunking of current and future experience (Ahissar & Hochstein, 2004; Barfield, 1986; Egan & Schwartz, 1979; Fahle, 2005; Geeves et al., 2013; Gobet et al., 2001; Gobet & Simon, 1998; Wickelgren, 1979). In effect, possessing knowledge allows one to optimize his or her experience gathering, and possessing experience allows one to optimize his or her learning when gathering knowledge. Taken together, these variables constitute the foundation for skill acquisition.

While skill acquisition is the ultimate outcome of VSAT, self-efficacy and processing efficiency moderate and mediate the direct relationship, respectively. Self-efficacy is closely examined in Bandura's (1989, 1997, 2010) social cognitive theory, and represents an individual's feeling that he or she is capable of performing a particular behavior, and that the performance of that behavior can enact a desired change. Self-efficacy is behavior-specific (Bandura, 1997), and has the potential to impact performance both directly and indirectly through outcome expectations, perceived barriers, and goals (Bandura, 1986, 1997, 2004; Becker, 1974; Glasgow, 2012). Additionally, because self-efficacy is behavior- or task-specific, it is not easily measured by so-called "universal" measures, and should be assessed with items phrased specifically to the task (Bandura, 2006). In many tasks, individuals with higher levels of self-efficacy stand a greater chance of performing better than those with lower levels of self-efficacy (Bandura, 1986, 1997; Berry & West, 1993; Bouffard-Bouchard, 1990; Lachman & Jelalian, 1984; Themanson, Pontifex, Hillman, & McAuley, 2011).

Processing efficiency is included in VSAT as a means of measuring the intermediary steps that exist between training and skill acquisition. Specifically, research in visual perceptual learning and eye-tracking indicates that measurable increases in processing efficiency begin to manifest when an individual transitions from novice toward expertize (Ahissar & Hochstein, 2004; Dreiseitl et al., 2012; Fahle, 2005; Krupinski et al., 2014). These measures of efficiency can be captured at the neurological level using equipment like functional magnetic resonance imaging (fMRI) machines, or at the visual level using eye-tracking technology. The advantage of including processing efficiency in VSAT is that it elucidates the primary outcome—allowing for gains in efficiency to be separated from gains in skill. For example, a student in a math class may become faster (i.e., more efficient) at completing math problems, even if his or her test scores have not yet increased. Likewise, a dermatologist in training may begin to identify suspicious lesions more quickly, even if his or her diagnostic accuracy has yet to improve. In both cases, the increases in processing efficiency arguably represent the seeds of skill acquisition, and may be indicative of small shifts on the spectrum toward expertise—shifts that would otherwise go unnoticed when limited to a single skill acquisition outcome.

From medical applications in dermatology or radiology, to more mundane applications in driver's education or sports, VSAT holds potential utility in any context wherein subjects are trained and then expected to perform a specific visual task. Through the use of VSAT, insight can be gained into the mechanisms of skill acquisition, and data can be captured to allow for the fine-tuning and development of training methods and materials. The current study represents the initial test of VSAT within the context of SSE—with the goal of scrutinizing the capability of SSE training materials to effectively educate a sample of laypersons. Figure 2 provides a model of VSAT applied to SSE, and a review of each variable within the model follows below.

Training method. The onset of expertise requires knowledge and experience, and both require exposure either through direct contact with stimuli or via training, where materials and message features serve as proxies for direct exposure. Training scenarios allow for subjects to develop familiarity with the nuances of a particular task, by feeding both the neurological processes that enable the discrimination of relevant vs. nonrelevant data, and establishing the higher-level processes that encourage skill development

(Ahissar & Hochstein, 2004). The method of training, and the written or verbal messages communicated, can understandably have an impact on the amount of skill developed. A variety of communication methods are available for training, but this project will focus on two message features that are both under-researched and potentially impactful for the field: illustrations vs. photos.

Illustrations vs. photos. Logically, one might assume that successful training would include materials and photographs that mimic the desired task as closely as possible. For example, training materials for SSE often contain photorealistic images of typical and atypical nevi as examples of what patients may find on their own bodies during the act of SSE (King, 2014). The assumption driving the inclusion of these visuals is that realism is better when it comes to visual training. However, dissenting viewpoints exist within the admittedly limited research, as to whether photorealistic images or graphic illustrations are more effective for training. Graphic illustrations, in the case of nevi r, are drawn representations of what an individual might see—with particular emphasis graphically placed over areas that should be of particular concern (e.g., exaggerating the border criteria of the ABCDE method, by portraying it as an illustrated, dark-colored circle surrounding a lighter colored circle). In regard to which method is superior, an interesting dichotomy exists between public preference and effectiveness. Research has shown that a preference for realistic visuals seems to exist among samples (Hegarty, 2011; see *naïve realism* in Smallman & John, 2005), despite evidence that illustrations hold a slight advantage in terms of comprehension (Moll, 1986; Readance & Moore, 1981) and provide the capability to visually discriminate against, or entirely remove, extraneous information (Fillippatou & Pumfrey, 1996)—possibly aiding novices in the pruning of unessential information (Ahissar & Hochstein, 2004).

Because visuals do have the potential to improve health education outcomes (Houts, Doak, Doak, & Loscalzo, 2006), it is important to understand *how* these visuals should be communicated. Numerous studies have shown that, even in cases where identical messages are communicated, the visual method that is used to send the message can significantly alter how it translates into execution (see Breslow, Trafton, & Ratwani, 2009; Hegarty, Canham, & Fabrikant, 2010; Novick & Catley, 2007; Sanfey & Hastie, 1998; Shah & Carpenter, 1995; Simkin & Hastie, 1987; Yeh & Wickens, 2001; Zhang & Norman, 1994). As such, given the limited amount of research currently available on the effectiveness of photorealistic vs. illustrative examples in SSE training, and the potential impact visuals can have on knowledge and performance, both conditions were included in the model for testing.

Moderators. A direct relationship between training and skill acquisition is anticipated, but the potential for moderating factors exists. Specifically, when subjects are trained and asked to perform a particular task, how capable they feel at performing that task, and their perception of the task's importance to their own lives, can significantly impact performance (Bandura, 1986, 1997, 2004; Glasgow, 2012). As such, self-efficacy and perceived importance are included within the model as potential moderators. Rationale for their inclusion is included below.

Self-efficacy. Within SSE literature, self-efficacy has been linked to a variety of related outcomes. For example, Robinson, Turrisi, and Stapleton (2007a, 2007b) found that promoting SSE performance with partners resulted in increased self-efficacy, increased perceived importance of SSE, and increased intentions to perform SSE in the future. Lev (1997) also found that higher levels of self-efficacy led to increased participation in cancer screening programs, increased self-care, and greater adherence to treatment recommendations. Hay et al. (2006) lent further support to these findings, discovering that self-efficacy mediated for SSE adherence 4 months after an initial visit to a dermatologist.

Self-efficacy has been shown to influence SSE performance and perceived importance, but the impact of self-efficacy on SSE accuracy remains unclear. No study has currently explored the role of self-efficacy as a moderator to SSE accuracy. However, self-efficacy has been shown to be positively correlated with cognitive performance (see Berry & West, 1993; Lachman & Jelalian, 1984; Themanson et al., 2011), even in cases of experimental induction (Bouffard-Bouchard, 1990). Therefore, self-efficacy is included in the model due to its potential impact on subjects' perceptions and performance.

Perceived importance. Perceived importance refers to how important an individual determines that a particular message is, in the context of all other variables present in his or her life. It was Taylor (1981; see also Fiske & Taylor, 2013) who originally described human beings as "cognitive misers," lacking the capability to fully process every message encountered in daily life. As such, the assumption is that individuals will devote more cognitive resources attending to messages that they deem personally important; leaving other interests (or noninterests) to compete for the remaining faculties. Importance may be linked to a variety of factors, including motivation, self-interest, desire to process, applicability, accountability, need for cognition, severity of consequences, or many other factors that increase the salience of a particular message (e.g., Cacioppo & Petty, 1983; Chaiken, 1980; Harkins & Petty, 1981; Harkins & Petty, 1987; Petty & Cacioppo, 1979; Petty & Cacioppo, 1984; Petty, Cacioppo, & Schumann, 1983; Tetlock, 1983).

Perceived importance of SSE has been tested by Robinson et al. (2007a), in comparing solo vs. dyadic learning groups. They discovered a correlation between dyadic learning and perceived importance of SSE, wherein the dyadic learning group reported higher importance than the solo learning group (Robinson et al., 2007a). The related construct of perceived relevance has also been discussed in health communication framing research, wherein Van Dillen, Hiddink, Koelen, De Graaf, and Van Woerkum (2004) determined that tailored messages were especially effective for those with higher levels of perceived message relevance. In the same study, however, it is insinuated that relevance is not synonymous with interest. For example, a health message may seem like it should be relevant to a smoker because it is promoting cessation behavior—which is good for the individual—but the individual may not be interested in ceasing to smoke, therefore the message is deemed less relevant.

In application to SSE, arguably, training materials should be deemed more important for subjects who see themselves at risk for skin cancer, who are interested in skin cancer, or who have had relatives or other loved-ones who have dealt with skin cancer. Conversely, perceived importance should be lower for individuals without direct experience or interest. A perceived importance measure is included in the model to examine the impact that importance of the message may have on visual attention and accuracy.

Mediators. The inclusion of mediating factors in the model serves two overarching purposes: (1) explicating the link between training and diagnostic accuracy, and (2) verifying the early onset of expert-like visual scanning patterns in trained laypersons (i.e., processing efficiency), as evidenced by eye-tracking metrics. It is anticipated that the acquisition of skill (following training) will be visible via fixation- and saccade-based eye-tracking metrics. Therefore, a selection of eye-tracking metrics is included in the model.

Eye-tracking metrics. The inverse relationship between expertise and the metrics of total fixation time, fixation duration, and time-to-diagnosis was addressed earlier. In sum, *fixations* represent the center of an individual's point-of-gaze, and are indicative of points of cognition. *Saccades* are the jumps between fixations, wherein cognition and visual signals to the brain are interrupted. The majority of eye-tracking measures rely upon fixation- and saccade-based metrics to determine points of interest and disinterest on the stimulus, and to infer general information about the subject based on his or her search patterns. In application to the current model, the following eye-tracking metrics are used to verify the onset of expert-like visual patterns among trained laypersons: total fixations, fixation duration, fixation density, fixations within a lookzone, total fixation duration (i.e. dwell time) within the lookzone, and duration before first fixation arrival (i.e., time to lookzone). Each of these metrics is explained in-detail in Chapter Three.

Skill acquisition. In the current study, skill acquisition is defined by diagnostic accuracy, which is calculated via the creation of a two-by-two grid. This grid allows for the assessment of sensitivity and specificity measures across all subjects. Specific information on how these measures were calculated can be found in Chapter Three.

Research Questions

Melanoma research states that we are currently in the midst of an epidemic, and the first line of defense—SSE—has been deemed a stopgap measure, while more effective means of skin cancer identification and referral are conjectured. SSE, however, has yet to be optimized, and additional research is needed to determine the factors that drive successful execution. VSAT is a model that aims to track the development of nevus identification skill in laypersons, and the coinciding progression from novice to expert. Synthesizing principles from visual perceptual learning and eye-tracking research, the model relies upon the measurable aspects of skill acquisition—namely speed, accuracy, and fixation-based eye-tracking metrics—to delineate the effectiveness of illustrated and photorealistic communication training interventions.

In context of the previously described findings, and within the framework of VSAT, the following research questions are proposed:

RQ1: Are features of visual training – such as training type or visual form – related to changes in processing efficiency?

RQ2: Are changes in processing efficiency related to greater sensitivity (RQ2a) or specificity (RQ2b)?

RQ3: Does training condition – ABCDE vs. UDS – yield significant differences in sensitivity (RQ3a) or specificity (RQ3b)?

RQ4: Does visual condition – illustration vs. photorealistic – yield significant differences in sensitivity (RQ4a) and specificity (RQ4b)?

RQ5: Is there a significant interaction between training and visual condition on sensitivity (RQ5a) and specificity (RQ5b)?

RQ6/7: Does self-efficacy moderate the relationship between training/visual condition and sensitivity (RQ6a/RQ7a) and specificity (RQ6b/RQ7b)?

RQ8/9: Does perceived importance moderate the relationship between training/visual condition and sensitivity (RQ8a/RQ9a) and specificity (RQ8b/RQ9b)?

RQ10: Does processing efficiency mediate the direct or indirect paths between training/visual condition, self-efficacy, perceived importance, and sensitivity and specificity?

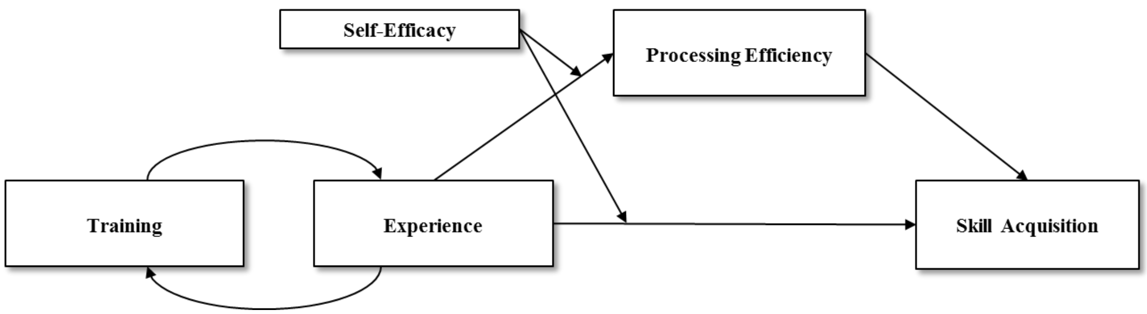


Figure 1. Visual Skill Acquisition Theory

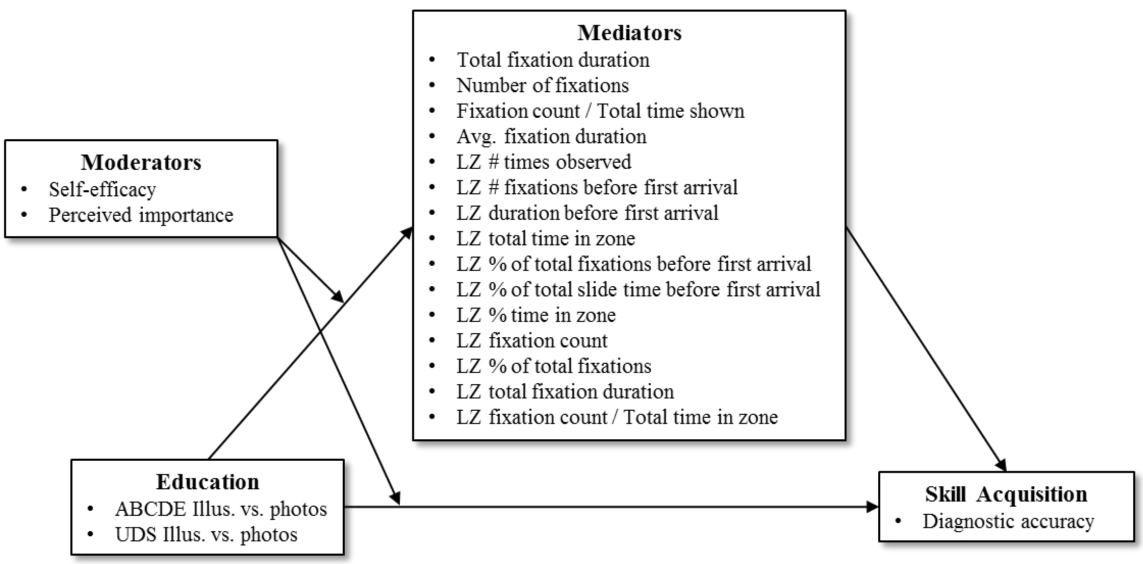


Figure 2. Model of VSAT in Application to SSE Training and Visual Skill Acquisition

CHAPTER THREE

METHOD

Design

A sample of 92 students was randomly assigned to a 2 (Training condition: ABCDE vs. UDS) × 2 (Visual condition: Photo vs. Illustration) between-participants experimental design (see Figure 3). Students completed a pretest, reviewed an educational SSE intervention, and performed a series of nevus identification tasks in an eye-tracking lab. Upon completion of the nevus identification task, or upon exiting the study, students were debriefed and compensated with extra credit.

Participants

College students over the age of 18, from a large, Western university, were invited to participate in the research project. Students were introduced to the project by the researcher, who visited various classrooms throughout the university to publicize the opportunity to participate. During these visits, students were informed that they had the chance to participate in a study focused on skin cancer, which would require approximately 20 minutes of their time. Interested students wrote their names on a schedule, and were expected to show up in the eye-tracking lab at their designated time. Participating students were offered extra credit in their coursework, in an amount determined by their professor (not exceeding 2% of the final course grade). Arrangements were made with each classroom professor to offer alternative extra credit opportunities for students who chose not to participate in this project. A total of 107 students signed up to participate in the research project.

Demographic Data

Of the 107 students who signed up, 15 were removed from the sample for the following reasons: 7 subjects moved significantly in their seats during a timed part of the experiment (e.g., leaned in very close to the computer monitor, or leaned over to check their phone); 5 subjects either had dirty contact lenses or glasses without antireflective coating, which hindered the eye-tracker's ability to accurately track their gaze; and 3 subjects were removed due to a research assistant failing to mark the experimental condition they were assigned to in the code book. Therefore, the final sample size for the study was $N = 92$.

A full demographic breakdown of the sample is included in Table 1. The sample consisted primarily of undergraduate students currently enrolled at the university (91.3%, $n = 84$), though 4.3% ($n = 4$) of participants had recently graduated, and the extra credit opportunity was opened up to a single class of graduate students, which contributed an additional 4.3% ($n = 4$) of participants. Mean age for the sample was 22.3 ($SD = 4.69$), with a slight bias toward females (54.3%, $n = 50$), and a significant portion who racially identified as White (87.0%, $n = 80$). The majority of students reported that their non-sun-exposed skin was "fair" (48.9%, $n = 45$) or "olive" (22.8%, $n = 21$) in color, followed by "very fair" (17.4%, *n* = 16). Overall, the sample was typical of the state where data were collected, but skewed when compared to the general U.S. population.

In addition to demographic information, subjects were also asked a series of questions meant to identify their history of skin cancer, the number of moles on their body, and whether they had visited the dermatologist before (see Table 2). A majority of the sample reported never having had skin cancer (97.8%, *n* = 90), with 14.2% (*n* = 13) reporting that their father had skin cancer, 3.3% (*n* = 3) reporting that their mother had it, and 1.1% for both brothers (*n* = 1) and sisters (*n* = 1). A total of 63.0% (*n* = 58) of subjects reported having visited the dermatologist before, with 30.4% (*n* = 28) having had a mole examined by a dermatologist, and 26.1% (*n* = 24) having had a mole removed or checked for cancer. A total of 21.7% (*n* = 20) of the sample reported having 50 or more moles on their body.

Eye-Tracking Equipment

Data collection was conducted in a university eye-tracking lab and an adjoining focus group room. Equipment within the eye-tracking lab included an Applied Science Laboratories (ASL) D6HS desk-mounted tracking device, configured for sampling at 120Hz, which is suitable for bright pupil tracking. Head tracking was handled via ASL proprietary algorithms, utilizing facial recognition software paired with a camera internal to the D6HS tracker. Because desk-mounted optics were used, no physical contact between the device and the subject was required for tracking.

A 24-inch Dell UltraSharp monitor, configured to 1920x1200 resolution, was used on the stimulus terminal. All images on this terminal were sized as not to interact with the outer 100 pixels horizontal and 200 pixels vertical on the monitor, in order to avoid aberrations from reaching the edge of the trackable range. Subject seating position was adjustable to place the eyes within a range of 22 to 24 inches from the monitor and D6HS system—accounting for subject height, posture, and comfort (Applied Science Laboratories, 2011). For stimulus presentation and data collection, Eyetellect Gaze Tracker 10 software was used (Eyetellect, 2014).

Procedure

A full outline of this study is portrayed graphically in Figure 4. What follows is a step-by-step explanation of the study procedure.

Pretest. Upon entering the eye-tracking lab, students were given a pretest survey, which consisted of basic definitions for the terms *skin self-examination*, *mole*, and *melanoma*, as well as demographic and other questions designed to capture the self-efficacy and perceived importance measures described later in this chapter. Following the pretest, subjects were led to the stimulus terminal, where they were seated and briefed on calibration and tracking processes.

Calibration process. After being seated, subjects were asked to look forward and to confirm that they were able to read a line of text in 12 pt. font shown on the screen. Afterward, as part of the calibration process, subjects were asked to keep their heads still while looking at the screen, during which time the researcher used the infrared camera internal to the D6HS to locate the subject's right eye (the system is capable of tracking using either eye, but, due to the location of the camera internal to the system, the right eye is the most reliable) (Applied Science Laboratories, 2011). Once the subject's right eye was located and placed into focus on the operator terminal, the presence of distinct pupillary and corneal reflections was verified. If these images were not clear, adjustments were made to the internal infrared light and the focal point of the D6HS camera. In cases where adjustments to these settings still did not result in clear pupillary and corneal reflections, adjustments to the subject's seating position were made to change the angle of the camera relative to his/her eye. If these efforts did not result in a clear reflection, the subject was dismissed from the project, but still fully compensated for his/her time.

Once clear images of the pupillary and corneal reflections were present on the operator computer, subjects were asked to keep their heads still while looking at the computer monitor, whereon an image of a square with nine numbered points was projected. Subjects were instructed to look at each of the nine points as directed by the researcher, while the researcher marked their point of gaze on the operator computer. Once all nine points had been reviewed, an "X" would appear on the operator computer, along with a reproduction of what each subject saw on the stimulus screen. The researcher would then ask the subjects to look at each of the nine points one more time, verifying that the "X" was an accurate representation of the subjects' fovea, or center of visual attention. Once this was verified, the subjects were then ready to be tracked using the Eyetellect Gaze Tracker 10 software (Eyetellect, 2014).

Experimental manipulation. Unbeknownst to subjects, at the moment they entered the Eye-Tracking Lab, they were each randomly assigned to one of 4 experimental conditions. Stimuli for these conditions were adapted from King, Carcioppolo, Grossman, John, and Jensen (2014), and an overview of each of the conditions follows.

ABCDE illustrated. Prior to beginning the nevi identification task, subjects within this condition saw a digital representation of an information pamphlet on the screen that focused on training in the ABCDE method of atypical nevus identification, featuring illustrated examples (see Appendix B).

ABCDE photorealistic. Prior to beginning the nevi identification task, subjects within this condition saw a digital representation of an information pamphlet on the screen that focused on training in the ABCDE method of atypical nevus identification, featuring photorealistic examples (see Appendix B).

UDS illustrated. Prior to beginning the nevi identification task, subjects within this condition saw a digital representation of an information pamphlet on the screen that focused on training in the UDS method of atypical nevus identification, featuring illustrated examples (see Appendix B).

UDS photorealistic. Prior to beginning the nevi identification task, subjects within this condition saw a digital representation of an information pamphlet on the screen that focused on training in the UDS method of atypical nevus identification, featuring photorealistic examples (see Appendix B).

Nevus identification task. Following training, subjects were ready to begin the nevi identification task. Images used in this task were acquired from MoleMap (http://www.molemap.co.nz/), and contained no identifying features beyond nevi (e.g., names, distinguishing marks, etc.). During the task, subjects were shown a series of images featuring sets of 4 nevi from the same patients, and asked to note if they believed any of those 4 nevi were atypical. Subjects were instructed that all nevi could be normal, or there could be one or multiple atypical nevi. Once a decision was made, the subjects either indicated to the researcher that all nevi were common, or they stated the identifying numbers of any nevi they felt were atypical. The researcher then noted each answer in the log book and advanced to the next slide until all slides had been viewed. At no time during this process did the researcher provide feedback to participants, in order to ensure that each subject received a comparable experience, and to aid in the isolation of training effects. The log book used by the researcher, including general information, software instructions, all 6 images used in this task, and the coding sheet, can be found in Appendix C.

Measures

Self-efficacy. Self-efficacy is a behavior-specific construct (Bandura, 1997). As such, in order to properly measure self-efficacy in the context of a particular behavior, items must be phrased within the vernacular and context of that behavior (Bandura, 2006). The application of universal efficacy measures, when the goal is to extrapolate to a particular behavior, is both inappropriate and inaccurate (Bandura, 1997, 2006). In light of this, Witte, Cameron, McKeon, and Berkowitz (1996) developed a series of self-efficacy items as part of a larger risk behavior diagnosis scale, and these items were adapted for the current study to make them relevant to SSE performance and nevus identification (see Appendix A). Four items from this measure were included in the pretest survey, and an additional item was created, for a total of 5 (M = 2.94, SD = .89, α = .87). These items were answered on a 1-5 Likert scale, anchored with *strongly disagree* (1) and *strongly agree* (5), respectively.

Perceived importance. Because human beings are "cognitive misers," who have limited capability to process all messages encountered in everyday life (Fiske & Taylor, 2013; Taylor, 1981), individuals are predisposed to devoting more cognitive resources in attendance to messages that they deem personally relevant or important. Perceived importance lacks a generally accepted measure in application to SSE; however, Robinson et al. (2007a) utilized a 4-item measure in their research pertaining to dyadic learning of SSE. This measure (excepting one partner-specific item) was adapted and expanded to yield 5 items quantifying perceived importance of SSE (M = 3.56, SD = .61, α = .85). These items were answered on a 1-5 Likert scale, anchored with *strongly disagree* (1) and *strongly agree* (7), respectively (see Appendix A).

Diagnostic accuracy. Diagnostic accuracy relies on metrics calculated via the creation of a 2-by-2 grid. The 4 squares of this grid (see Table 3) consist of the following scores: *true-positive* (TP)—cases that are atypical, and were deemed so by subjects; *false-positive* (FP)—cases that are common, but were deemed atypical by subjects; *false-negative* (FN)—cases that are atypical, but were deemed common by subjects; and *true-negative* (TN)—cases that are common, and were deemed so by subjects.

Construction of the 2-by-2 grid allows for the calculation of sensitivity and specificity for subject diagnoses. *Sensitivity* refers to the potential for subjects to accurately detect an atypical case, and is a function of TP/TP+TN. *Specificity* refers to the potential for subjects to accurately detect a common case, and is a function of TN/TN+FP. Taken together, these metrics provide more than a simple indication of correct vs. incorrect decisions—allowing for a more clear distinction to be made between the relative benefits of individual training methods to accuracy, and yielding data to support future meta-analyses (see Kittler, Pehamberger, Wolff, & Binder, 2002). Means and standard deviations for sensitivity and specificity were *M* = .475, *SD* = .179 and *M* = .791, *SD* = .133, respectively.

Eye-tracking measures. Eye-tracking metrics allow for the detection and quantification of visual scanning patterns. As noted previously, fixation-based eye-tracking metrics have been shown to inversely correlate with visual skill—effectively discriminating between novices and experts (Dreiseitl et al., 2012; Krupinski, 1996; Krupinski, 2005; Krupinski et al., 2014; Kundel et al., 1978; Kundel et al., 1989; Lesgold et al., 1988; Nodine et al., 1996; Nodine et al., 2002). Fixation-based eye-tracking metrics were used to track subject skill progression, and an overview of these metrics follows.

Fixation-based metrics. Fixation-based metrics derive information about subject attention and cognition by examining areas where the subject's gaze stops momentarily over the stimulus. The meaning behind fixation behavior is context-dependent, in that variations in task (e.g., encoding vs. search) can ascribe very different meaning to the observed behaviors. For example, in an encoding scenario, such as looking at a magazine advertisement, a greater number of total fixations may indicate greater interest in the stimulus. However, in a searching task, where a subject is asked to identify a single item among many, a greater number of fixations may be indicative of confusion or uncertainty in locating the item of interest (Jacob & Karn, 2003). Despite these context-dependent differences in interpretation, researchers are consistent in their claims that fixations are an indicator of some level of cognition (Goldberg & Kotval, 1999; Jacob & Karn, 2003; Just & Carpenter, 1976). The following fixation-derived metrics were used for analysis.

Total fixations. This is the total number of fixations recorded as the subject looks across the stimulus/stimuli. As mentioned above, a greater number of fixations can be indicative of interest during encoding tasks, or indicative of confusion during searching tasks (see Goldberg & Kotval, 1999; Salvucci & Goldberg, 2000). A hallmark of expertise is a reduced number of total fixations compared to less-experienced individuals; therefore, it is anticipated that total fixation counts will be lower (and accuracy, higher) for individuals with whom training has been most effective.

Fixation duration. This is the total time that the subject spent either on a single fixation, or the total fixation time across all fixations. Greater fixation duration can be indicative of uncertainty or difficulty in deciphering the stimulus, or it could mean that the stimulus was particularly appealing to subjects, depending on context (Hooge & Erkelens, 1996; Just & Carpenter, 1976). Again, the link between expertise and fixations manifests in the form of an inverse relationship. Therefore, it is anticipated that total fixation duration will be lower (and accuracy, higher) for individuals with whom training has been most effective.

Fixation density. High fixation density manifests in eye-tracking data as clusters of fixation points, tightly grouped together. Fixation density can be indicative of search efficiency—where greater density indicates effective searching, and lower density indicates unstructured or inefficient searching (Bruce & Tsotsos, 2009; Cowen, Ball, & Delin, 2002; Engelke et al., 2013; Mackworth & Morandi, 1967).

Fixations within a lookzone. Lookzones are defined areas of interest that the researcher has marked for further analysis, which are invisible to subjects. For example, if a researcher was interested in how many subjects observed the face of a particular person in an advertisement, he/she could place a lookzone around that face. During analysis, fixations within the lookzone could then be tracked separately from fixations on the remainder of the advertisement. Typically, greater fixations within the lookzone means one (or both) of two things: either the objects within the lookzone were more conspicuous than those in the remainder of the stimulus, or the objects in the lookzone were more important to the subject compared to competing elements in the advertisement (see Pan et al., 2004; Poole, Ball, & Phillips, 2005).

It is important to note that, when dealing with a lookzone around text, it is recommended that the average number of fixations in that lookzone be divided by the total number of words in the lookzone (Poole et al., 2005). This is done to discriminate between an inflated fixation count elicited due to simple reading, vs. a higher fixation count due to interest/difficulty in recognizing the target.

Total fixation duration (i.e., Dwell time) within the lookzone. This is the total time that the subject spends fixating, either across the entire stimulus, or within a particular lookzone of interest. This is a useful measure to contrast how visual attention was spread between two or more targets in the stimulus (e.g., a lookzone vs. the remainder of the stimulus). Additionally, it can be a measure of anticipation, when gaze precedes a particular action within the stimulus (e.g., a subject visually anticipating a window popping up after clicking on a button) (Hauland, 2003; Mello-Thoms, Nodine, & Kundel, 2002).

Duration before first fixation arrival (i.e., time to lookzone). This metric relies on the total time elapsed before arriving at the lookzone or area of interest, to determine that element's relative importance to other competing elements within the stimulus (Byrne, Anderson, Douglass, & Matessa, 1999). Greater time equals less importance.

Related to this metric are *posttarget fixations*, which refer to the number of fixations that take place outside of the lookzone after encountering it. Higher numbers of posttarget fixations imply that the object(s) within the lookzone are of low priority compared to other elements of the stimulus (Goldberg & Kotval, 1999).

Analysis

Statistical analyses were performed using IBM SPSS software version 22. Statistical power calculations were executed using G*Power 3.1.5 (Faul, Erdfelder, Buchner, & Lang, 2009; Faul, Erdfelder, Lang, & Buchner, 2007). The analytical approach utilized two-way ANOVAs and moderated mediation analyses. For ANOVA analyses, effect size standards are small (f^2 = .10), medium (f^2 = .25), and large (f^2 = .40). For the moderated mediation model, effect size standards are small (f^2 = .02), medium (f^2 = .15), and large (f^2 = .35) (Faul, Erdfelder, Buchner, & Lang, 2009; Faul, Erdfelder, Lang, & Buchner, 2007).

Achieved power for the two-way ANOVAs was excellent for the detection of large effects (.97), good for the detection of medium effects (.66), and poor for the detection of small effects (.16). Achieved power for the moderated mediation model (with 9 variables in the model) was excellent for the detection of large effects (.98), good for the detection of medium effects (.68), and poor for the detection of small effects (.11).

Whenever small sample size is a concern, so is Type 2 error—or the chance of lacking enough power to detect significant effects. Capturing eye-tracking data is a laborious process, and, as such, sample sizes in eye-tracking literature tend to be smaller than those of comparable non-eye-tracking studies. While the current study utilizes a very large sample by eye-tracking standards, it is below average for non-eye-tracking studies that would address similar issues. Despite these concerns, the traditional significance threshold of $p < .05$ was used for analyses, and consideration was reserved for any significance figures that approached the threshold.

Tests of Randomization

Initial tests were run to demonstrate whether potential covariates and/or moderators varied significantly by experimental condition.

Test 1a: Self-efficacy. A two-way ANOVA with Bonferroni corrections was conducted, with self-efficacy as the outcome, and training and visual condition as fixed factors. Main effects were nonsignificant for both training, $F(1,92) = .12$, $p = .732$, and visual condition, $F(1,92) = 2.47$, $p = .126$. The training × visual condition interaction was also nonsignificant, $F(1,92) = .000$, $p = .998$.

Test 1b: Perceived importance. A two-way ANOVA with Bonferroni corrections was conducted, with perceived importance as the outcome, and training and visual condition as fixed factors. Once again, main effects were nonsignificant for both training, $F(1,92) = .41$, $p = .526$, and visual condition, $F(1,92) = .27$, $p = .605$. The training × visual condition interaction was also nonsignificant, $F(1,92) = .34$, $p = .560$.

Test 1c: Demographic correlations. A bivariate correlation matrix was created to determine whether any potential covariates differed significantly by experimental factor. Results indicated that no significant differences existed between covariates with respect to training or visual condition (see Table 4a and Table 4b). Taken together, results from tests 1a, 1b, and 1c support the notion that adequate randomization exists within the sample; therefore, demographic factors were not utilized as covariates for further analyses.

Table 1.
Demographic Information

		n	%
Gender:	Male	42	45.7%
	Female	50	54.3%
Age:	18-25	84	91.3%
	26-35	6	6.5%
	35 and older	2	2.2%
Race/Ethnicity:	White	80	87.0%
	Black	3	3.3%
	Asian/Pacific Islander	7	7.6%
	Native American/American Indian/Alaskan Native	1	1.1%
	Hispanic/Latino	8	8.7%
Marital Status:	Single	50	54.3%
	Single, but in a relationship	23	25.0%
	Married	19	20.7%
Education:	Some college	68	73.9%
	Associate's degree/2 year degree	16	17.4%
	4 year college degree	8	8.7%
# freckles as a child:	None	26	28.3%
	Few	44	47.8%
	Many	21	22.8%
Color of non-sun-exposed skin:	Very fair	16	17.4%
	Fair	45	48.9%
	Olive	21	22.8%
	Light brown	7	7.6%
	Dark brown	3	3.3%
Natural hair color as a teenager:	Red	6	6.5%
	Blonde	24	26.1%
	Light brown	30	32.6%
	Dark brown	25	27.2%
	Black	7	7.6%

Note. "Race/Ethnicity" allowed for multiple answers, therefore, reported percentages will exceed 100. *N* = 92.

Table 2.
History of Skin Cancer, Numbers of Moles, and Visits to the Dermatologist

		n	%
Have you ever had skin cancer?	No	90	97.8%
	Basal cell carcinoma	1	1.1%
	Unknown type	1	1.1%
Has anyone in your immediate family had skin cancer?	Father	13	14.2%
	Mother	3	3.3%
	Brother	1	1.1%
	Sister	1	1.1%
# of times you have had a severe sunburn that blistered	Zero	28	30.4%
	1-2	42	45.7%
	3-5	12	13.0%
	6-10	7	7.6%
	More than 10	3	3.3%
Do you have 50 or more moles?	No	72	78.3%
	Yes	20	21.7%
# moles on body > 5mm	Zero	45	48.9%
	1-2	34	37.0%
	3-5	12	13.0%
# moles on right arm > 5mm	Zero	82	89.1%
	1-2	10	10.9%
Have you ever:	Been to a dermatologist?	58	63.0%
	Had a mole examined by a dermatologist?	28	30.4%
	Had a mole removed or checked for cancer?	24	26.1%
	Had a nurse check your skin for cancer?	18	19.6%

Note. *N* = 92.

Table 3.

Example of 2 x 2 Grid for Calculation of Sensitivity and Specificity

	Gold Standard - Atypical	Gold Standard - common
Coded Positive	TP	FP
Coded Negative	FN	TN

Table 4a.

Demographic Bivariate Correlation Matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
1.		.02	.00	.07	.07	.20	.20	-.18	-.11	.11	-.01	-.14	.05	.05	.09	.18	.05	.15	.11
2.			-.02	.08	.02	.16	.13	.06	-.11	.11	-.16	-.08	.09	.15	.03	-.03	.08	.04	.04
3.				.48*	.02	.21*	.04	-.11	-.09	-.09	-.13	-.10	-.06	-.21*	-.32*	-.02	-.05	-.02	-.12
4.					.37*	.38*	.05	-.06	.03	.08	.06	-.09	.09	-.19*	-.08	.02	.07	.12	.12
5.						.12	.17	-.13	-.06	.26*	.19*	-.06	.01	-.10	-.09	.08	.08	.12	.03
6.							.16	-.17	-.08	.17	-.06	.02	-.06	-.08	-.05	.01	.01	-.04	-.08
7.								.11	-.03	.34*	-.03	-.06	.17	.11	-.02	.11	-.02	.05	.09
8.									-.02	-.02	.12	.05	.31*	.11	.11	-.02	.05	-.02	.23*
9.										-.01	.05	-.03	-.05	.03	-.03	-.13	-.07	.17	.20*
10.											.19*	-.03	.19*	.03	-.03	.07	.15	.17	-.05
11.												.37*	.34*	.08	.14	.07	.48*	.42*	.28*
12.													.07	.06	.31*	.15	.30*	.12	-.03
13.														.01	.12	-.04	.23*	.31*	.19*
14.															.06	.03	-.02	-.09	.05
15.																.08	.16	-.06	.16
16.																	.40*	.21*	.13
17.																		.65*	.30*
18.																			.32*
19.																			

Note. Bivariate correlations among variables. Variable key is in Table 4b, on next page. N = 92.

*p < .05

Table 4b.

Variable Key for Table 4a

1. Training
2. Visual Condition
3. What is your gender?
4. What is your age?
5. What is the highest level of education you have completed?
6. What is your marital status?
7. Has any close blood relative (parent, brother, sister, or child) ever had skin cancer? - Father
8. Has any close blood relative (parent, brother, sister, or child) ever had skin cancer? - Mother
9. Has any close blood relative (parent, brother, sister, or child) ever had skin cancer? - Brother
10. Has any close blood relative (parent, brother, sister, or child) ever had skin cancer? - Sister
11. How many moles do you have on your body that are larger than a pencil eraser (5 mm)?
12. How many moles do you have on your right arm that are larger than a pencil eraser?
13. Do you have 50 or more moles on your body?
14. How many freckles did you have as a child?
15. How often do you use a tanning bed?
16. Have you ever been to a dermatologist?
17. Have you ever been to a dermatologist to have a mole examined?
18. Have you ever had a mole removed and checked for cancer?
19. Have you ever had a health care worker (e.g., a nurse) check your skin for cancer?

Note. *N* = 92.

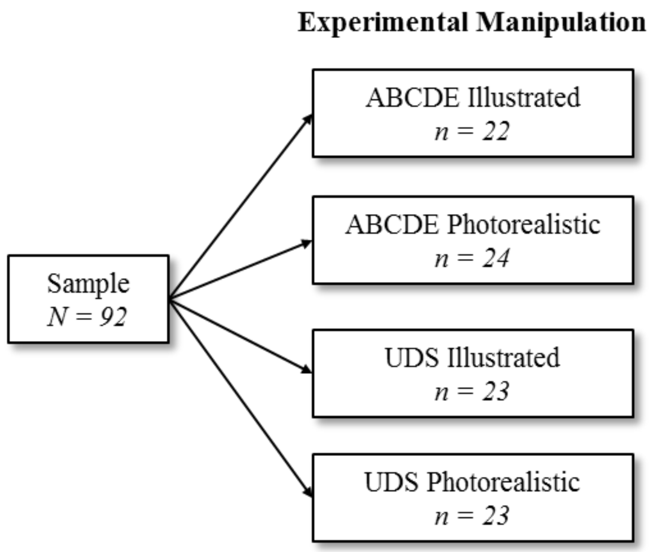


Figure 3. Study Design

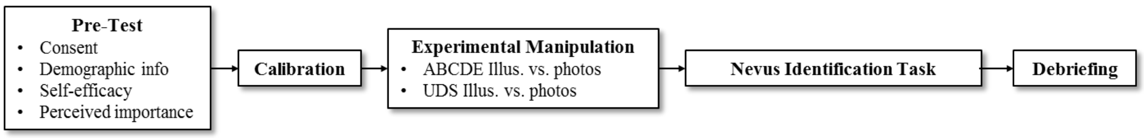


Figure 4. Study Procedure

CHAPTER FOUR

RESULTS

The primary objective of the current study was to determine which combination of training methods and visual features yielded the greatest gains in subject sensitivity and specificity when identifying atypical nevi. Eye-tracking measures were employed as mediators to more closely scrutinize training effectiveness, and, as part of the larger model, self-efficacy and perceived importance were examined as potential moderating factors.

Bivariate Correlation Matrix: Eye-Tracking Measures

A bivariate correlation matrix was created to examine relationships between predictors, outcomes, and all eye-tracking variables. As can be seen in Table 5, strong correlations were common among the eye-tracking variables. This is expected as these variables, in many cases, measure very similar things (e.g., total time looking at a particular image, and the total time fixating on that image) and/or represent combined measures merging one or more instruments (e.g., Fixation Count / Total Time in Zone). The relationships of interest in this matrix were the significant correlations between the eye-tracking metrics and the predictors and outcomes.

RQ1 asked whether training (coded: UDS = 0, ABCDE = 1) or visual condition (coded: Illustrated = 1, Photorealistic = 2) were significantly related to changes in visual processing efficiency. Training was positively related to Total Time Shown ($r = .27$), Total Fixation Duration ($r = .29$), Average Fixation Duration ($r = .44$), Total Time in Lookzone ($r = .25$), and Total Fixation Duration in the Lookzone ($r = .26$), indicating that subjects trained in the ABCDE method tended to look at the images longer before coming to a decision, spend more time fixating on the images and the atypical nevi, and exhibited longer individual fixation times than their peers trained in UDS. Conversely, the measures for overall Fixation Count / Total Time Shown ($r = -.41$) and Fixation Count / Total Time in the Lookzone ($r = -.31$) were inversely correlated with training, indicating that training in UDS resulted in higher values for these measures. Higher values, in this case, means less efficiency; therefore, training in UDS resulted in subjects exhibiting more fixations than their ABCDE-trained counterparts, in relation to the amount of time they spent scanning.

In regard to visual condition, a single eye-tracking variable correlated positively: Number of Fixations Before First Arrival in the Lookzone ($r = .22$). This indicates that subjects trained in the ABCDE method exhibited a greater number of fixations looking at the images before locating the atypical nevi, when compared to their counterparts trained in UDS.

RQ2a and RQ2b asked whether changes in processing efficiency are related to sensitivity and specificity, respectively. At this point, the answer to RQ2a appears to be no, as there were no eye-tracking variables that significantly correlated with sensitivity. For specificity, however, there are a number of significant relationships to discuss, lending an affirmative to RQ2b. Specifically, the eye-tracking variables of Total Time Shown (r = -.32), Total Fixation Duration (r = -.31), Number of Fixations (r = -.31), and Number of Fixations Before First Arrival in the Lookzone (r = -.20) each inversely correlated with specificity. One of the primary arguments of VSAT is that training begets processing efficiency, and processing efficiency begets greater accuracy. These correlations provide early indicators for the link between processing efficiency and accuracy. Two other eye-tracking variables—Percent of Time Spent in the Lookzone (r = .25) and Percent of Total Fixations in the Lookzone (r = .26)—correlated positively with specificity, providing further support for the processing efficiency argument (because they serve as indicators that a greater portion of these subjects' viewing time and fixations were spent looking at the atypical nevi).

Relationship between Training Condition, Visual Condition, and Accuracy

To examine the relative impact of training and visual condition on accuracy, both sensitivity and specificity were included as outcomes in a pair of two-way ANOVAs.

Sensitivity. A two-way ANOVA with Bonferroni corrections was conducted, with sensitivity as the outcome, and training and visual condition as fixed factors. Results indicated a significant main effect for visual condition, $F(1,88) = 7.102$, $p = .009$, wherein illustrations ($M = .524$, $SD = .197$) resulted in greater sensitivity than photos ($M = .425$, $SD = .159$, $d = .55$). The main effect for training, $F(1,88) = .538$, $p = .465$, and the training × visual condition interaction, $F(1,88) = 1.128$, $p = .291$, were not significant (see Table 6).

Specificity. A two-way ANOVA with Bonferroni corrections was again conducted, with specificity as the outcome, and training and visual condition as fixed factors. The main effect for training was not significant, $F(1,88) = 2.120$, $p = .149$; however, results indicated a significant main effect for visual condition, $F(1,88) = 4.079$, $p = .046$, wherein photos ($M = .821$, $SD = .108$) resulted in greater specificity than illustrations ($M = .770$, $SD = .137$, $d = .41$) (see Table 7). In addition, the interaction for training × visual condition, $F(1,88) = 3.554$, $p = .063$, was significant within a 90% confidence interval, such that those within the UDS Photo condition displayed greater specificity than all other combinations of training and visual condition (see Table 8).

RQ3a and RQ3b asked whether training condition yielded any significant benefits for sensitivity and specificity, respectively. In both cases, the answer was no, as training in either ABCDE or UDS failed to provide a direct accuracy benefit over the other method. RQ4a and RQ4b asked the same question for visual condition. For sensitivity, the illustration condition yielded a significant, direct increase in accuracy over the photo condition. Therefore, the answer to RQ4a is yes, as it appears that illustrated training examples hold the greatest potential to increase sensitivity, regardless of training method.

For specificity, the photo condition exhibited a significant, direct accuracy benefit over the illustration condition—providing a yes for RQ4b, and creating an interesting juxtaposition between illustrated visuals and the benefits they provide for sensitivity, and the similar relationship between photorealistic visuals and specificity. Of arguably greater interest, however, is the interaction that manifested between training × visual condition, in the form of vastly superior accuracy for the UDS/photo condition. The interaction proved to have a stronger impact on specificity than any of the observed direct effects (thus providing a yes answer for RQ5b), and it is explored in-depth in the next section. The answer to RQ5a was no, due to a nonsignificant interaction for sensitivity.

Moderated Mediation Models

To gain further understanding of the potential mediating role of eye-tracking measures in VSAT, and to confirm the role of self-efficacy and perceived importance as potential moderators, a conditional process modeling program called PROCESS was used (Hayes, 2008, 2012). Specifically, PROCESS Model 10 (moderated mediation) was employed for the following analyses (Hayes, 2013), and all indirect effects were subjected to follow-up bootstrap analyses with 1000 bootstrap samples and 95% bias-corrected confidence intervals. Visual processing variables were included in these models based on observed results from the bivariate correlations mentioned earlier.

Moderated mediation and sensitivity. A moderated mediation model was run using PROCESS, which included visual condition as the predictor, Percentage of Total Fixations Before First Arrival in the Lookzone as a mediator, self-efficacy and perceived importance as moderators, and sensitivity as the outcome. The model was not significant, $r = .31$, $R^2 = .09$, $F(6,85) = 1.45$, $p =.21$, and self-efficacy, $r = -.02$, $SE = .05$, $t = -.35$, $p = .73$, and perceived importance, $r = .02$, $SE = .07$, $t = .32$, $p = .75$, failed to moderate. No other factors provided significant mediation (see Table 9).

Moderated mediation and specificity. A moderated mediation model was again run using PROCESS, which included training as the predictor; with Total Fixation Duration, Number of Fixations, Fixation Count / Total Time Shown, and Percent of Time

Spent in Lookzone as mediators; self-efficacy, perceived importance, and visual condition as moderators; and specificity as the outcome. In this case, the model was significant, r = .59, R^2 = .34, F(9,82) = 4.7783, p =.001, with Percent of Time in Lookzone serving as a significant mediator, and both self-efficacy and visual condition significantly moderating the mediation (see Figure 5). No other eye-tracking variables mediated the relationship (see Table 10), and perceived importance failed to moderate, r = -.01, SE = .06, t = -.11, p = .91.

In order to fully understand the model, and what is driving the advantage observed for UDS/photo, it is necessary to review the conditional direct and indirect effects contained in Table 11. To summarize these data, for those in the photo condition with very high self-efficacy, UDS increased specificity directly. For those in the photo condition with self-efficacy levels at the mean or lower, there was a conditional indirect effect through Percent of Time in Lookzone—which is to say that these individuals spent a larger amount of their viewing time on target (observing the atypical nevi)—and time on target is positively related to specificity. This indirect path is what ultimately made the UDS/photo condition so beneficial for them, because it increased Percent of Time in Lookzone, and that led them to a more accurate conclusion.

Thus we can conclude that the answers to RQ6a, RQ7a, RQ8a, and RQ9a are no, due to a lack of significant moderated mediation with sensitivity. For specificity, self-efficacy was a significant moderator for the model, so the answers to RQ6b and RQ7b are yes. The answers to RQ8b and RQ9b are no, however, due to perceived importance's failure to moderate within the model. Finally, the answer to RQ10 is yes, thanks to the significant moderated mediation model for specificity, and the interplay between self-efficacy, Percent of Time in Lookzone, and the explained criteria for the conditional direct and indirect paths.

Table 5a.

Bivariate Correlation Matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
1.		-.34*	.07	-.27*	.09	.09	.11	.02	.02	.05	-.07	-.01	.12	-.14	-.18	.08	.15	.14	.12	.01
2.			-.15	.20	-.32*	-.31*	-.31*	.14	-.14	-.04	-.20*	-.18	-.11	.05	.04	.49*	-.15	.39*	-.12	-.06
3.				.02	.27*	.29*	.11	-.41*	.44*	-.04	.04	.08	.25*	-.14	-.09	-.06	.10	-.02	.26*	-.31*
4.					-.07	-.08	-.06	-.05	-.01	.01	.22*	.09	-.08	.18	.20	-.10	-.09	-.16	-.08	-.05
5.						.99*	.89*	-.46*	.43*	.73*	.07	.23*	.91*	-.32*	-.37*	-.25*	.80*	-.16	.90*	-.31*
6.							.84*	-.50*	.51*	.67*	.07	.17	.91*	-.35*	-.36*	-.22*	.76*	-.15	.91*	-.36*
7.								-.09	.04	.84*	.10	.20*	.78*	-.32*	-.41*	-.25*	.88*	-.18	.75*	.02
8.									-.92*	-.02	-.03	-.23*	-.44*	.07	.01	.13	-.08	.07	-.47*	.79*
9.										-.07	.05	.09	.43*	-.16	-.02	-.09	.02	-.08	.46*	-.78*
10.											-.04	.14	.72*	-.36*	-.49*	-.07	.86*	.04	.69*	.06
11.												.52*	-.03	.48*	.61*	-.29*	-.03	-.36*	-.03	-.03
12.													.09	.66*	.44*	-.36*	.10	-.24*	.08	-.11
13.														-.44*	-.45*	.11	.85*	.13	1.0*	-.42*
14.															.89*	-.23*	-.43*	-.22*	-.44*	.07
15.																-.14	-.52*	-.24*	-.44*	-.08
16.																	.04	.82*	.12	-.21*
17.																		.21*	.83*	.03
18.																			.14	.02
19.																				-.45*
20.																				

Note. Bivariate correlations among variables. Variable key is in Table 5b, on next page. $N = 92$.

*$p < .05$

Table 5b.
Variable Key for Table 5a

1. Sensitivity
2. Specificity
3. Training
4. Visual Condition
5. Total Time Shown
6. Total Fixation Duration
7. Number of Fixations
8. Fixation Count / Total Time Shown
9. Average Fixation Duration
10. Lookzone: Number of Times Observed
11. Lookzone: Number of Fixations Before First Arrival
12. Lookzone: Duration Before First Fixation Arrival
13. Lookzone: Total Time in Zone
14. Lookzone: Percentage of Total Slide Time Before First Arrival
15. Lookzone: Percentage of Total Fixations Before First Arrival
16. Lookzone: Percent of Time Spent in Zone
17. Lookzone: Fixation Count
18. Lookzone: Percentage of Total Fixations
19. Lookzone: Total Fixation Duration
20. Lookzone: Fixation Count / Total Time in Zone

Note. *N* = 92.

Table 6.
Two-Way ANOVA – Main Effects for Sensitivity

		n	*M*	*SE*
Training	UDS	46	.461	.026
	ABCDE	46	.488	.026
Visual Condition	Illustrated	45	.524	.027
	Photo	47	.425	.026

Note. *N* = 92.

Table 7.
Two-Way ANOVA – Main Effects for Specificity

		n	*M*	*SE*
Training	UDS	46	.814	.018
	ABCDE	46	.777	.018
Visual Condition	Illustrated	45	.770	.018
	Photo	47	.821	.018

Note. *N* = 92.

Table 8.
Two-Way ANOVA – Training × Visual Condition for Specificity

		M	*SE*	*LBCI*	*UBCI*
UDS	Illustrated	.764	.025	.714	.814
	Photo	.863	.025	.813	.913
ABCDE	Illustrated	.775	.026	.724	.826
	Photo	.779	.025	.730	.828

Note. $N = 92$.

Table 9.
Tests of Mediation – Sensitivity

	Effect	*Boot SE*	*Boot LLCI*	*Boot ULCI*
TOTAL	-.017	.020	-.0579	.0182
Total Time Shown	-.001	.096	-.1899	.2478
Total Fixation Duration	.022	.088	-.0591	.3743
Number of Fixations	-.014	.031	-.1089	.0266
Average Fixation Duration	-.001	.027	-.0605	.0482
Fixation Count / Total Time Shown	-.007	.020	-.0625	.0147
LZ Number of Times Zone Observed	-.001	.014	-.0444	.0205
LZ Number of Fixations Before First Arrival	-.011	.014	-.0487	.0094
LZ Duration before First Fixation Arrival	.004	.011	-.0080	.0451
LZ Total Time in Zone	-.009	.017	-.0831	.0105
LZ Percentage of Total Fixations Before First Arrival	-.021	.024	-.1046	.0103
LZ Percentage of Total Slide time Before First Arrival	.014	.020	-.0121	.0748
LZ Percent of Time Spent in Zone	-.001	.011	-.0245	.0236
LZ Fixation Count	-.004	.013	-.0454	.0118
LZ Percentage of Total Fixations	-.002	.014	-.0424	.0186
LZ Total Fixation Duration	.004	.014	-.0115	.0523
LZ Fixation Count / Total Time in Zone	.001	.008	-.0076	.0268

Note. N = 92.

Table 10.
Tests of Mediation – Specificity

	Effect	*Boot SE*	*Boot LLCI*	*Boot ULCI*
Total Time Shown	.056	.143	-.1029	.6074
Total Fixation Duration	-.023	.113	-.4632	.1021
Number of Fixations	.032	.050	-.0187	.2095
Average Fixation Duration	.003	.029	-.0331	.0843
Fixation Count / Total Time Shown	-.005	.021	-.0881	.0188
LZ Number of Times Zone Observed	-.019	.042	-.1513	.0375
LZ Number of Fixations Before First Arrival	.002	.009	-.0065	.0378
LZ Duration before First Fixation Arrival	-.001	.010	-.0265	.0193
LZ Total Time in Zone	-.031	.034	-.1586	.0076
LZ Percentage of Total Fixations Before First Arrival	.001	.019	-.0347	.0456
LZ Percentage of Total Slide Time Before First Arrival	.001	.018	-.0297	.0465
LZ Fixation Count	.010	.026	-.0214	.0799
LZ Percentage of Total Fixations	-.005	.017	-.0595	.0165
LZ Total Fixation Duration	.005	.030	-.0306	.0962
LZ Fixation Count / Total Time in Zone	.001	.013	-.0162	.0478

Note. $N = 92$.

Table 11.

Conditional Direct and Indirect Effects

		Self-Efficacy	*Effect*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Conditional Direct Effect(s)	Illust.	1.600	.0632	.0476	1.3278	.1879	-.0315	.1578
		2.400	.0323	.0358	.9018	.3698	-.0389	.1035
		3.000	.0091	.0343	.2659	.7909	-.0592	.0775
		3.600	-.0140	.0402	-.3486	.7283	-.0941	.0660
		3.800	-.0217	.0434	-.5008	.6178	-.1081	.0646
	Photo	1.600	.0053	.0543	.0977	.9224	-.1028	.1134
		2.400	-.0256	.0394	-.6490	.5181	-.1040	.0528
		3.000	-.0487	.0337	-1.4460	.1520	-.1158	.0183
		3.600	-.0719*	.0355	-2.0241	.0462	-.1426	-.0012
		3.800	-.0796*	.0377	-2.1097	.0379	-.1547	-.0045

	Mediator		*Self-Efficacy*	*Effect*	*Boot SE*	*BootLLCI*	*BootULCI*
Conditional Indirect Effect(s)	% time in lookzone	Illust.	1.600	-.0115	.0213	-.0568	.0291
			2.400	.0049	.0175	-.0256	.0471
			3.000	.0172	.0186	-.0110	.0660
			3.600	.0295	.0226	-.0072	.0827
			3.800	.0336	.0244	-.0054	.0924
	% time in lookzone	Photo	1.600	-.0545*	.0266	-.1225	-.0137
			2.400	-.0381*	.0191	-.0878	-.0098
			3.000	-.0258*	.0161	-.0721	-.0029
			3.600	-.0135	.0169	-.0577	.0134
			3.800	-.0094	.0179	-.0547	.0208

Note. Negative coefficients indicate a preference toward UDS, while higher coefficients indicate a preference toward ABCDE. $N = 92$. $^*p < .05$

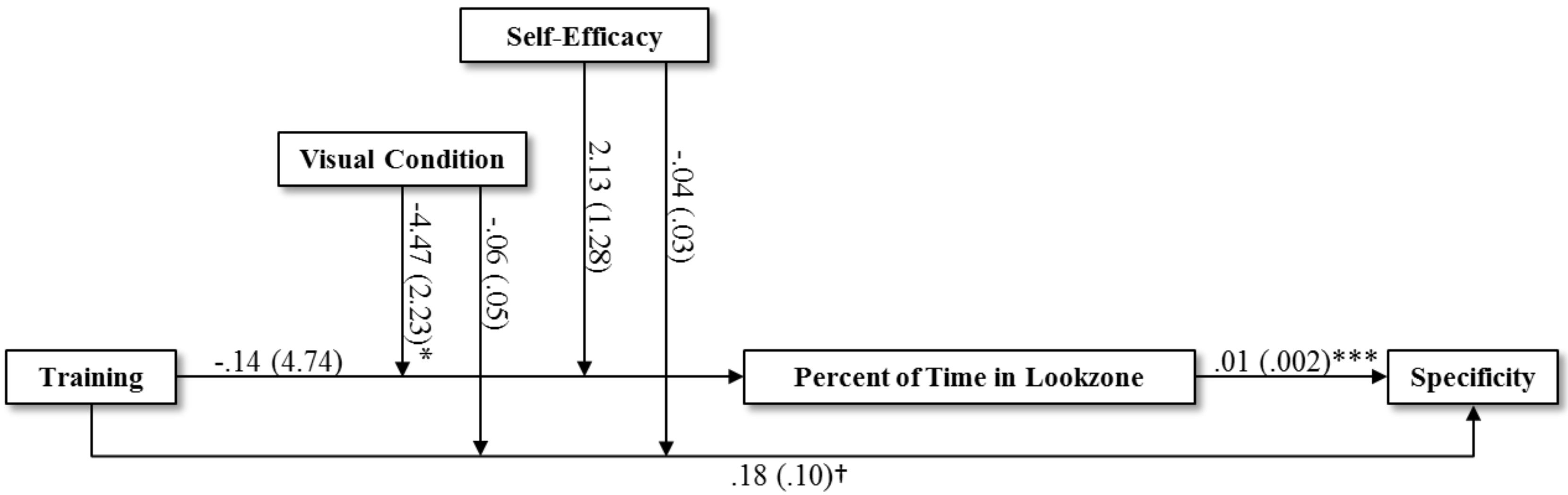


Figure 5. Moderated Mediation Analysis – Specificity
N = 92, †p < .10, **p* < .05, ****p* < .001

CHAPTER FIVE

DISCUSSION

Skin self-examination techniques, especially in the hands of laypersons, are ineffective at engendering accuracy to detect atypical nevi. Regardless of the method used for instruction, prior studies have failed to show a significant, tangible benefit for individuals trained in SSE (Buettner & Garbe, 2000; Carli et al., 2002; Goodson & Grossman, 2009; Hamidi et al., 2010). Many research studies focusing on SSE measure the diagnostic accuracy of laypersons, and then use those scores to discuss improvements for the practice. Through the use of eye-tracking technology and moderated mediation models, the current study sought to add to this body of literature—examining the visual and psychological mechanisms employed during a series of mole search tasks given to trained laypersons. Additionally, VSAT was proposed, and evidence of a significant moderated mediation path was discovered. A review of this study's contributions to the literature follows, as well as a discussion of ramifications and opportunities for future research.

Sensitivity and the Benefit of Illustrated Training Examples

The current study found very different stories when comparing the impact of training on both sensitivity and specificity. For sensitivity, a main effect was discovered in support of illustrated training materials, such that those who received instruction with illustrated visuals manifested significantly higher sensitivity scores, regardless of whether their training was in ABCDE or UDS. These findings are consistent with earlier research on illustrations vs. photos in training materials, which showed a knowledge acquisition advantage for illustrations, counter to the general perception that realistic visuals are better in this regard (Moll, 1986; Readance & Moore, 1981). Before moving forward with this finding, however, there are three challenges that need to be considered. First, the literature on illustrations vs. visuals for knowledge acquisition has remained largely stagnant since the late 1980s (with few exceptions, see Hegarty, 2011; Smallman & John, 2005), so while the current findings do lend support to the claims made in the existing literature, this body of research is in need of an update before broader claims of the utility of illustrations can be made. Second, research comparing ABCDE to UDS within the same design is scarce (see Tsao et al., 2015, p. 721), especially when looking at layperson populations, so it is unclear whether ABCDE or UDS should have emerged superior when comparing the two methods. King et al. (2014) examined the capability of both ABCDE and UDS to increase layperson accuracy, while simultaneously exploring the impact of visual dose. They found that sensitivity and specificity between ABCDE and UDS were generally comparable, but there was a slight sensitivity advantage for ABCDE instruction paired with a moderate visual dose (King et al., 2014). Further research is needed, however, to better understand what advantage is inherent in SSE training, the visual style, or the visual dose, as they pertain to sensitivity. Third, the current study found no significant interactions to support increases in sensitivity, which means that there are limited options available within the current design to help unpack this finding.

Researchers looking to explore this finding could focus on determining what specific training features show potential for increasing sensitivity, and test these within a design featuring both the ABCDE method and UDS.

Specificity and the Benefit of Photographic Training Examples

For specificity, the story is more complicated. In contrast to the findings for sensitivity, photorealistic visuals provided main effect in this case. Specifically, individuals trained with materials featuring photographs of moles achieved significantly higher specificity scores than their peers who had illustrated training examples, regardless of whether they were trained in ABCDE or UDS. This finding counters the research mentioned earlier in support of illustrations (Moll, 1986; Readance & Moore, 1981), and adds more data to the case that this line of research may stand in need of an update.

Specificity deals with the capability of individuals to tell that a common nevus is truly common, and it could be the case that photographs are better suited to showing an individual how a common mole looks, while illustrations are better suited to helping individuals identify the key features of an atypical mole. Girardi and colleagues (2006) may agree with at least the first half of this conclusion, as they explored the viability of photographs as an educational technique counter to the ABCD method, and found that, while photographs did not increase sensitivity when implemented into training, they did provide a “strong” increase in specificity (p. 2278). The authors’ reasoning behind this finding is that “a quick look at a few photographs is sufficient to improve the ability of [laypersons] to recognize a melanoma just by optimizing their spontaneous image recognition capacities” (Girardi et al., 2006, p. 2266). This appears to be a misnomer, however, because if training with photographs improved the ability of laypersons to identify atypical nevi, then a significant path between photo training and sensitivity should have manifested in the current study, but it did not. Instead, illustrations benefited sensitivity the most, and photographs benefitted specificity via both a significant main effect and interaction. This is an important distinction, because it appears that the greatest benefit of using photographs in training is not the potential to tell that an atypical nevus is atypical, but to tell that a common nevus is common, whereas sensitivity (and the ability to identify atypical nevi) benefits the most from illustrated examples.

Specificity, the Training × Visual Condition Interaction, and Self-Efficacy

The specificity finding becomes even more compelling when the interaction is examined within the current study's moderated mediation model. For individuals with higher levels of self-efficacy, training in the UDS/photo condition resulted in significant, direct gains for specificity. For those with lower levels of self-efficacy, training in the UDS/photo condition caused these individuals to spend a greater percent of their time focused on the atypical nevi, before arriving at a decision (and exhibiting higher specificity than any other combination of training methods). In either case, the UDS/photo interaction resulted in greater specificity, but self-efficacy moderates the path, and ultimately determines whether subjects exhibit the mediation from "time on target" or not.

The discriminating nature of self-efficacy within the model is not altogether surprising. There is a wealth of research available that examines the positive impact that higher levels of self-efficacy can have on task performance (Bandura, 1986, 1997, 2004; Berry & West, 1993; Bouffard-Bouchard, 1990; Glasgow, 2012; Lachman & Jelalian, 1984; Themanson et al., 2011), and the significant direct path to greater specificity is a testament to the greater ability of these higher-self-efficacy subjects—even if the mechanism is not clear in the current model. For those with lower levels of self-efficacy, however, the mechanism *is* clear, and eye-tracking fixation data are at the heart of it. Fixations are a measure of cognitive effort (see Goldberg & Kotval, 1999; Jacob & Karn, 2003; Just & Carpenter, 1976), and, by accounting for the location of fixations, inferences can be made about how individuals cognitively process the images they see. UDS/photo individuals with lower levels of self-efficacy spent a greater percent of their time, on average, fixating on the atypical nevi before arriving at a decision. This may represent greater adherence to the training principles before coming to a decision. It may also represent a quantifiable sign of lower self-efficacy, as lower confidence may introduce lag time into each decision a subject makes—or cause them to delay before making their choice known to the researcher. In either case, lower-self-efficacy levels bring subjects through a mediation path that is observable through eye-tracking, and this provides an early indicator of the model's potential to detect processing efficiency.

While only a single eye-tracking variable mediated the model in the current study, that does not mean that there are not more relationships to discover. There are a number of different correlations between the predictor, eye-tracking, and outcome variables that may not fit within the current model, but are nonetheless there (see Table 5). These correlations serve as indicators that the method and visual nature of SSE training can significantly impact eye-tracking measures of visual processing efficiency, even if the mechanisms driving these relationships are currently unknown. Additional research is needed to unpack these correlations, and to determine what ramifications, if any, they have for future SSE training practices.

It is too early in this line of research to claim that indicators of processing efficiency (in the form of lower fixation durations and totals) do not significantly mediate the model. The current study represents a first pass in this domain, utilizing a smaller sample of laypersons. Significant inverse relationships between skill acquisition and fixation duration/totals are supported in the literature (see Dreiseitl et al., 2012; Krupinski et al., 2014), but these occur within samples of experts. It is conceivable that differences in processing efficiency for trained laypersons may be very small compared to other groups (especially experts), and thus would require a larger sample to detect. Because laypersons are a drastically understudied population in respect to SSE accuracy, there is a significant amount of ground to be covered in establishing guidelines and standard practices. At this juncture, the significant moderated mediation model serves as one piece of a larger foundation, and there is much work to be done in this area.

Early Support for VSAT

The presence of a significant moderated mediation path from training to specificity provides early support for VSAT as a viable model of visual skill acquisition. In application to SSE, VSAT presented an opportunity to explore both the visual and psychological mechanisms that mediate and moderate the direct relationship between training and skill. It is not anticipated that VSAT will only apply within the context of

SSE, however, as the model holds potential application in any context wherein individuals are challenged to develop a visual skill and to exercise it.

As an example of VSAT's application versatility, in the driver's education example that was mentioned in Chapter Two, the basic premise of training leading to skill acquisition, with processing efficiency as a mediator, still holds. When driving a vehicle, a driver must develop the capability to apply not only what was taught during the driver's education course, but also to draw upon experiences gained afterward. The amount of training and experience a driver possesses has a direct impact on their driving skill. Additionally, the consistent exercise of skills learned in training, and the storing and pruning of relevant data from new experiences, allows future decisions to be made more quickly when driving. It is reasonable to assume that a driver with 20 years of experience would have more skill than a teenager fresh out of a driver's education course—or even a young adult that has been driving for 10 years—and would be able to visually recognize a safe vs. dangerous scenario more quickly (through efficiently pruned cognitive processes, and consequently optimized visual ones). VSAT allows for visual skill acquisition during driving to be tested, much like SSE skill acquisition was tested in the current study. Other applications, across other disciplines relying upon visual skill, are not out of the question.

Next steps for VSAT. As work continues on expanding VSAT, there are parts of the model that require experimentation and expansion. One of these areas is within the knowledge acquisition portion of the model. In the current study, training was the sole measure of knowledge acquisition, although knowledge can be gained from both structured training and through experience. Training and experience, while connected, are separate constructs, and arguments could be made to the benefit or derogation of either in different contexts. The VSAT model acknowledges this relationship as separate constructs, but what was missing was a method of assessing the impact of both training and experience effectively. A budding line of research, dubbed rapid exposure theory (RapX; John, Jensen, & Coe, 2015), offers one method of quantifying the impact of experience.

RapX and the future of VSAT. A primary advantage that experts hold over novices is the sheer number of exposures that they have encountered. These exposures help to develop the higher-level neurological processes necessary for optimized cognition, and provide the foundation for experience—a key discriminator between experts and novices (Ahissar & Hochstein, 2004; Dreiseitl et al., 2012; Krupinski et al., 2014). Lombardo and Eichinger (1996) proposed the “70/20/10 model of learning”—stating that 70% of learning results from direct experience, 20% from external feedback and direction, and 10% from study and formal learning. Given that a significant portion of learning relies upon experience, one could suggest that optimizing the acquisition of experience would significantly impact learning outcomes.

RapX proposes that rapid, massive exposure to task-relevant stimuli could approximate the benefits of naturally occurring experience, and allow the timetable of skill acquisition to be reduced. Time has been necessarily linked to experience acquisition (Ericsson, 2014), and RapX does not seek to refute this claim. Instead, RapX questions whether the timetable of traditional experience acquisition could be condensed by presenting the types of imagery that would normally be encountered over time, and presenting it within a much shorter timeframe. For example, if a dermatologist views 1,000 lesions over the course of a month, and reaps the expanded experience of those exposures, could a comparable benefit be gained by instead showing those 1,000 lesions in rapid sequence within a single viewing session? RapX believes that it could.

RapX approaches the presentation of multiple stimuli in a different manner than rapid serial visual presentation (RSVP), a technique that utilizes rapid image projection to test the limits of human visual attention and recall (Intraub, 1981; Potter, 1975, 1976; Potter, Staub, Rado, & O'Connor, 2002; Potter, Wyble, Hagmann, & McCourt, 2014). In RSVP, a typical experiment would task subjects with locating one item amongst many shown in rapid succession, in order to determine if the subject was able to correctly identify a desired element (Potter et al., 2014). This may be performed with or without initial prompting, but research has shown that providing subjects with prior information about an intended target improves detection (Çukur, Nishimoto, Huth, & Gallant, 2013; Evans, Horowitz, & Wolfe, 2011; Peelen & Kastner, 2011). In RapX, on the other hand, subjects are not expected to locate a particular image among many, but are instead expected to extract relevant information from each image they view. The goal is not to test the limits of subject visual attention, but to provide an accelerated proxy for real world experience, and to help subjects build familiarity with visual elements relative to the simulated task.

Typically, messages designed to train laypersons in nevus identification techniques (e.g., pamphlets, websites, etc.) rely on only a single example for each principle (King, 2014). However, while high-quality individual examples can contribute to learning, multiple exposures to stimuli are necessary to feed the weighting and pruning processes requisite for expertise (Ahissar & Hochstein, 2004). A few exposures, regardless of quality, rarely encapsulate every facet of a particular task, or every scenario that may be encountered during real-world practice. A key advantage for exposure to multiple stimuli, then, is that a greater range of possible scenarios are made salient for the trainee, thus expanding his or her range of knowledge on the subject.

Despite its centrality to the study of learning, experience has not been fully theorized in the literature, and RapX represents an initial step in determining the impact that rapid exposure to a variety of cases can have on skill acquisition among laypersons. Its inclusion in VSAT moving forward will allow for a more thorough examination of how training and experience influence not only skill, but also the mediating factor of processing efficiency.

Limitations and Future Research Directions

The current study serves as a complement to early dermatology research using eye-tracking technology to quantify visual processing of atypical nevi. While this study attempted to provide a robust design, it is not without limitations. First, the sample size of the current design, while being significantly larger than what is presently available in the literature, is still only large enough to detect medium to large size effects. Therefore, it is possible that significant differences may indeed exist between training conditions that were undetectable with the currently available power. Second, the sample was heavily skewed toward White, college-age individuals, which is not representative of the general population that is expected to perform SSE. Therefore, the current design is acceptable for identifying mechanisms, but inadequate for generalization at this point. Third, in the current design, knowledge acquisition was only tested via training, while VSAT proposes that knowledge acquisition comes through a synthesis of training and experience.

Subjects were asked general questions about familiarity and family history of skin cancer, but no measures were included in the analyses to either weight or remove those cases. Finally, the current study only used one type of nevus search task. Research has shown that search accuracy can be significantly impacted by the presentation style of the task (e.g., subjects are typically more accurate when nevi are shown full-screen, rather than in smaller photos) (Robinson & Turrisi, 2006). Therefore, the results of the current study may be higher or lower than those that would be observed in a sample that was presented with a wide variety of search tasks, featuring variations in nevi size.

Future studies could consider exploring other potential factors that could mediate or moderate the link between training and sensitivity or specificity—specifically the other significant relationships identified in the bivariate correlation matrix (Table 5). Additionally, future applications of VSAT should approach training and experience as separate dimensions of knowledge acquisition, to determine if different levels of either can impact accuracy outcomes separately, or through an interaction effect. This can be accomplished through the inclusion of RapX in the model, or some other method of measuring or bestowing experience within the sample. Future researchers could also examine the visual patterns of dermatologists and other experts using a similar methodology, to lend support to the claim that processing efficiency increases with expertise (in the form of reduced fixations). Finally, future studies should consider implementing several image presentation types within their designs, so that subject accuracy can be compared between variations in nevi portrayal (e.g., full backs, arms, isolated photos, full screen images, etc.).

Conclusion

SSE, in its current form, is an ineffective practice. In a variety of contexts, and drawing upon a variety of training methodologies, researchers have shown that SSE fails to provide a consistent accuracy benefit for laypersons. The current study sought to scrutinize SSE—using eye-tracking technology to search for evidence of gains in processing efficiency, which should naturally follow the development of proficiency in a visual search task like SSE. Preliminary evidence suggests that photorealistic training methods offer significant gains in SSE sensitivity, while illustrated training methods offer similar gains in SSE specificity. Additionally, the UDS/Photo training combination was especially effective at increasing specificity, with self-efficacy determining the nature of that relationship. Overall, a case was made for VSAT as a model of visual skill acquisition that can begin to explain the transition from novice toward expertise in SSE.

The discipline of dermatology stands to benefit from broader use of eye-tracking technology to quantify the visual search patterns of any individuals expected to differentiate between common and atypical lesions—whether they be physicians in a clinical setting, med students in a lab, or laypersons performing SSE at home. The latter group, in particular, has not been studied in previous dermatology research using eye-tracking technology, so a large number of questions still remain, even in consideration of the current study. These questions will be addressed in time, but foundational work, like the current study, is necessary to focus the discussion, and to provide a starting point for future claims to build upon.

APPENDIX A

SCALES

Witte et al. (1996) Adapted Self-Efficacy Measure
Items were answered on a 1-5 Likert scale, anchored with *strongly disagree* (1) and *strongly agree* (5), respectively.

1. I am able to perform a skin self-exam.
2. Checking my skin for cancer is easy for me.
3. It is not difficult to check my skin for cancerous moles.
4. I can do skin self-exams.
5. I could tell the difference between skin cancer and other types of ordinary skin growth.

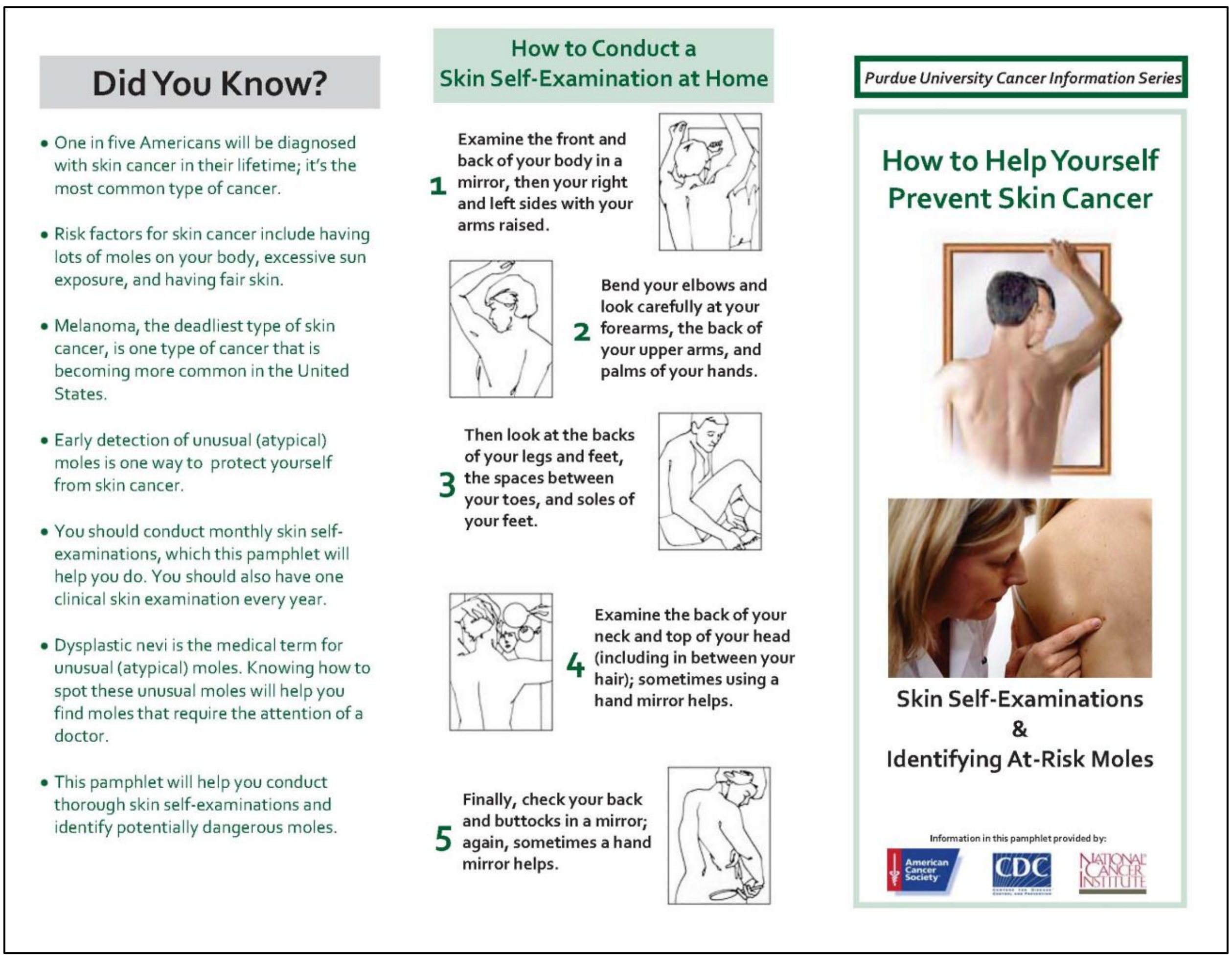
Robinson, Turrisi, and Stapleton (2007a) Perceived Importance Measure
Items were answered on a 1-5 Likert scale, anchored with *strongly disagree* (1) and *strongly agree* (5), respectively.

1. It is very important for me to know the difference between a melanoma and other types of moles
2. It is very important that I carefully check the skin of my FACE every month
3. It is very important that I carefully check the skin of my BODY every month
4. Knowing how to avoid skin cancer/melanoma is important to me
5. I think it is important to perform skin self-examinations regularly

APPENDIX B

TRAINING MATERIALS

Front Page (Identical for all Conditions)



Did You Know?

- One in five Americans will be diagnosed with skin cancer in their lifetime; it's the most common type of cancer.
- Risk factors for skin cancer include having lots of moles on your body, excessive sun exposure, and having fair skin.
- Melanoma, the deadliest type of skin cancer, is one type of cancer that is becoming more common in the United States.
- Early detection of unusual (atypical) moles is one way to protect yourself from skin cancer.
- You should conduct monthly skin self-examinations, which this pamphlet will help you do. You should also have one clinical skin examination every year.
- Dysplastic nevi is the medical term for unusual (atypical) moles. Knowing how to spot these unusual moles will help you find moles that require the attention of a doctor.
- This pamphlet will help you conduct thorough skin self-examinations and identify potentially dangerous moles.

How to Conduct a Skin Self-Examination at Home

1 Examine the front and back of your body in a mirror, then your right and left sides with your arms raised.

2 Bend your elbows and look carefully at your forearms, the back of your upper arms, and palms of your hands.

3 Then look at the backs of your legs and feet, the spaces between your toes, and soles of your feet.

4 Examine the back of your neck and top of your head (including in between your hair); sometimes using a hand mirror helps.

5 Finally, check your back and buttocks in a mirror; again, sometimes a hand mirror helps.

Purdue University Cancer Information Series

How to Help Yourself Prevent Skin Cancer

Skin Self-Examinations

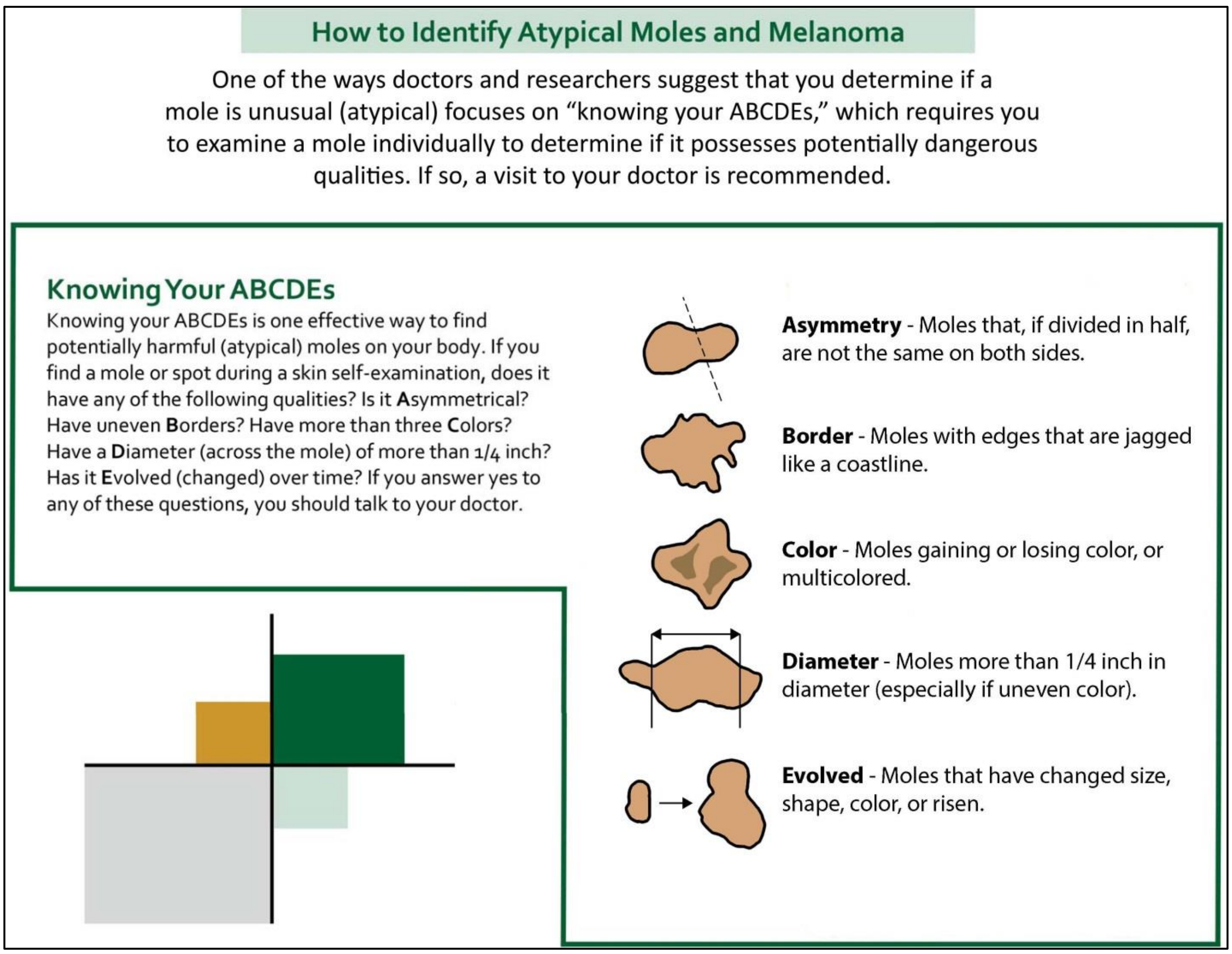
&

Identifying At-Risk Moles

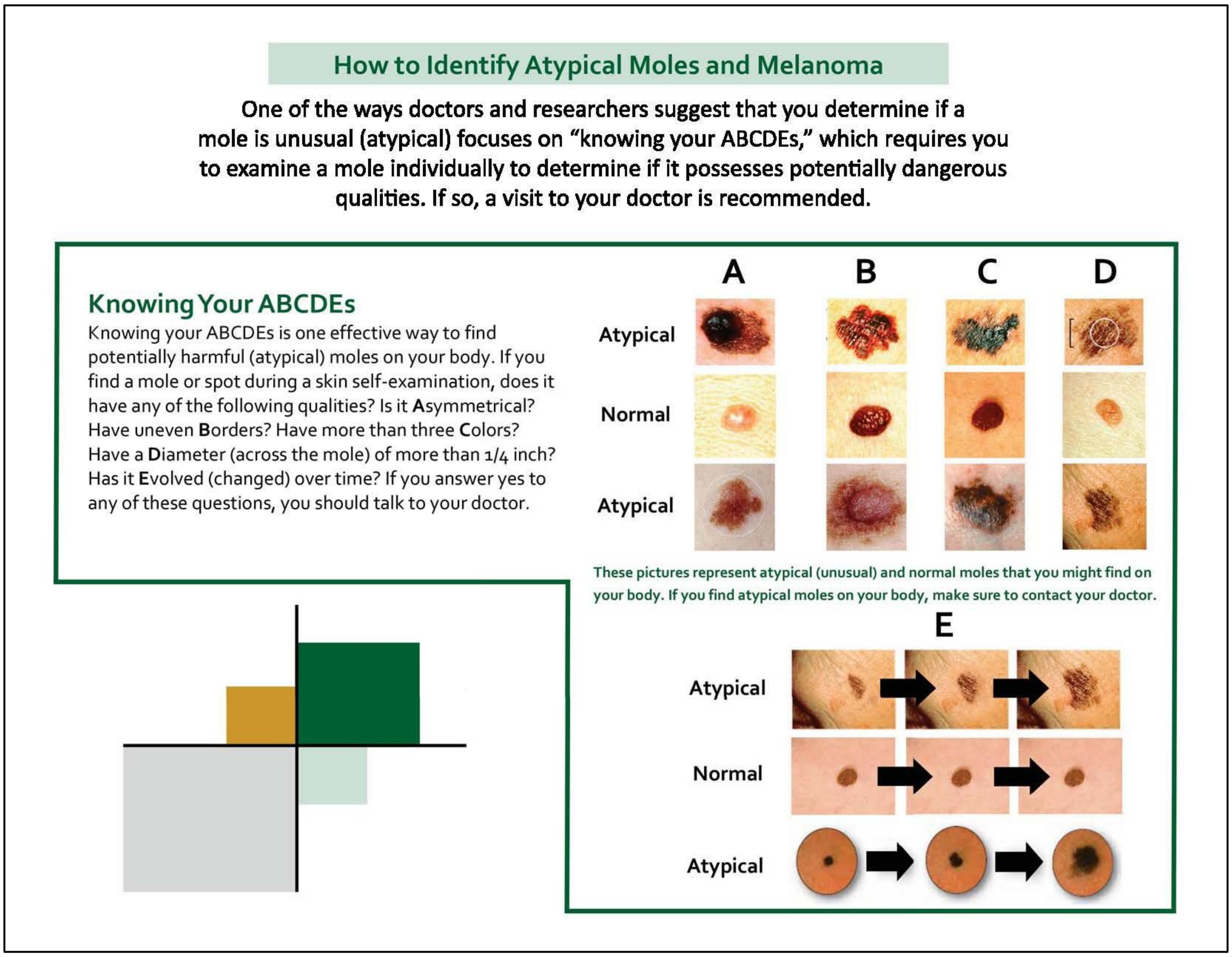
Information in this pamphlet provided by:

American Cancer Society CDC National Cancer Institute

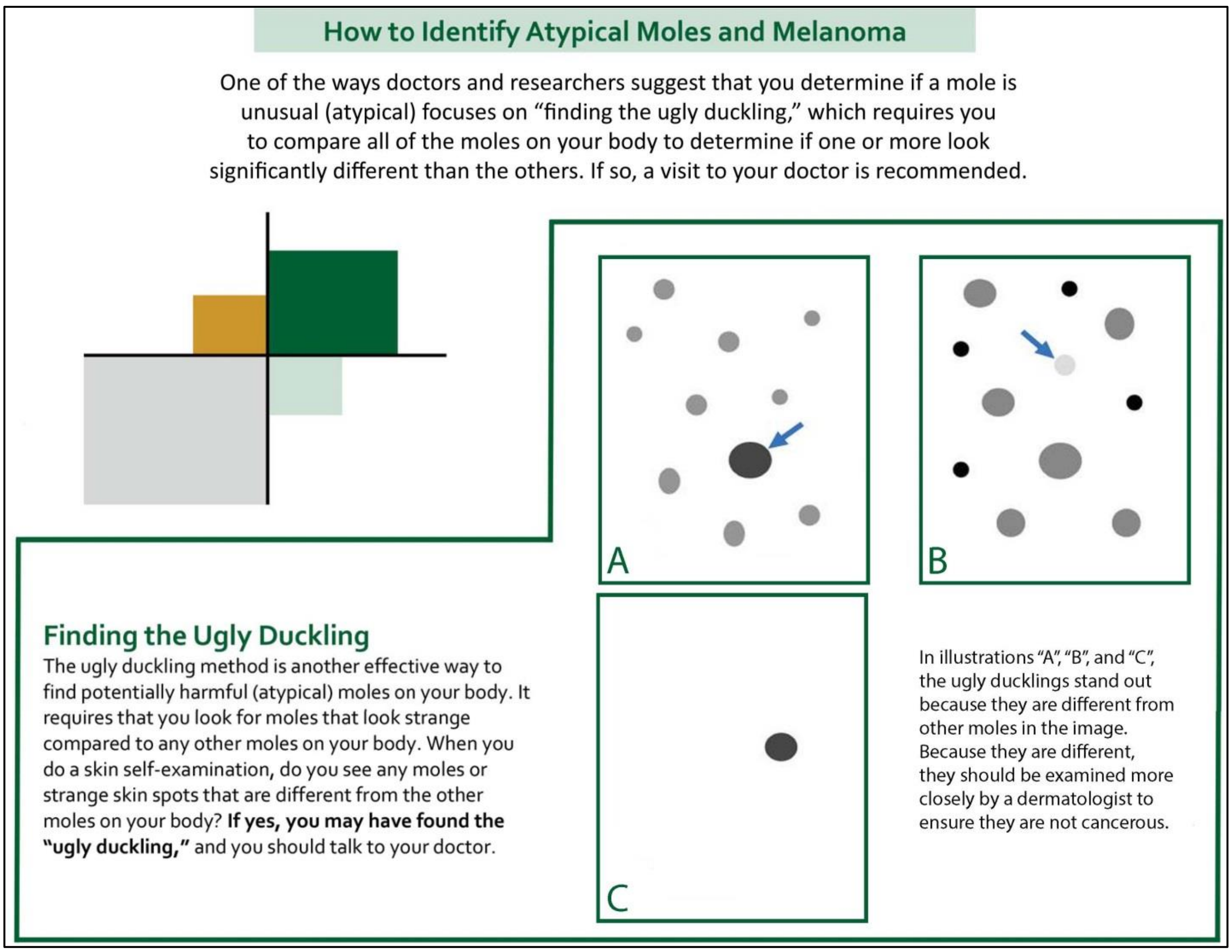
ABCDE Illustrated



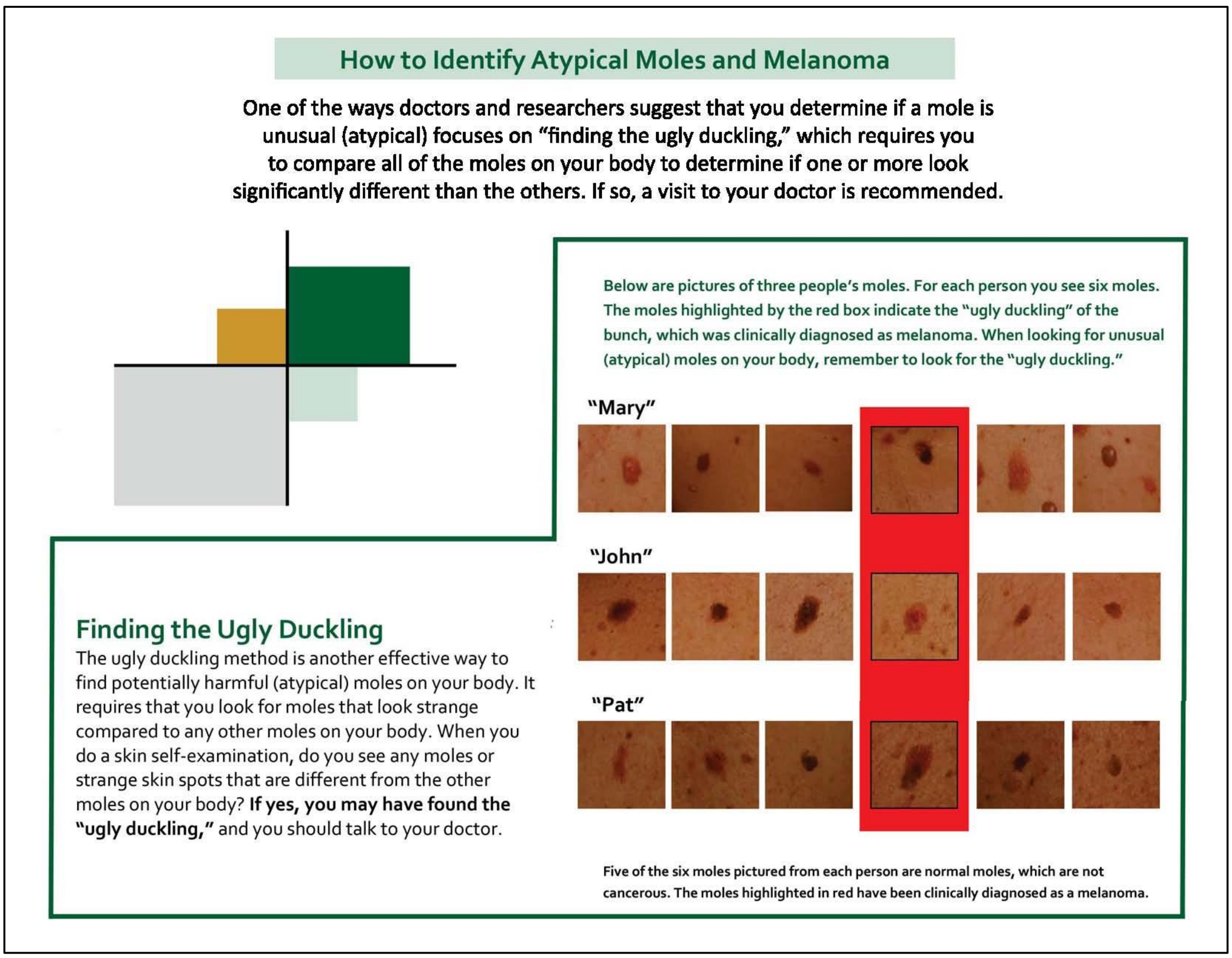
ABCDE Photorealistic



UDS Illustrated



UDS Photorealistic



APPENDIX C

RESEARCHER GUIDE

Researcher Guide

Visual Patterns in
Atypical Mole Identification

About the Study:

The purpose of this study is to examine how individuals visually process images of moles, after being trained in one of two different skin self-examination (SSE) techniques. The goal for participants is to look at selected photos of moles, in order to identify which moles appear atypical (holding an increased chance of being melanoma).

This guide includes supplemental materials that will help you to follow along as you run subjects through the eye-tracking lab.

Included in these materials you will find photos that indicate the location of atypical moles on the various photos that the subjects will see. Your task is to guide the subject through the process, and to write down their answers about the location of atypical moles. More information will follow on the following pages.

Step 1: Qualtrics Survey

- After subjects have been led into the lab, they should be instructed to take the Qualtrics exam located here: LINK TO SURVEY

- NOTE: The first question of the survey will ask YOU to enter their subject number. This number should match the subject number used to identify this subject on any other document or piece of paper.

Step 2: Training Pamphlet

- After taking the Qualtrics survey, subjects should be presented with the training pamphlet appropriate to their condition (either "ABCDE"/"Ugly Duckling Sign" illustrated or Photo), and asked to read through it in its entirety.

Step 3: Calibration

- Following the reading of the training pamphlet, subjects should be calibrated on the eye-tracking equipment, and Gazetracker should be opened in preparation for running the experiment.
- At this point, let the subjects know that they will be shown a series of independent mole photos. Instructions will be provided in the series of slides, and if they have any questions they can ask you at any time.
- As the researcher, you will control slide progression, so ask the subject to let you know when they are done looking at a particular slide, and you can then advance to the next slide (more info on this later).

Step 4: The Presentation

- You are now ready to start the subject on the presentation. The following sections will outline what the subjects will see image by image, and your role as they go through the slides.

Step 5: Mole Identification Tasks

- In this section, subjects will be given instructions on what to do to identify potentially atypical moles in groups of four.
- Your task is to note on the coding sheet whether the subject identifies an atypical mole in the series or not.
- Here are the images:

IMAGE 0: Instructions

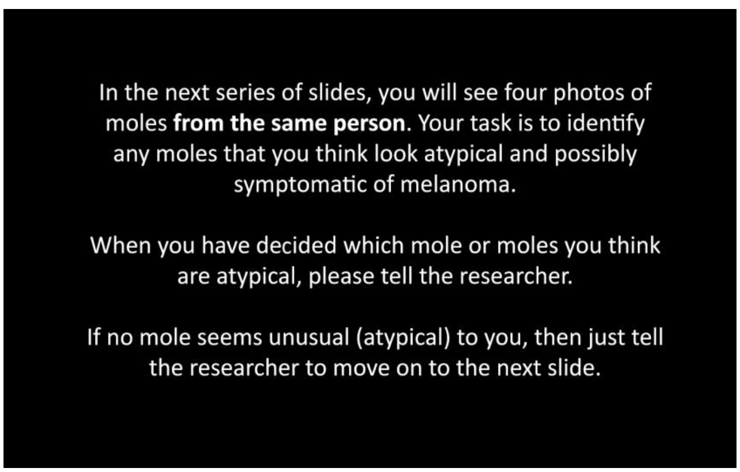


IMAGE 1: **#2 is atypical**

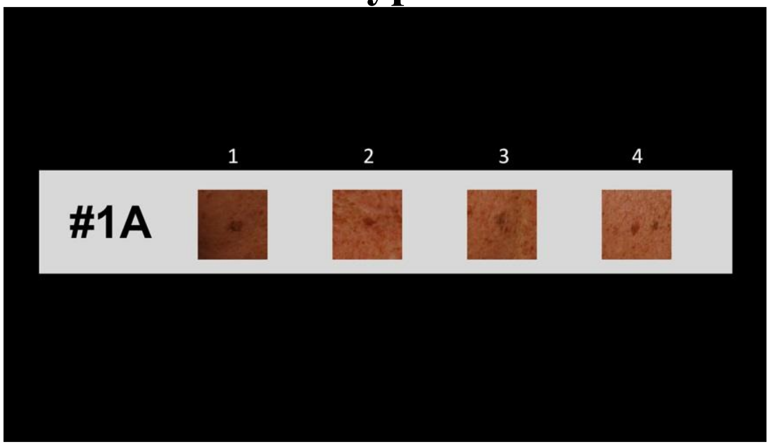


IMAGE 2: **#1 is atypical**

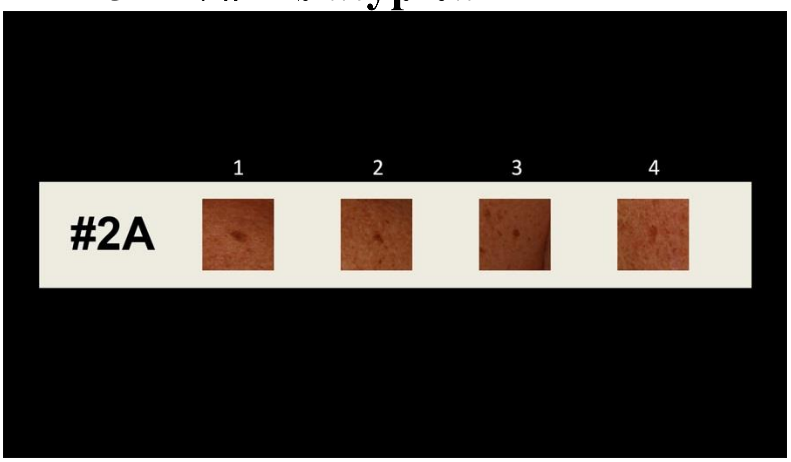


IMAGE 3: **#2 is atypical**

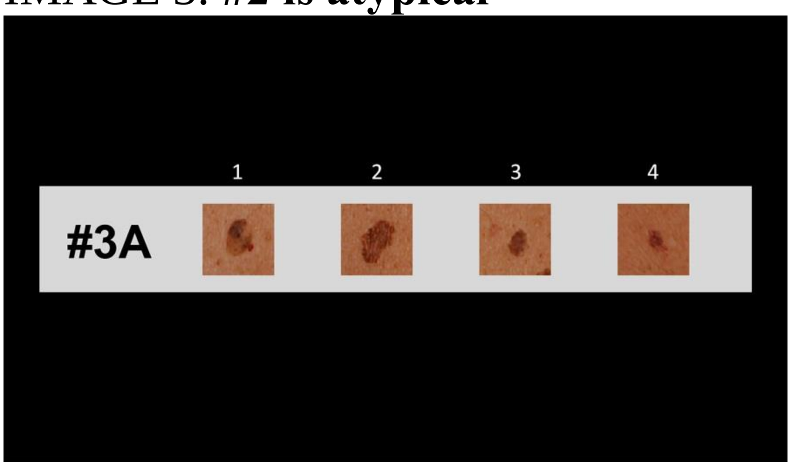


IMAGE 4: **NONE ARE ATYPICAL**

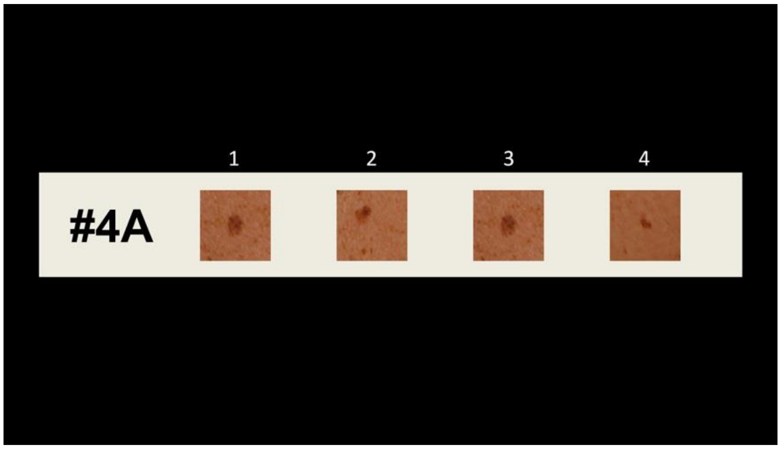


IMAGE 5: **#3 is atypical**

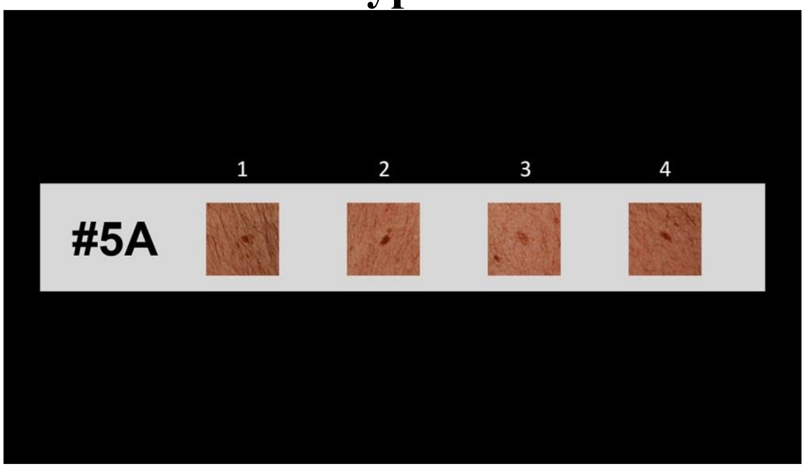
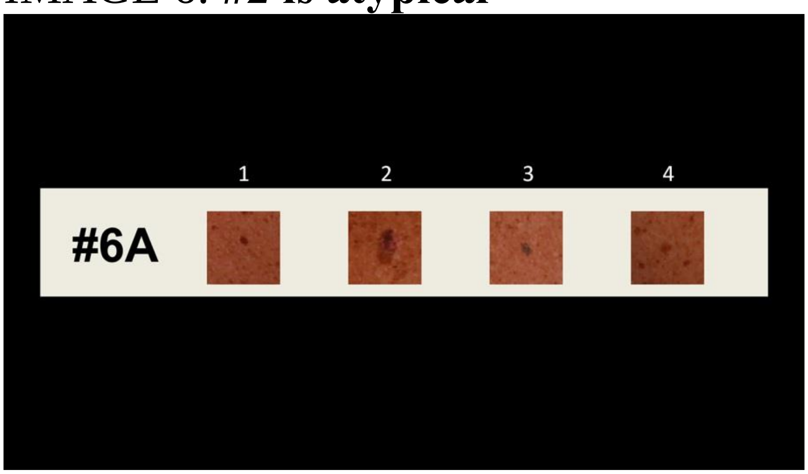


IMAGE 6: **#2 is atypical**



STEP 7: Debrief & Release

- At this point, subjects should be debriefed on the purpose of the project, and asked whether they have any questions or concerns.
- Afterward, thank them for their time and they are free to go about their merry ways.

Coding Sheet

Visual Patterns in Atypical Mole Identification

Subject #:________

Condition (circle one):

(1)ABCDE – Illus. (2)ABCDE – Photo (3)UDS – Illus. (4)UDS – Photo

Mole Identification Tasks

Please note which mole the subject thought was atypical in each series. If none, please circle "none."

#1A.	1	2	3	4	NONE
#2A.	1	2	3	4	NONE
#3A.	1	2	3	4	NONE
#4A.	1	2	3	4	NONE
#5A.	1	2	3	4	NONE
#6A.	1	2	3	4	NONE

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