As digital technology becomes increasingly pervasive and embedded into our everyday experience, there is a growing awareness of the significance of physical interaction with the material world [1]. Recent research is providing evidence of the crucial importance of materiality and physical experience in creative cognition and illuminates the ways in which technology might be developed to enhance its usefulness as a creativity support tool [2]. From earliest times, art-making has involved the manipulation of tools and materials. The physical properties of implements and the response to bodily interaction have always been sources of inspiration to artists and designers, not only in the process of crafting an artifact but also as stimulation for the artist’s imagination. As tools, materials and technology have evolved from generation to generation, so creative processes and cognition have been influenced and changed. Investigating the complexity of the workings of the human mind and explaining how creative thoughts develop are not without their difficulties. Observations of art-making, however, can yield insight into creative processes as well as provide a deeper understanding of individual approaches to innovation [3]. Active participation in the creative act as a collaborator provides the researcher with an empathic experience [4], illuminating how it feels to be physically, emotionally and intellectually involved in this process. Through “disciplined noticing” [5] and qualitative ethnographic research methods, a collaborative creative investigation can reveal issues that might escape notice in a more formal research environment [6]. By using the “studio as laboratory” and utilizing the mutual creative experience of artist and artist-researcher, it is possible to make an analysis of observed and experienced creative processes [7]. This kind of active participation in the research provides insight into the creative mind and at the same time generates novel artifacts that exhibit the creative act.

This article draws from a research project I undertook using this methodological approach. The investigation has focused specifically on how digital technology influences the creative practice of textile artists and designers and in particular its impact on creative cognition. Considerable changes in the working practice of the artists involved in this study have occurred over the last 10 years. Until recently the process of creating artwork for printed textiles has been constrained by the limitations of the manufacturing and craft processes used to translate visual imagery into printed surface [8]. Recent developments in digital print machinery mean that there is now a significant advantage to the digital development of artwork, and practitioners are beginning to embrace the technology and explore ways of working creatively with it [9]. Digital tools are no longer useful solely for pre-print design development but are also being used in the early stages of concept formation and visual idea generation. In my research I have sought to understand how textile artists and designers create visual concepts in order to develop artworks using digital technology. Findings reflect the specialist nature of this domain, in which material tactile qualities, handcrafting and visual simulation are fundamental to creative action.

CONCEPT GENERATION
Memory and Lived Experience
Memory is vital in the creative process and the ability to experience sensory stimulation: to engage in an emotional response and then remember it is crucial in the germinal phase of concept development [10]. Ward [11] describes how new ideas rely on stored information for their creation. Memory of human experience and the sensory stimulation it provides is fundamental to a visual artist’s creative action. Findings from research in experimental neuroscience have revealed the importance of memory in the human ability to make sense of human experience [12]. Emotional responses to sensory stimulation have been found to enhance the strength of memories due to the release of neurochemicals in the brain [13]. Norman [14] asserts that this results in the modification of perception, decision-making and behavior; emotions “change the parameters of thought.” The way in which the world is experienced and perceived, remembered and imagined provides inspiration, sometimes unexpected, for the development of visual representations by artists and designers.

Digital tools such as video and still cameras, computers with scanners, graphics tablets and pens are useful devices with which practitioners are able to explore visual concepts. The research described in this paper has illuminated ways in which experience of the material world influences the development of visual representations, using ethnographic qualitative research methods, including case studies and practical investigations. My research also identifies how physical experience helps define the parameters of thought that are crucial for

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A b s t r a c t
Our perception of the physical world is informed by our bodily sensory experiences. This rich source of information stimulates the brain and is remembered and remade in the creative processes that feed our imagination. How does experience of materiality shape our creative use of digital imaging tools, and how does the technology influence creative practice? This article contends that creative processes are heavily reliant on our memories of physical experience and that tools to support creative digital practice could be enhanced to utilize the rich multi-sensory stimulation it provides. This paper presents collaborative artmaking that has been used to investigate issues arising from case study research, enabling the author to empathically experience the artist’s creative processes and to provide insight into how digital tools can support creative practice.

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the critical decision-making processes fundamental to creative action.

My research involved three separate field studies comprising in-depth video-recorded interviews with textile art and design practitioners in their working environments. The practitioners, Susan Brandeis, Alison F. Bell and Debra Bernath, were chosen for their expertise and reputation for combining both traditional and digital creative practice; their selection followed recommendation from professional associations, industry and academia. Experienced practitioners were selected for this study because they were considered able to provide invaluable insights into the different characteristics of digital tools compared with traditional tools and how their use impacts upon creative practice.

Empathy, in the form of collaborative art-making, was used as a tool in the research process. Following each field study, I devised a series of collaborative practical investigations with each practitioner to investigate findings from the case study data concerning the ways in which memory of shared experiences influences the generation of ideas and how digital tools can support this. Because of the field study, it was possible to develop a shared visual language in which commonalities in definition, description of aesthetic characteristics and qualities were identified among those involved. Alignment of ideals and goals was possible as a result of the mutual understanding of meaning, values and skills. The collaborative investigations also provided an opportunity to utilize complementary as well as shared expertise and knowledge, combining the professional experiences of the practitioners. I, as researcher, shared with the artists the goal of making work that evolved from their common remembered experience. This provided a clear end goal as focus and added momentum to the project. The mutual experiences, shared empathically amongst all of us, provided a means of gaining insight into how it felt to be engaged in the creative process and provided an appreciation of the issues concerning useful adoption of digital technology in practice. My role as researcher was extended beyond observation to participation within the research process.

Working iteratively and in layers, I worked collaboratively with each artist to develop a series of images for digital ink-jet printing onto fabric [15]. The practitioners and I worked in different physical locations to create the artworks. Image files were communicated electronically via web sites or exchanged on compact discs. The art-making process was documented using video recording. E-mail correspondence and telephone conversations provided feedback on the developing work.

The initial field study visits provided me opportunities to make memories of a shared experience that I later used to stimulate a body of artwork with each practitioner. Physical experiences were

Fig. 1. (left) Photograph of the shore, Kilmory, Isle of Arran, Scotland. (right) Watercolor sketch of the same view. (Photo and sketch © Cathy Treadaway) The drawing made on site was perceived as being richer in conveying memory of the experience than the photographic image of the same location.
recorded on-site in personal research journals, in sketchbooks and using video and still photography. Printed photographs, sketches, ephemera and written notes were collated and compiled later in sketchbooks to use as visual resources with which to develop ideas. Sedivy and Johnson [16] note that the production of these kinds of visual notes and rough sketches in the initial stages of creative thinking is “extremely common” in the visual arts. The sketchbook was found to be instrumental for the generation of initial visual ideas in each of the investigations. Drawings produced on location, while the practitioners were physically immersed in the environment, were later perceived to be richer in conveying memory of the experience than the digital photographs taken at the same time and in the same place. Photographic images were unable to convey the emotional response of the practitioner; how it felt at that time and in that location. By comparison, the sketches incorporated the muscular and gestured response of the body within the environment; for example, the wet paper trapped the gritty sand blown onto the sketch, resulting in textured marks that spontaneously captured the memory of physical sensation of sand on skin, wind on face and site temperature. In the collaborative investigation with the artist Alison Bell, the incongruity of the photographic representation compared to the physical sketch became the stimulus for the artwork Kilnory (Fig. 1).

Findings from the research as a whole indicate that practitioners continue to find sketchbooks vital in digital art and design practice. The physical property of the book and the ability to flip through quickly, at a glance, in a non-sequential manner, assist the recollection and assimilation of visual ideas. The activities of cutting out images, sticking, manipulating and assembling photographs, sketches and ephemera within a physical book also provide bodily satisfaction and time for reflection. Digital imaging tools were found useful as memory prompts. Photographs and visual representations created in situ can be stored and retrieved with ease in digital format and, although they do not encode the richness of sensory experience, were shown in the research to be useful in rekindling memories.

Conceptual Blending and Idea Association

Perceived experience is also influenced by memory of previous experiences; we bring to the present personal and cultural influences that have been previously sensed or learnt. What we perceive is “the product of past experience and future expectations” [17]; our perception of experience is dynamic, changing and modulating through sensory stimulation and the merging of memory. Retention of the sensory experience is enhanced by emotional involvement and enables similar experience to be recognized and rekindled later in the imagination [18].

The emotional connection with an occurrence and recognition of a similar past experience facilitate decision-making and influence the priority assigned to the selection of a particular concept in the creative process. Physical experience provides a wealth of sensory data to be processed and filtered in the brain. How to make sense of, and remember, the rich collection of data the body acquires occurs through a process of idea association and perceptual redundancy. Fauconnier and Turner [19] state that routine cognition requires compression of experience and that this takes place through a process of conceptual blending. Gombrich [20] contends that the brain uses techniques including perceptual redundancy to cluster visual cues. This filtration and amalgamation of ideas stimulates creative or imaginative thought; the potential to visualize and restructure concepts through sketches, symbols and diagrams generates further ideas [21].

A similar process of amalgamation and filtering was observed in this research as the practitioners began to review and select from the collected imagery. All three artists who participated in the project were observed using the computer to review and select appropriate imagery from a variety of sources (sketches,
Fig. 3. Drawing on the tablet PC: The author found that the co-location of hand and eyes when working on a tablet PC enabled a more fluid drawing experience. (Photo © Cathy Treadaway)
scanned artwork, photographs, etc.) in order to playfully integrate them to generate visual concepts. Artist Alison Bell stated that she purchased her computer to function as an “electronic sketchbook.” and described it as being “like a doodle pad. . . I just sit and play, like I do with a sketchbook.”

Unlike a physical sketchbook, however, the digital medium facilitates moving imagery from multiple sources. This virtual mixing on the computer screen is far-reaching; images can be combined from still and video cameras, scanned imagery and objects, the Internet and electronically rendered artwork. Ideas and associations can be merged into a single image. Debra Bernath, a designer who participated in the study, uses the computer as a repository for libraries of imagery to be used in design work. Reviewing and categorizing imagery becomes a priority in the early stages of concept generation in her work, and files containing collected images are used as a potential resource for new ideas in future projects.

**IDEA DEVELOPMENT**

**Idea Selection and Evaluation**

A physical act of collecting imagery through photography, making sketches or gathering material objects requires a selective process in which an assessment is made of the appropriateness or value of the item or image. This process is refined further when images are reviewed and then selected from the range of possibilities available. The selection criteria are frequently rooted in intuitive visceral processes that are often difficult to explain analytically. Subjective judgments are, however, embedded in tacit knowledge and connoisseurship and help to define whether a line, mark or image is considered a happy accident or mistake. Dormer describes tacit knowledge as a body of knowledge gained through experience; connoisseurship, however, can only be experienced through the senses and cannot be taught [22]. Experience of this emotional valuation is difficult for artists to express or explain verbally. Norman [23] contends that the affective system provides critical assistance to decision-making, enabling rapid value judgments to be made. Recorded data from this investigation indicates that the selection of ideas at the generative stage of image development can be rooted in memory; sensory prompts stimulate recognition of previous experience.

An example of this was observed during the creation of the artwork *Kilnmore* (Color Plate A). I was working in my studio in Wales on a section of the image in which I wanted to include visual elements that would contribute to a shared memory of the location with the artist Alison Bell: a beach on the Isle of Arran, Scotland. After a review of photographs in the sketchbook, I chose an image that depicted impressions of seagull feet in the sand. The video-recorded data of the development of this section of the artwork also captures the background noises outside the studio window; the cry of a seagull is clearly audible. Although there was no conscious connection between the selection of the image from the sketchbook and the cry of the bird, the sound stimulated recognition and selection of a particular visual memory. My response was spontaneous rapid sketching of impressions of seabird feet using a tablet computer in a variety of colors and weights of line (Fig. 2). The audible sound had acted as a visual memory prompt.

In each of the practical investigations in this study, a mutually agreed framework detailing the objectives and process was defined before the work commenced. The appropriateness of imagery within this framework formed an important tool for evaluating the selection of ideas. In each case, the image being developed was intended to depict a specific time and location shared by myself (the researcher) and the artist. Where there was deviation from this framework, the creative direction of the work became difficult, and the creative energy dissipated. Although this decision-making process could be articulated at the end of the project, at the time of making the image, the knowledge that the work was no longer evolving successfully remained intuitive; it was a gut reaction that the image no longer felt right.

The decision that closure had been reached and the artwork was complete proved particularly difficult in each investigation. Digital working methods ensured that the process of idea generation could be swift, and imagery was found to develop rapidly in great complexity. Knowing when to stop exploring multiple ideas and begin to refine selected concepts became a key issue in each of the investigations. In commercial design work, the customer often imposes time limitations; nevertheless, the practitioner more often decides the amount of time spent on idea generation in any creative project. Findings from this research indicate that the menu-driven decision-making process in digital practice is particularly intensive. However, all those involved in the investigations described the collaboration as being “less inhibiting” than working independently; the process was felt to be “liberating.” There was a reduction in the sense of responsibility for the decision-making process that one of the artists described as being “surprisingly satisfying and sort of a relief. . . . I became more playful and adventurous.”

**Play, Spontaneity, Happy Accident and Intuition**

Play is a vital component in the development of visual concepts and an essential ingredient in creative thinking [24]. The playful manipulation of the selected imagery, its trial-and-error manipulation and layering with associated or randomly selected elements was observed by all parties to be integral to each practitioner’s practice. Both the artists and I described a playful approach to using the technology in each practical investigation, and the word “play” recurs throughout the recorded verbal protocols. Access to digital tools that provided creative freedom to change shape, scale and color were shown to enable playful, risk-free manipulation of visual elements within the developing image.

In non-digital rendering of design ideas, the methods used to create imagery would be difficult and time-consuming, if not impossible, to achieve; layering of photographic imagery would require laborious print techniques or collage work. The facility to save images at each stage of development, to step backwards, to undo and change a layer provides the visual artist with a risk-free environment in which to explore ideas. The emotional response to this is positive; it feels good to play with ideas and experiment with imagery. Research by Isen outlined in Norman [25] affirms the benefit of positive emotions in creative thinking. “When people are relaxed and happy their thought processes expand, becoming more creative, more imaginative.”

The importance of spontaneity, happy accident and intuition in the creative process were key findings from the case study. Bell in particular stressed the significance of spontaneity in her non-digital practice, where the craft technique of silk painting forces the artist to relinquish full control of the color, which moves and bleeds through the wicking effect of the fiber. The digital craft is less spontaneous; it is heavily reliant on menu selections from prescribed and repeatable sets of commands, in contrast to the unpredictable interaction of physical material and human action. Nevertheless
Bell has developed a digital working practice in which she engineers spontaneity through complex layering and scanning techniques or the post-printing embellishment of the artifact by hand with colored dyes or stitch.

**Physicality and Materiality in Process**

**Making by Hand**

The importance of making by hand, hand rendering and manipulative skill in the creative process was another key finding from analysis of the case study data. All those interviewed for my research stressed the importance of manipulative and tactile making skills in the development of visual ideas. The physical action of grasping a drawing implement and feeling the friction of tool upon surface; the sensory feedback of hand on surface; and the manipulation of paper and fabric were all considered important stimulants for deriving novel visual ideas. Wilson in *The Hand* [26] asserts the connection between hand and brain in developing imaginative thought. Recent research in neuroscience has found that separate streams of sensory information are fed to the brain from visual stimulation [27]. These have been shown to enable both physical manipulative action and also the perception of objects. Pytherch [28] links the sense of touch with sight and perception and asserts that both provide information to the brain in different ways. Haptic senses result from successive experiences in which substance is encoded; vision provides information concerning shape and location. Research by Goodale and Milner [29] identifies how visual control of physical prehension informs perception and cognition in order to mediate physical action. These connections between vision, touch and cognition inevitably have an impact on the perception of physical experience and influence imaginative thought [30]. Harris [31] contends that those practitioners who have learned haptic skills such as textile handcrafting are more likely to feel constrained by the lack of sensory stimuli inherent in digital crafting.

These collaborative investigations provided an opportunity to evaluate digital tools to support sketching and visualization of developing concepts. Each of the practitioners involved in the research commented on frustrations in the physical use of digital drawing input devices. They cited lack of perceived haptic sensory feedback as a major concern. In some instances, frustration was expressed with the disconnection between hand use and visual feedback on a computer monitor. I found that co-location of hand and eyes when working on a tablet PC enabled a more fluid drawing experience (Fig. 3). The limitations of bimanual co-ordination in digital working were also expressed. The most experienced digital practitioner found this less of an issue due to her use of hot keys with her non-dominant hand and a drawing input device in the dominant hand. However, she also expressed the need to work with her hands, away from the computer, for periods of time to stimulate novel thinking. The same artist used her non-dominant hand for occasional drawing to create different kinds of spontaneous digital marks and also to rest her over-worked dominant hand.

The rapid proliferation of visual ideas is a major characteristic of digital visual art practice: iterations can be quickly modified to create multiple options for further exploration. Findings from this research indicate that the subsequent decision-making process can be exhausting for the artist. In non-digital practice, the hand rendering process takes time and provides periods of reflection in parallel with fabrication of the artwork. Sternberg and Tardiff [32] contend that “creativity takes time.” Slowness of making in handcraft provides an opportunity for idea association and imaginative thought to develop and for critical aesthetic decisions to be considered. The digital crafting process, by comparison, has been observed to encourage non-reflective thinking due to its speed in processing ideas and actions [33]. Manipulation of physical materials and tools was found to expand thought processes and provide relief from the memory-intensive tasks required in using digital technology [34].

**Verification and Sampling**

At various stages in the investigation, work in progress was digitally ink-jet sampled, either on paper by the practitioner or on fabric by myself. The facility to digitally share design imagery enables multiple copies of the artwork to be available for simultaneous sampling. This is a great advantage compared to hand-rendered artwork, where usually only one original copy exists. The material outcome comprised digitally printed fabric. A variety of weights and fibers were selected for sampling to explore how the surface texture and weight of cloth impacted the translation of color and line of the digital image. For some textile artists, the prototyping stage provides new opportunities for creative insight. Irregularities in the surface of the cloth create accidental visual effects that can be regarded as potential opportunities for creative exploitation.

During the investigation with textile artist Susan Brandeis, the sampling process helped identify color issues that led to substantial reworking of the digital imagery. The distributed nature of the collaborative process highlighted the significant difficulties concerning the communication of color across networks and media. For those visual arts practitioners working outside industry, with no access to commercial calibration tools, this impacts creative practice in a variety of ways. Findings from the research as a whole reveal that creative practice is enhanced when color issues are regarded in a positive way and considered to be potential avenues for further exploitation. Campbell [35] and Polvinen [36] confirm these findings, recommending that color management difficulties be approached empirically. Accuracy in color data transfer across networks and between digital monitors, peripherals and printing devices is a major concern for those involved in professional creative collaborative practice.

**Conclusion**

Dormer [37] describes the creative process as “the interplay between what we see now and how we interpret what we have seen in the past.” Materiality and remembered physical experiences stimulate the imagination and are crucial to the development of creative thought. Perception of the physical world informs our interactions with digital technology and the ways in which visual representations are imagined and developed into artworks. The collaborative and empathic nature of the practical investigations was able to provide me with insight into the working processes of the artists through shared experience, imagery and process. Future developments in digital creativity support tools should take into account the practitioner’s desire for interfaces that enable greater haptic sensory input, leading to enhanced expression of gesture and emotion experienced in the physical world and communicated in the resulting artwork.

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**References and Notes**

*Unedited references as provided by author.*

1. B. Shneiderman, “Leonardo’s laptop: Human needs and the new computing technologies” (Cam-
bridge, Mass., MIT Press, 2003) p. 19: “Even if these tools are wonderful and helpful; low or no technology may be the wiser choice in many cases. The therapeutic benefits of walking in the woods, holding a baby, and talking to your friends should always be respected.”


4. Empathy (Greek *empathia*) is defined as “the action of understanding, being aware of, being sensitive to, and vicariously experiencing the feelings, thoughts, and experience of another of either the past or present without having the feelings, thoughts, and experience fully communicated in an objectively explicit manner,” <www-mm.com/>.


7. Edmonds et al. [3].


10. Treadaway [2].


15. This work was done using Adobe Photoshop software.


18. Gombrich [17].


23. Norman [14].


29. See Wing [27]. Research by Goodale and Milner, p. 17.

30. See Treadaway [2].


34. Treadaway [2].


37. Dormer [22] p. 102.

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