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On-body Interaction-based Characteristics for Special Effects Makeup

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Abstract: *This paper investigates an on-body interaction-based approach that can support the creative development of special effects makeup. For this purpose, we classified expression types and deduced characteristics through on-body interaction-based case studies. First, when designing for on-body interaction, input systems that recognize body parts for interaction must consider accessibility. Second, in on-body interaction-based design, biological systems exhibit variation in the skin's signaling compounds. In contrast, applying prosthetic makeup technology enables a new variable design approach. Furthermore, external variability contributes considerably to the overall diversity in special effects makeup based on on-body interaction. Third, on-body interaction-based special effects makeup follows a bio-driven approach, where biocompatibility is required to design interfaces in direct contact with the body. Therefore, conventional special effects makeup materials only require skin compatibility, whereas on-body interaction-based designs also require biocompatibility. Therefore, on-body interaction-based characteristics for special effects makeup are accessibility, variability, and biocompatibility.*

Keywords: *on-body interaction, special effects makeup*

1. Introduction

Recently, designers have explored the idea of immediately reactive on-body interactions. These studies pertain to the beauty industry, which extends into many research areas, from medical and wellness to performance and art. In particular, the entertainment industry drives special effects makeup, but potential spin-off technologies can be studied in medicine, robotics, and even wearables for gaming. Therefore, special effects makeup is an art field that requires various techniques involving physical interaction with the human body. Through the use of bodily contact case studies, this study aims to understand the type characteristics for special effects makeup while also examining innovative special effects makeup techniques. The case study focuses on body interaction-based research using special effects makeup's techniques and materials. Through studies, we classified them into skin-based, kinetic-based, and muscle-based types and deduced accessibility, variability, and biocompatibility as on-body interaction-based characteristics for special effects makeup. We hope the information and framework presented in this paper will contribute to creative ideas for novel and impactful special effects makeup in the future.

2. Background

2.1 Special Effects Makeup

Special effects (SFX) and prosthetic makeup are areas of makeup that cover injuries, diseases, three-dimensional work, and some character effects. From realistic wounds to terrifying monsters, both branches of makeup artistry are commonly used in TV, film, and theater. Special effects makeup is the term used for the team applying pre-made prosthetics or smaller on-skin effects. This type of makeup can include creating the appearance of things such as wounds, scars, and wrinkles for aging effects by applying it directly to the skin. The materials used for special effects makeup include on-skin silicone, liquid latex, and gelatine, all perfect for creating smaller pieces that will be applied to the actor's skin [1]. Prosthetic makeup (i.e., special effects or FX makeup) considers the art and craft of transforming personal facial identification [2]. It uses prosthetic sculpting, molding, and casting techniques to create advanced cosmetic effects. It can also drastically alter the appearance of a human face through molded facial parts, skin-like silicone masks, and plastic surgery [3]. It is an artistic technique that is widely used in film and theater to augment facial morphology or texture. These are usually made from foam latex, gelatin, or silicone. Combining art and science, prosthetic makeup also plays a crucial role in medical recovery [4]. The skills makeup artists use across prosthetics and special makeup effects are very similar, and there are many crossovers. Therefore, SFX makeup is often used as a catch-all term to discuss both disciplines, and the line where SFX stops and prosthetics begins is blurred. Hence, it can be especially challenging for makeup artists. Recently, the scope of expression has expanded to include animatronics, with prosthetic technology added to mechanical devices. In addition, 3D printing technology has been rapidly expanding its applications and has also been applied to the production of prosthetic props. Advances in 3D printing can combine traditional manufacturing techniques and 3D printing in special effect makeup to work in less time and increase productivity, saving traditional materials and the workforce. Therefore, special effect makeup requires extensive research on the application of various fields involving physical interaction with the human body.

2.2 On-Body Interaction

Harrison's research in 2010 and 2011 demonstrated that using the human body as a way of interaction between a person and a device could enhance usability. Harrison defined this method as "on-body interaction" [5–7]. The human body offers vast, always-available, and quickly accessible real estate for interaction. For these reasons, on-body interaction has received considerable attention in the human-computer interaction community. Bodies provide capacities that come from having actuators and sensors tied to a single structure (i.e., body) that enables acting (i.e., agency), joint activity (i.e., doing things with others in coordination through shared attention), and adaptation to the built environment (i.e., having effects on the constructed world in a way that is sensitive to the physical attributes of the local environment). Each potentiality is special and requires a bodily agent with attention-directing capacities and effectors [8]. Technological advances have opened up new interactive opportunities using the body as an input and output platform. Such on-body interfaces offer new interaction possibilities for creative design in special effects makeup.

3. Related Work

To study on-body interaction-based special effects makeup, we classified them into the skin, kinesthetic, and muscle-based types.

3.1 Skin-Based Interaction

Skin is a fundamental biological interface to sense the world and communicate with others [9]. Skin-based interfaces appropriate the body as an always-available, spatial-tangible surface for sensing and displaying information. Several techniques have been developed for sensing input on one’s skin [10].

Skintillates are an epidermal wearable interactive devices with on-skin displays that mimic tattoos (Fig. 1 and 2). Skintillates explicitly allows the customization of the visual aesthetic and the electronic functionality, enabling open, creative, and unique designs in an on-skin wearable device. Skintillates also afford a wide range of unique designs varying in size, shape, color, body location, sensing, and electronic properties. All Skintillates comprise five essential layers (Fig. 1), of which three come in a single commercially available package. Skintillates fabricate on temporary tattoo paper, which rests on top of a paper substrate before the tattoo is applied. A nonconductive inkjet-printed art layer can be printed on the tattoo substrate before the electrically functional conductive layer is screen-printed. Additional layers, such as an electronics layer, can be added to enable more complex interactions and expressivity. Before applying the Skintillate device onto a user’s skin, an adhesion layer is applied on its top. Skintillates are fabricated using a standard screen-printing process and are applied to a user’s skin in the same manner as conventional temporary tattoos (Fig. 2). One of the most important aspects of wearing tattoos, either temporary or permanent, is to express personal identity. Skintillates aim to augment the self-expression of tattoo artwork with electronics [11].

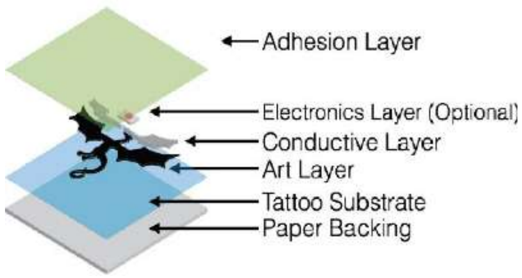

Fig. 1 Different layers of a basic Skintillate device

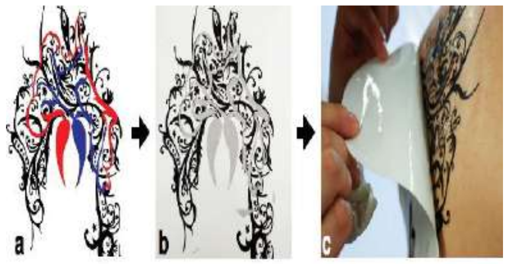

Fig. 2 Skintillates fabrication process workflow. **(a)** the art layer (in black) and the electrical traces (in red and blue) are designed in a standard design program, **(b)** the art layer (in black) isinkjet printed, and the conductive layer (in silver) screen-printed on the tattoo substrate and **(c)** the Skintillate device is applied on skin and released from the paper backing.

A living tattoo (Fig. 3) that responds to the chemical compounds on human skin is designed to integrate a collection of multiple chemical-sensing cells printed on the surface of a bilayer elastomeric sheet and carefully attached to human skin (Fig. 3a). The thin (~75 μm), flexible, transparent, and gas-permeable bilayer elastomeric sheet is fabricated by successive spin-coating deposition of two silicone elastomeric layers, where the upper layer is mechanically robust and flexible. The lower layer is skin-adhesive, which gives robust bonding to the skin via van der Waals forces alone without needing additional fixtures or tape. As shown in Fig. 3b, the skin can deform in different modes (i.e., stretching, compression, and twisting) freely and reversibly without detaching from the living tattoo. Moreover, the robust bonding between the hydrogel and the elastomer sheets and their mechanically soft nature prevent detachment. Further, the elastomer layer effectively reduces water loss from the printed hydrogel, thus maintaining cell viability and device functionality. To examine the practical applications of the living tattoo, three signaling chemicals (e.g., AHL, Rham, or IPTG) are smeared on the skin, respectively. When the chemicals are received, the adhered tattoos exhibit green fluorescence in corresponding 3D-printed patterns. Monitoring different chemicals by the living tattoo device on the skin shows experimental results (Fig. 3c) [12]. Therefore, living tattoos open new avenues for aesthetic-plus-functional applications.

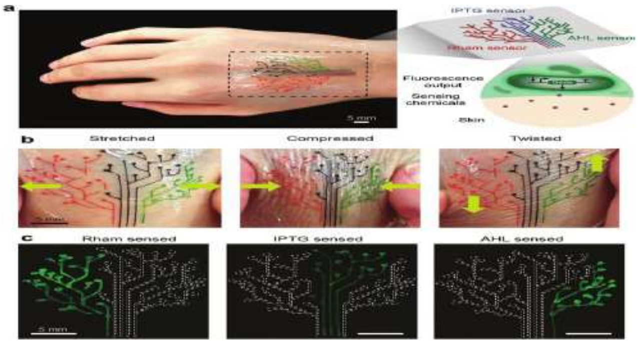

Fig. 3 3D printed living tattoo for chemical detection on human skin **(a)** The design of the living tattoo **(b)** The living tattoo on the skin in different states **(c)** The response of the living tattoo on the skin smeared with Rham (left), IPTG (middle), or AHL (right)

Human skin, as a natural and remarkable integrated sensor network, can transduce environmental stimuli (i.e., tension, pressure, temperature, and vibration) into electrical signals, which are then processed by the brain for the generation of effective instruction. Inspired by this multisensory feature of natural skin [13–15], electronic skins (e-skins) with similar sensibilities are proposed and gradually developed into a compelling interactive medium for numerous novel applications, such as artificial prosthetics [16, 17] and health monitoring. In addition, wearable devices, new materials, and rational manufacturing methods were developed. Fig. 4 is a CCM e-skin that is flexible, strain-sensitive, and user-interactive by transferring the conductive CCM layer inside the silicone rubber. This bioinspired e-skin has two core components: a conductive strain-sensing layer and a stretchable silicone-based thermochromic layer. The CCM e-skin can be attached to the human skin for monitoring human activities by two artificial sensory channels: the digital channel and the visual channel. The electromechanical/digital channel comprises a strain sensor that can detect human body movements by analyzing variations of the resistance signal. In contrast, the optical channel is based mainly on the mechanisms of Joule heating and thermo/mechanochromism. This multimodal fusion strategy enables the CCM e-skin to study human activities with ever-increasing intuition and accuracy. These features demonstrate that the CCM e-skin provides a new platform for visual monitoring human motions with potential applications in autonomous artificial intelligence, skin prostheses, and health care devices [18]. Recent advances have made skin electronics thin, bio-compatible, and robust enough to be worn on the skin for on-skin interaction [19]. Therefore, it allows investigating a novel application in on-body interaction-based special effects makeup for touch-sensitive interfaces.

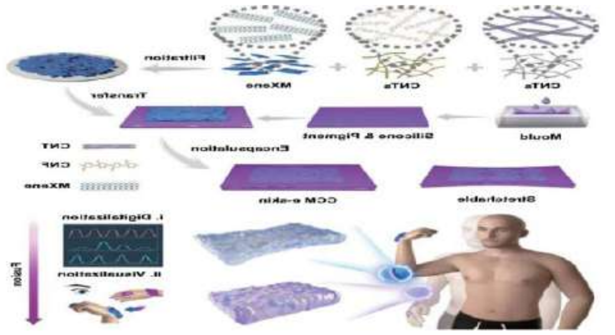

Fig. 4 Schematic illustration of the preparation of digital-visual fusion CCM e-skin. CNTs, CNFs, and Ti3C2 MXenenanosheets were first mixed and filtrated to obtain the CCM film. Subsequently, a sticky substrate was fabricated after procuring silicone and pigment with a PTFE mold. Finally, the CCM film was transferred onto the silicone and pigment substrate and further encapsulated to construct a flexible and user-interactive CCM e-skin. The CCM layer served as the strain sensing and Joule heating layer, and the silicone and pigment substrate served as the thermochromic component and encapsulation layer.

3.2 Kinesthetic-Based Interaction

The kinesthetic senses are the body's position and movement sensibilities, which are only discernible through introspection. Kinesthesia, vision, and touch are associated with the sense of body ownership. All three can combine, or each, on its own, can generate uniqueness. The two primary kinesthetic senses are the senses of our body's position and movement [20].

The SkinWire (Fig. 5) approach starts with placing electronic components into individual printed circuit board (PCB) islands that distribute over the body surface. Next, the islands are linked by a new skin-wiring method that uses a sewing-like method to place conformal multi-stranded metallic wires on thin silicon substrates. The process affords on-skin interfaces with the needed wiring in limited surface areas. Furthermore, SkinWire can be applied to an index finger and thumb-based inertial measurement unit (IMU) tracking. Importantly, SkinWire seeks to merge aesthetic considerations into the design of hand gestural sensing systems, which have historically been developed from a technical standpoint over the past two decades [21]. SkinWire draws upon body craft practices but expands them for the functional component needed for our wearable devices. Inspired by the emerging body art trend of body wiring, the SkinWire approach uses readily accessible materials and affords aesthetic customization. Fig. 5 presents an example of shifting a hand-gesture interface onto the skin to demonstrate the approach's feasibility. The IMUs are attached to the hand's phalanges, where the orientation is recovered. In particular, we place sensors on the distal and proximal phalanxes of the index finger and the distal phalanx and metacarpal of the thumb. This data can be used with a kinematic model to reconstruct the posture of the hand or used more broadly as part of a gesture recognition system. The IMUs are then connected to a microcontroller, BLE, and battery situated on the back of the hand. Finally, some of SkinWire's options with the prototypes are shown in Fig. 6. Note that these prototypes are aesthetic examples with limited durability since they are fabricated with a straight stitch, not the evaluated zigzag stitch. SkinWire devices can be customized with the rich offerings of readily available body art decorations. Future aesthetic options will require exploring new materials and further studies on durability [22].

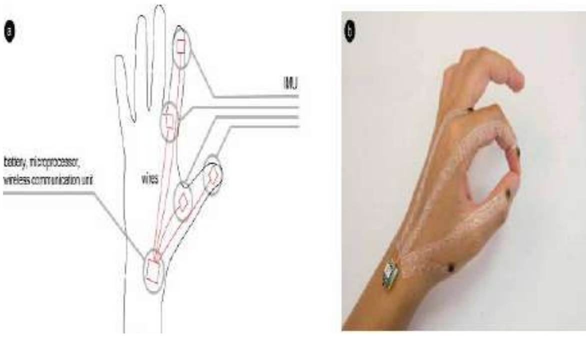

Fig. 5(a) Layout of the on-skin hand gestural interface **Fig. 6** Aesthetic customization of Skin Wire devices with Explored in this paper **(b)** Implementation of Systemcolored wires and non-functional decorative elements such as **(a)** gems and **(b)** temporary tattoos

Springlets are expressive and silent mechanical tactile on-skin interfaces (Fig. 7). Embedded with shape memory alloy springs, Springlets are thin and flexible stickers that can be worn in various body locations, including the neck and cranium, thanks to their silent operation. Furthermore, it uses thin and flexible shape memory alloy (SMA) springs to create a wide range of gestures such as pinch, directional stretch, press, pull, drag, and expand beyond squeeze. SMA springs are thin (μm coil radius) and very soft alloys that contract like muscles when current is applied, generating smooth, powerful, and silent movements. They have a higher force-to-weight density than any electromechanical actuator [23]. Under their flexibility and compact form, SMAs can adapt to numerous mechanical tactile designs. A Springlet sticker is composed of three functional layers (Fig. 8).It explores new interactive experiences in tactile social communication, physical guidance, health interfaces, navigation, and virtual reality gaming, enabled by Springlets' unique and scalable form [24]. Mechanical stimulation is the most commonly used method to create a tactile sensation. The mechanoreceptors of the skin easily perceive vibration, skin stretch and deformation, and relative tangential movement on the skin surface at a finer spatial resolution compared to thermal and electro-tactilestimulation [25]. This enables a more expressive range of mechanotactile gestures.

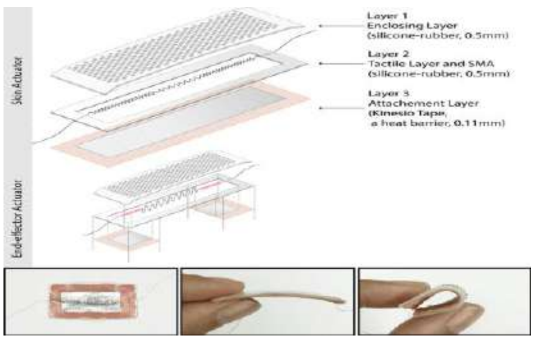

Fig. 7 They are easy to fabricate and customize for
Fig. 8 Springlets' multi-layer sticker structure
various body locations and tactile patterns using

By exploiting skin deformations, Skin-On interfaces (Fig. 9) provide novel input capabilities and haptic feedback that users are familiar with. Furthermore, by mimicking natural human skin, Skin-On interfaces can also better communicate the interactivity of these systems and facilitate the discoverability of gestures, which in turn enhances interaction. For instance, the back of a mobile device can be covered with artificial skin that can sense novel user gestures (e.g., grab, twist, scratch, etc.) and provide tactile and kinesthetic feedback to enhance user expressiveness and experience for mediated communication or interface control. In particular, it follows a bio-driven approach inspired from the human skin to design this new interface type. The Skin-On interface uses silicone to reproduce the skin (Fig. 10) [26]. However, the interface does not focus on interacting directly with human skin but instead aims to mimic its properties to augment interactive devices.

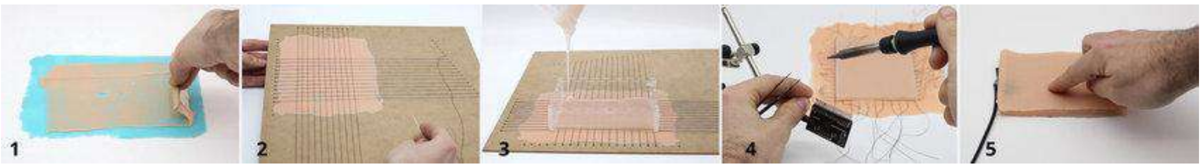

Fig. 9 Skin-On Interface **(a)** is a new paradigm in which we augment interactive devices such as **(b)** smartphones, **(c)** interactive watches, or **(d)** touchpads with artificial skin.

Fig. 10 The fabrication process of Skin-On artificial skin **(1)** Epidermis layer, **(2)** Electrodes, **(3)** Hypodermis layer, **(4)** Electronics, **(5)** Aesthetics

Silicone has proven to be a suitable material for replicating the three skin layers. For example, this material is used to create skin simulators for medical training [27–29] because of its mechanical properties. It is also used in the movie industry to create props and special flesh-like prosthetic effects due to its texture and pigmentation. Hence, silicone appears as a promising material to reproduce skin properties within Skin-On interfaces [30]. Additionally, it is the most commonly used material for prosthetics, as its texture and flexibility make prosthetics look almost realistic. Artists then use pigments to color the silicone for creating the translucent look of human skin [31]. The introduction of silicone has been another innovation in special makeup since the 1990s, enabling realistic skin expression, and now it has become a common material used by special effect makeup artists.

3.3 Muscle-Based Interaction

Our bodies largely retain the same shapes, proportions, and methods of controlling movement of muscles. Thus, it gives us the opportunity to control and embed sensors and actuators to our body surface using our muscle movements as the interface [32]. In addition, facial expressions and body gestures communicate emotional content in nonverbal human interactions. Therefore, the ultimate objective of muscle-based interaction is to locate wearable technologies on the body surface and use muscle movements as an interactive interface.

FX e-makeup (Fig. 11) is a beauty technology that uses special effects makeup to hide electronic components that sense facial muscle movements, acting as a second skin. When strategically placed on the muscles, FX e-makeup sensors act as switches [33]. In Fig. 11 (a), the sensor on the brow is associated with the lower outer brow raiser action unit. It is activated when the user raises their eyebrows and both sensor contacts are touched. In Fig. 11 (b), the eyelid sensor (associated with the lid tightener action unit) senses blinking when the lid tightens, and both contacts are touched. Fig. 11 (c) shows the sensor associated with the jaw drop, lipspart, and lip corner puller action units. It senses a smile when there is no contact, in the opposite way of the other sensors. Finally, the sensor in Fig. 11 (d) is associated with the lip pressor action unit, which activates when both lips press together. Wires can be hidden with FX makeup materials, including ink and latex. Special effect makeup materials combine with beauty technology sensors for a precise application to specific muscles. Finally, face paint is used to color the user's face black [34].

(a) Eyebrow sensor**(b)** Eyelid sensor

(c) Smile sensor**(d)** Closing lips sensor
Fig. 11FX e-makeup interface

Winkymote (Fig. 12) is an infrared remote controller for people with quadriplegic disabilities that triggers house appliances by blinking. Special effects makeup and sensors are placed on the user's face to sense his voluntary muscle movements [35]. A communication interface controlled by voluntary blinking activates infrared-controlled devices that simulate a remote control developed for individuals with quadriplegic disabilities. It is an infrared-controlled interface that uses FX e-makeup sensors connected to an infrared-transmitting module mounted on the user's necklace. These sensors are placed close to the outer end of each eye, i.e., close to the lid tightener action unit. They are connected through wires to the infrared-transmitting module mounted on the person's chest. Whenever he/she winks tightly, the switch closes, sending a digital signal to the microcontroller that activates sound feedback informing an infrared LED to send the appropriate sequences for triggering the TV. Blinking with left, right, or both eyes turns the TV on or off or changes the channels up and down [36]. It is hidden in makeup that can be applied to the faces of people with quadriplegia to allow them to change TV channels simply by blinking.

Fig. 12 Winkymote prototype using hydrogel

The Morphace (Fig. 13) system combines prosthetic makeup, which already helps on-body appendages integrate with actors' native skin, with shape-changing and property-tunable wearables, thereby increasing the expressive and interactive potential of shape-changing interfaces on the face. It is a design approach that imbues prosthetic makeup with customizability and transformative properties, which allows it to seamlessly 'camouflage' on the original face and transform it. It enables novel design uses, including artificial tears, augmented facial expression and morphology, interactive blush, and encoded freckles. Morphace draws inspiration from the biological structure of human skin, which consists of layers with unique properties and functions (Fig. 14). Morphace skin is akin to human skin in that it consists of layers with unique functions. Its dynamic changes enable interactive applications, unique aesthetics, and effective feedback. The unique placement of Morphace on the face connects the functions of interactive applications to the functions of facial organs. Because Morphace blends with natural skin, users could wear the "invisible" transformative patches without worrying about attracting unwanted attention. Morphace uses prosthetic makeup to push the limits of integrating transformative wearables onto the face with dynamic expressions. From an engineering perspective, it provides a new angle to develop on-skin, shape-changing interfaces [37].

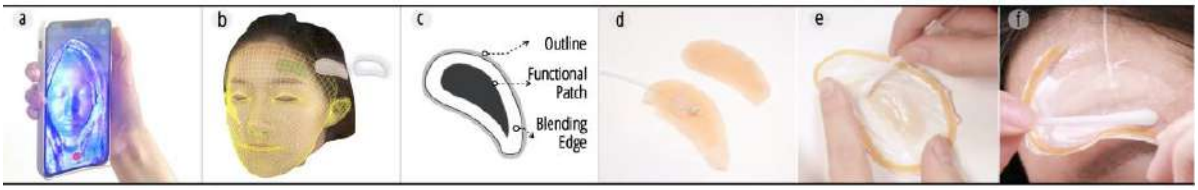

Fig. 13 Morphace is a computer-aided fabrication approach that blends transformative wearables with native skin using prosthetic makeup techniques. Morphace's fabrication process consists of **(a-b)** designing and simulating on a scanned face, **(c-d)** fabricating functional primitives, and **(e-f)** applying the prosthetic patch.

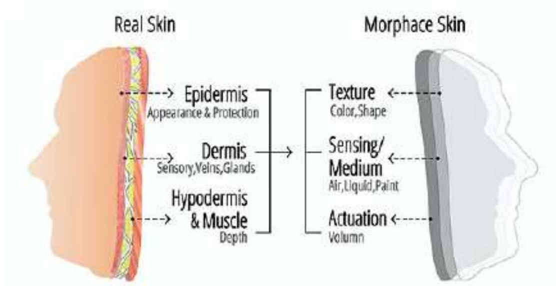

Fig. 14 Morphace skin mimics the structure and function of human skin with enhanced transformative abilities.

Unlike traditional makeup techniques, prosthetic makeup provides more flexibility to integrate functional components that are thick or volumetric. Prosthetic makeup techniques can be applied using nonconventional special effects materials, such as flexible silicone or materials familiar to makeup artists. It will allow us to make transformative skin wearables and experiment with and design new forms of interaction and expression.

4. Characteristics

We identified accessibility, variability, and biocompatibility as on-body interaction-based design characteristics for special effects makeup.

4.1 Accessibility

Accessibility can be defined as a category of usability. As with any usability measure, accessibility is necessarily defined relative to user task requirements and needs [38]. It is essential for the proper design of on-body interaction-based systems. The human body offers a large and quickly accessible surface for always-available, eyes-free interaction [39]. Therefore, special effects makeup based on skin interaction can interact with the body through sensory, visual, and kinesthetic senses due to its proximity to the body. Furthermore, since the physiological properties of the body vary across locations, interaction is likely to be very influential. In addition, unconventional on-body interaction locations with skin appendages, such as eyelashes, nails, lips, hair, etc., can be utilized. Therefore, on-body interaction-based approaches have great potential for special effects makeup centered on the human body.

4.2 Variability

Biological systems are inherently variable, with their dynamics influenced by intrinsic and extrinsic sources. These systems are often only partially characterized, with significant uncertainties about specific sources of extrinsic variability and biochemical properties [40]. Traditionally, intrinsic variability is the foundation of most physical, chemical, and biological phenomena [41].Living tattoos (Fig. 3) exhibit the variability of fluorescent colors in 3D-printed patterns when signaling chemicals are applied to the skin. Moreover, with dynamic shape changes leveraging prosthetic makeup technology, Morphace can have a color, texture, or medium change (Fig.13). These enable artificial tears, augmented facial expressions and morphology, interactive blush, encrypted freckles, and other new variable design approaches. External variability makes up a sizable portion of the overall diversity in special effects makeup based on on-body interaction.

4.3 Biocompatibility

Some special effects makeup products may contain strong chemicals that can cause serious side effects in a small number of people. Therefore, a skin compatibility test is essential. A bad reaction to the skin compatibility test includes itching, burning, stinging, heat, redness, blistering, swelling, and any other apparent reactions [42]. On the other hand, the negative list of biocompatibility is selected or occasionally developed based on the non-toxic, non-immunogenic, non-thrombogenic, non-carcinogenic, and non-irritant properties of the material. By default, such a list of negatives becomes the definition of biocompatibility [43]. On-body interaction-based special effects makeup follows a bio-driven approach, designing a type of interface in direct contact with the body. In particular, biocompatibility is assessed by applying designs that respond to the chemical compounds on human skin, bio-inspired electronic skin, artificial skin, and epidermal wearable interactive devices with on-skin displays to special effects makeup. Therefore, conventional special effects makeup materials require only skin compatibility, but designs based on on-body interaction need biocompatibility as well.

5. Conclusion

New materials and technologies are changing the entertainment industry. The use of special effects covers an extensive range of techniques, not just makeup, which opens up new research possibilities in several areas. Furthermore, special effects makeup is a field that introduces technology into art. Therefore, it can expand the scope of research through the convergence of technology and the application of other areas. Consequently, it can express futuristic technologies through on-body interaction-based research. This paper proposes an on-body interaction-based characteristic for special effects makeup.

First, input systems that recognize the body parts used for interaction must consider accessibility when designing for on-body interaction. Due to its proximity to the body, special effects makeup based on on-body interaction can access and interact with the body through sensory, visual, and kinesthetic senses. Furthermore, because different parts of the body have different physiological properties, interaction is likely to be very important. In addition, nonconventional on-body interaction locations with body appendages can also be utilized. Second, biological systems are inherently variable. Therefore, in interaction-based design, living tattoos exhibit variability when signaling chemicals are applied to the skin. In contrast, applying prosthetic makeup technology enables a new variable design approach. In special effects makeup based on on-body interaction, external variability contributes significantly to the total variability. Third, on-body interaction-based special effects makeup follows a bio-driven approach, designing a type of interface in direct contact with the body. Special effects makeup must be biocompatible by incorporating designs that respond to the chemical compounds on human skin, bio-inspired electronic skin, artificial skin, and epidermal wearable interactive devices with on-skin displays. We hope the insights provided by these three characteristics will inspire you to investigate the potential applications of special effects makeup from a new perspective and expand your skills.

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