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Responses in Light, Sound and Scent — A Therapeutic Interactive Yoga System

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ABSTRACT
We describe an interactive system that uses gesture recognition to enhance the yoga experience through visual, auditory and olfactory feedback. Ancient theories associated with Kundalini yoga provide the theoretical basis for this research. The sensory feedback provided by the Therapeutic Interactive Yoga System promotes an immersive, multisensory experience that corresponds to the system of sensory stimuli outlined by chakra theory. As a user performs yoga, the system monitors the user's body and responds with colour, sound and scent appropriate to the user's yoga postures. Testing reveals that the Yoga System succeeds in producing an "enjoyable" and "relaxing" environment — one that seems to enhance the personal, meditative and therapeutic experience of yoga.

Keywords
Interactive systems, sensory feedback, olfactory feedback, yoga, yogic postures, energy centres, chakras, experiential interface.

Figure 1: The therapeutic system in action. A user demonstrates the interactive nature of the system by performing a yogic posture and observing the corresponding projected video image.

1 INTRODUCTION

According to the tradition of Kundalini yoga, the human body possesses seven main energy centres, also known as chakras. Each chakra is the intersection of energetic pathways within the body, and speci c organs and mental states are associated with each chakra. The consistent practice of yoga seeks to open the chakras and improve energy circulation throughout the body. Kundalini theory also postulates that the body's chakras correspond to certain visual, auditory and olfactory stimuli — namely, the seven pitches of the C Major scale, the seven colour groups of the visual spectrum, and seven basic aromatherapy scents. These concepts form the theoretical basis of the Therapeutic Interactive Yoga System.

The research objective was to develop an interactive system capable of heightening the yogic experience so that it might enhance the therapeutic qualities of yoga. In order to design and build such a system, we combined aspects of yogic theory, the concept of "human energy centres" and various Human-Computer Interaction design techniques. The system was designed to monitor the user's movements and to provide the user with the appropriate visual, auditory and olfactory feedback in order to deepen the meditative experience. If one accepts that the regular practice of yoga bene ts the human body because it assists in systematically activating the body's chakras, then the Therapeutic Interactive Yoga System seeks to enhance the yoga experience by further stimulating these energy centres.

Yoga, Gesture Recognition and Sensory Feedback

Several special qualities inherent in the practice of yoga make it particularly well-suited for this type of interactive system. First of all, yoga consists of precise postures that happen slowly with long hold times. Not only does this make gesture recognition simple, it means that yoga postures are a good domain for sensory feedback — particularly olfactory and musical feedback. Because yoga happens slowly, the mood surrounding the yoga participant can "evolve" at a pace that allows auditory and olfactory displays to be effective.

Furthermore, the theory of yoga is well established. The postures are well-defined and the gestural language is already learned. Combined with the slow time scale that defines the transition from one posture to another, this greatly simplifies gesture recognition. If we are able to track a few points on the participant's body, an algorithm that considers simple Euclidean distances in a static time slice is all that is required for effective and efficient yoga posture recognition.

Therefore, on both the input side (recognition of postures) and the output side (sensory feedback), yoga is a good match with a multi-sensory, interactive system. In terms of testing an experience that relies on ambient visual, auditory and olfactory feedback, we feel that yoga provides a good testing ground. Moreover, yoga theory outlines a system of appropriate sensory stimuli that correspond to certain postures. Given this framework, yoga is an excellent domain in which to test a multi-sensory "experiential" system.

Energy Centres and Sensory Feedback

From a physiological perspective, the human body's seven chakras correspond to the seven main nerve ganglia that branch from the spinal column [1]. Some physiologists claim that each chakra holds the energy key to its associated area of the body [10]. By bringing energy into each of the seven chakras, one is able to unblock and release life force. Yoga, a Sanskrit word that literally means "union" or "joining together," has as its purpose the unification of body, emotion and mind by activating the chakras. Each chakra may be activated or stimulated by a particular yoga posture or set of postures. Also associated with each chakra is a colour, a pitch and a scent [5]. Table 1 outlines the relationship between the energy centres and various types of sensory stimuli.

The Therapeutic Interactive Yoga System (also known as The Yoga Project) has as its theoretical basis the concepts described above. Briefly, the idea behind the Yoga Project is this: as the human body is positioned into a certain yoga posture (thereby activating a particular chakra), the yogic experience may be enhanced if the body receives the sensory stimuli that correspond to the "activated" chakra. Therefore, the project was conceived with the idea of providing feedback to as many senses as possible in order to produce what some authors call "encompassing experiential enhancement." The goal is to deliver visual, auditory and olfactory stimuli to enhance the yoga experience in a "holistic" manner.

2 RELATED WORK

Among the existing projects relevant to the design of the Therapeutic Interactive Yoga System, some projects relate to the gesture recognition component of the Yoga Project. Other research pertains to the production of a multi-sensory "enhanced experience."

BioMuse

The BioMuse is a bio-electric signal controller that allows users to control computer functions directly through eye movement or brainwave signals. The BioMuse does not rely on a traditional input device. Instead, signals are acquired by attaching non-invasive transdermal electrodes to the body. The device amplifies these "biosignals," digitizes them, and then uses its library of algorithms to process the signals. Intended primarily as a development platform, the BioMuse is advertised as being able to "control virtually any digitally interfaced device" [2]. We studied the BioMuse in order to consider how a "non-traditional" input device might be used effectively.

Chakra	Colour	Pitch	Scent
Crown	Violet	B	Lavender
Third Eye	Indigo	A	Patchouli
Throat	Blue	G	Geranium
Heart	Green	F	Eucalyptus
Navel	Yellow	E	Rosemary
Spleen	Orange	D	Melissa
Root	Red	C	Ylang-ylang

Table 1: The relationship between chakra, colour, pitch and scent. "Crown" refers to the top of the head. "Third eye" refers to the middle of the forehead.

We do hope that the Yoga Project is able to make a "connection" with the participant's body. However, when it comes to acquiring input data for the Therapeutic Interactive Yoga System, we are not interested in measuring what is going on inside the body. The theory of yoga takes care of this — it describes a system of postures that relates body position to chakra activity. Our goal is not to measure "chakra activity" directly. We believe that monitoring body posture (and the transition from one posture to another) is sufficient as input for the Yoga Project.

WorldBeat

With their research into musical design patterns, Jan Borchers and Max Mühlhäuse examine semantic models and suitable interaction metaphors for interfacing with multimedia data. They point out that "most multimedia data today is sampled and quantized from analog sources. Even with sophisticated recognition and indexing techniques it remains difficult to associate human-centered, semantic content and structural information with it" [3]. Their artistically innovative WorldBeat system is an attempt to overcome what they call the "multimedia semantics problem." One component of the WorldBeat exhibit is the Virtual Baton, a system that allows users to influence the tempo and dynamics of prerecorded MIDI tracks by "conducting" the playback.

The gesture recognition component of a device like the Virtual Baton must be fast, sophisticated and accurate. The composer may move her or his hands quickly, and such movements must be identified and relayed to the system al-

Figure 2: A recommended asana for position number one.

most instantaneously. Time lag between input and output ruins the experience and cannot be tolerated.

Such problems are not large obstacles for the Therapeutic Interactive Yoga System. Posture recognition must be accurate, but by taking advantage of the nature of yoga (slow with long hold times), the gesture recognition software can monitor the user's movements over relatively long time intervals (*e.g.,* every 5 or 10 seconds, instead of milliseconds for a system where speed and time lag are critical). The entire process of yoga is relaxed — this greatly simplifies gesture recognition.

Manjushri Mandala System

The Manjushri Mandala System [11] produces rich patterns of colour and projects them onto a cinema-sized screen. The effect is described as "pleasing and relaxing" as users observe colourful kaleidoscopes on the large screen. A mandala is a symbolic pattern (usually in the form of a circle) divided into four separate sections or bearing a multiple projection of an image. Most mandala forms are symmetric with respect to rotation and they are designed to draw the eye of the observer to the centre of the image. Used as an aid to meditation, the Manjushri Mandala kaleidoscopes are composed of large flickering pixels that rotate in mandala forms. Although not an interactive system, the Manjushri Mandala System succeeds in promoting a powerful, relaxing effect. The Yoga Project hopes to foster a similar effect — but with a more sophisticated, interactive system.

Immediate Future Productions

Among the various yoga enhancement systems are the "Video Music" productions by Immediate Future Productions (IFP). The team at IFP works mainly on visual and music effects for New Age artists, as well as the production of "instructional and experiential videos" [7]. Their Video Music productions present images and music in synergistic interplay. Video Music is designed to generate a sense of peace and inspiration. Some of IFP's work has been included on instructional yoga videos.

Like the Manjushri Mandala System, IFP's Video Music is not an interactive system, but it succeeds in producing a meaningful, meditative experience. As mentioned, the Yoga Project also seeks to produce an immersive experience, but one that is interactive and includes not only visual and auditory displays, but olfactory feedback.

Iamascope

The Iamascope is an interactive multimedia experience in which the participant has direct input into the system's visual and auditory feedback [4]. As the performer stands in front of a large circular screen, his or her movements are monitored by a video camera. A computer incorporates the performer's movements when generating a dynamic mandala-like visual scene. The resulting kaleidoscopic motion and colour imagery are projected onto the screen. The experience is enhanced with the addition of musical tones, also based on the participant's movement. The participant is rewarded with immediate and direct visual and auditory feedback, as exquisite kaleidoscopic variations and rich sustained choral sounds are synchronized with the visual image. With practice, many performers are able to obtain a high level of control and creativity with the Iamascope.

The Yoga Project aims to create an effect that is in some ways similar to that of the Iamascope — certainly, the Yoga Project seeks to re-create the interactive nature of the Iamascope. However, unlike the Iamascope that has no gestural language, the Therapeutic Interactive Yoga System bases its gestures on the well-defined theory of yoga.

3 SYSTEM DESIGN

As mentioned above, the core structure of the project's design is the chakra system with its corresponding colours, pitches and scents. Based on this framework, a set of yoga postures were selected to correspond to each chakra. Initially, seven asanas (yoga postures) were chosen, but this set was reduced to four in order to simplify the design and the testing of the system. These four postures are shown in Figures 2 to 5.[1]

Four modules

During the design phase of the project, four system "modules" were proposed — gesture recognition, visual feedback, auditory feedback and olfactory feedback.

- A Polhemus Fastrak 3-D motion tracking device was chosen as the key input device for what would become the "gesture recognition module." The main requirements of the gesture recognition software were that it

[1] Figure 2, Figure 3, Figure 4 and Figure 5 featured at Holistic Online, *http://www.holisticonline.com*

Figure 3: A yoga position compatible with "Position Two."

Figure 4: Asana for yoga position number three.

be able to record and identify yoga postures reliably. Logic control for switching between "posture stimuli" would also be handled by the gesture recognition module.

- A colourful kaleidoscope was selected to approximate yoga mandalas. Initially, a set of solid colours was proposed for the "visual feedback module." However, research into other therapeutic systems[2] indicated that a mandala/kaleidoscope effect would be preferable.
- Auditory feedback was to consist of a "module" capable of playing several distinct audio tracks. All music for the Yoga Project would be written specifically for the system using MIDI software and a MIDI keyboard. As the Yoga Project was designed to promote a meditative experience, the music tracks were to be composed with smooth transitions and a "relaxing" quality.
- The module for olfactory feedback presented a challenge since there is little existing research and literature on scent/smell systems. This meant the Yoga Project needed a creative solution for the production of olfactory feedback. The requirements of the "aroma module" were that it be capable of producing distinct aromatherapy scents on demand.

All of the feedback modules represent a first step in producing a meaningful sensory experience. From the beginning of the design stage, it was hoped that user testing would help the system to evolve — allowing the project team to refine each of the feedback modules and further enhance the experience.

4 IMPLEMENTATION

Essentially, the Therapeutic Interactive Yoga System involves a single user who performs yoga while three Polhemus Fastrak sensors are attached to the user's body — one on each hand or wrist, and one on the chest or neck. The Polhemus unit is connected to a Linux workstation that records and recognizes yoga postures and then co-ordinates the sensory feedback modules of the system. A video projector and a large screen are the key components of the visual feedback module. Auditory feedback is played through a MIDI system on multimedia speakers. Olfactory feedback is handled by an X-10 Home Automation package connected to the Linux computer and to several Spa Scenter[3] Professional Aromatherapy Diffusers.

Figure 5: Asana for "Position Four."

Design Decisions — Colour, Pitch and Scent

Despite the fact that most of the literature on chakras focuses on seven distinct energy centres, recent versions of the Yoga Project record and recognize only four asanas. The decision to "go to four instead of seven" was made partly out of necessity, but also because we felt a four-asana version created a better experience — at least, for a project at this stage of development.

The first versions of the Yoga Project dealt with seven specific yoga positions, as described by chakra theory. Very quickly, it became obvious to the project team that this was not a good solution for a project in early development. First of all, obtaining more than three aromatherapy diffusers proved difficult. Also, the X-10 hardware and set-up was costly, and the equipment required to interface with seven aromatherapy diffusers would have been even more so. Then, there was the question of filling the room with seven varieties of scented oil — it was thought that this would be overwhelming. We opted for more experience with the aro-

[2] In particular, Manjushri Mandala and IFP's Visual Music.

[3] A trademark of Hubmar Incorporated.

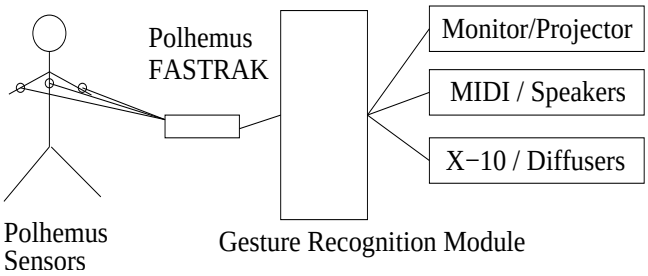

Figure 6: Sketch/overview of the system's components. Within the GR module is a process that reads the data from the Fastrak sensors and communicates with three processes — each responsible for one of the three output devices. The main GR process also interfaces with a database of postures. This gesture database is built during the calibration or "training" phase.

matherapy diffusers before subjecting our participants to a room brimming with scented oil.

Furthermore, the visual feedback system seemed to perform poorly when limited to a narrow range of colour. Only a pulsating red mandala was deemed "interesting." Other kaleidoscopes restricted to such a narrow range were innocuous, but not captivating. By combining shades (Violet and Indigo together, for example), the mandala affect was much improved.

Seven positions also created trouble for the participants involved in testing the gesture recognition module. Half of the participants were new to yoga and they found it difficult to remember seven distinct positions. They would often "lose" a position — after programming seven positions, they were not be able to remember all seven. These new-to-yoga participants were used to iron out bugs in the system. Future testing aimed at refining the experience produced by the Yoga Project will include mostly experienced yoga practitioners. The section on Future Work discusses how a seven-asana version of the system might fit into the next phase of comprehensive user testing.

Based on our experience with the early versions of the system, the decision was made to cut the number of yoga positions to four. This way, good use could be made of the three available aromatherapy diffusers (no scent for the root position, but Lavender for Crown/Third Eye, Eucalyptus for Throat/Heart, and Rosemary for Navel/Spleen). The mandalas projected on the laboratory screen had more life, and the test subjects found the whole procedure of performing asanas much less frustrating. Table 1 was redrawn for the Yoga Project tests — as shown in Table 2.

We acknowledge that this deviates slightly from the theory of chakras and stimuli, but we feel it still supports the fundamental concepts behind the practice of yoga. With the exception of three "forgotten for the moment" scents and music

Position	Chakras	Colours	Pitch	Scent
1.	Crown Third Eye	Violet Indigo	B	Lavender
2.	Throat Heart	Blue Green	G	Eucalyptus
3.	Navel Spleen	Yellow Orange	E	Rosemary
4.	Root	Red	C	None

Table 2: The relationship between yoga position, colour and scent for the four-asana version of the system.

tracks, energy centres still receive the stimuli prescribed by the original "formula." At this point in project development, we are unable to provide the full complement of scents, so the olfactory stimuli component of the project had to be compromised. However, even if we were able to produce seven scents, with little Human-Computer Interaction literature on olfactory stimulation, it might be prudent to be careful with the noses of our participants.

That said, this is an initial experiment with olfactory stimulation; future versions of the Yoga Project will improve on the work done so far. Adding aromatherapy and X-10 hardware, while expensive, is not so difficult now that we have a fully functioning four-asana version of the Yoga Project. Even though we had to cut some corners on the system, we feel we were able to preserve key elements of the initial vision — we have produced a system that creates a multi-sensory, interactive experience. Rather than apologizing for the four-asana version, we choose to celebrate it as a first step.

Here is a re-cap of the Yoga Project's components:

- Visual feedback in the form of a computer-generated pulsating mandala, with four programmed colour options, sent to a video projector.
- The sound component consists of four looped music tracks which play through a MIDI system. The sound is then sent to a powered speaker system.
- The scent module relies on an X-10 home automation system. Three aromatherapy diffusers are connected to three separate X-10 appliance modules. Control of the X-10 master module is handled by the Linux workstation.

Gesture Recognition

Recording the yoga postures and "recognizing" them is done from within a TCL/Tk control panel. First, the control panel allows the system to be calibrated for the current yoga participant — based on the position of the three Fastrak sensors. During this "training" phase, the participant performs and holds all four yoga postures. After this information is collected, a simple algorithm that relies on Euclidean distance measures handles the "recognition" of one posture from an-

other. Information from the Polhemus sensors is sampled every five seconds. We feel this to be more than adequate for the recognition of yoga asanas. Other more sophisticated algorithms for posture recognition where examined, but because yoga postures are fairly precise and they are held for minutes at a time, this simple solution was selected and implemented.

Visual Feedback
The inspiration for the visual feedback component of the Yoga Project lies in a yoga video produced by Shirley MacLaine in the late 1980s. *Shirley MacLaine's Inner Workout* [8] presents viewers with delicate, pulsating mandalas that gradually shift through the visual spectrum, accompanied by selections of pre-recorded music and MacLaine's voice. We sought to re-create the mandala effect found on *Inner Workout*, but also to make the visual feedback component part of a truly interactive experience.

After a bit of research, we decided to go with a series of kaleidoscope-esque patterns that vary in colour according to the participant's current yoga position.

Auditory Feedback
The music that plays through the small multimedia speakers was composed exclusively for the Yoga Project. Using Cubase software and a Yamaha EX-5 keyboard, MIDI tracks were written that conformed to the project requirements:

- All tracks are soothing and relaxing.
- The four tracks selected for the final testing and the final demo are in the keys of B, G, E and C.
- No sharp transitions exist at any point on any track.

The MIDI tracks are all 16 bars long, and they are looped so that they may run indefinitely. As the user moves from one yoga posture to another, the Linux computer raises the volume on one MIDI track while lowering the volume on the currently playing track. Transitions are smooth and pleasing.

Olfactory Feedback
The "smell module" of the Yoga Project was a challenge. Unable to find much literature on how to successfully incorporate olfactory feedback into an interactive system, we built and tested a makeshift computer-controlled aromatherapy "multidiffuser."

The multidiffuser consists of three Spa Scenter diffusers are each plugged into an ActiveHome X-10 Appliance Module. Lavender scented oil is added to one of the diffusers. A second diffuser gets Eucalyptus oil and the third receives Rosemary. The Linux computer interfaces with the X-10 Command Module and controls the power supply to the diffusers. As the participant makes a transition from one yoga posture to another, the appropriate diffuser is turned on and any diffuser currently running is switched off. This part of the system works surprisingly well. Scent changes are subtle, but noticeable, and contribute to the experience.

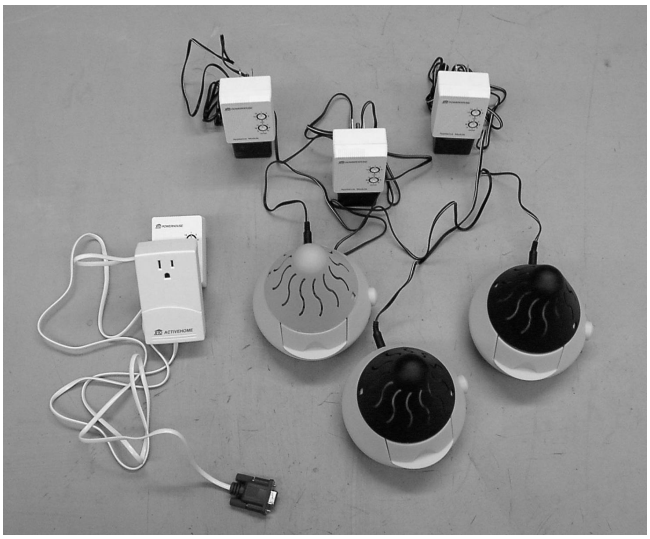

Figure 7: X-10 switching hardware shown with three aromatherapy diffusers.

5 TESTING / USER FEEDBACK

The Yoga Project was designed to be simple to use. However, as no users' manual exists at this early stage in development, a trained "operator" was present for all trials and demonstrations of the system.[4] Among those who participated in the testing of the Yoga Project, no one felt that the system was complicated or difficult to use, but everyone appreciated the presence of the operator to explain the theory behind the project and the calibration procedure. Once "calibrated," most people could use the system by themselves, but the calibration procedure proved difficult for one person alone.

Four test subjects were used during the preliminary tests. According to the participants, the gesture recognition module did not make any noticeable errors. The system reliably recorded and identified positions that ranged from nearly identical to, in the words of one participant, "completely wacky." In order to further test the system, during one demonstration, the operator taped two of the Fastrak sensors to the surface of a desk and moved the remaining sensor to record subtly different "postures." The system made no errors and identified the changes as different postures — even these slight changes were enough to trigger the logic of the gesture recognition software. Euclidean distances and the sensitive Polhemus Fastrak appear to be excellent choices for this type of system.

[4] Demonstrations of the Yoga Project took place in the Human Communications Technology (HCT) research laboratory at the University of British Columbia.

There were only good comments on the visual feedback module. Those with yoga experience found the kaleidoscope effect and the colour changes to be appropriate. Colours matched with their knowledge of chakra theory. With the lab lights turned off, the projector bathed the participants in light, just as anticipated.

The mandalas were "best liked" by the participants, but the auditory feedback was a close second. No one found the music intrusive, and 75% of test subjects found that the music enhanced the experience. Roughly 25% of the participants were disappointed by the quality of the sound coming from the diminutive speakers. Such criticism was not directed at the music *per se*, but at one component of the audio system.

The olfactory feedback system also received positive comments, but the majority of the participants were unsure whether or not the aromatherapy oils greatly enhanced their experience. They enjoyed the scents from the diffusers, but could not reliably identify which scent was predominant at any particular time. The large lab space with poor ventilation is quite probably a factor; as is the fact that no one has spent more than one hour (total) with the system. In a sense, the "smell module" is too much of a novelty. More testing and research is required in analyzing the system's olfactory feedback. Still, this part of the Yoga Project represents a breakthrough of sorts.

6 CONCLUSIONS AND FUTURE WORK

We feel that this system needs a more thorough and comprehensive evaluation of what has been called the "experience" it promotes. However, even from the preliminary testing described above, it seems as though the Yoga Project succeeds in cultivating an "enhanced" environment for the practice of yoga. In this sense, the project is a success — the system responds to a single user's movements and provides him or her with visual, auditory and olfactory feedback which, according to the theory behind the project, enhances the meditative and therapeutic experience.

That said, research is never complete when design is based only on theory. Good HCI relies on user testing as well as on user-centered design. Preliminary user testing is promising — we can safely say that all participants have "enjoyed" their Yoga Project experience. However, such early results are very limited. More user testing is required to evaluate the system and to "fine tune" the sensory feedback, so that the initial thesis of yoga enhancement through sensory stimuli can be more fully explored.

Such testing might help us further develop the theory of chakras and visual, auditory and olfactory stimuli. By consulting those who know a lot about yoga, the project team might be able to refine the gestures and stimuli to further enhance the experience. This could be done with or without major changes. For now, the four-asana version is recommended. However, over time (and with a few more research dollars) a fully-functioning seven-asana version should be developed.

Related to questions regarding the future development of the system are concerns over the "purpose" of the Therapeutic Interactive Yoga System. The "role" of the system has yet to be defined. Is the Yoga Project a teaching tool? Is it a personal relaxation device? Perhaps the Yoga Project can do both.[5] By consulting yoga instructors, the uses of the Therapeutic Interactive Yoga System might become more clear. It could then be tailored to fit different purposes — perhaps different versions could be developed to suit different needs.

The best way to describe the Yoga Project in its current state is to say that it is an excellent first step. We have been able to create the type of multi-sensory, interactive experience imagined at the beginning. What remains is to further examine people's reaction to this environment and then to tailor the experience so that it may be more profound and more meaningful.

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