

The Living Room: Exploring the Haunted and Paranormal to Transform Design and Interaction

Michelle Annett^{1,3}, Matthew Lakier², Franklin Li², Daniel Widgor¹,
Tovi Grossman³, George Fitzmaurice³

¹ DGP Lab, University of Toronto
Toronto, Ontario, Canada
{mkannett, daniel}
@dgp.toronto.edu

² University of Toronto
Toronto, Ontario, Canada
{franklin.li, matthew.lakier}
@mail.utoronto.ca

³ Autodesk Research
Toronto, Ontario, Canada
{tovi.grossman, george.fitzmaurice}
@autodesk.com



Figure 1. Design concepts exemplifying various elements of Haunted Design: (a) Awakenings, (b) Séances, and (c) Raising the Dead.

ABSTRACT

Within this work, a novel metaphor, *haunted design*, is explored to challenge the definitions of ‘display’ used today. Haunted design draws inspiration and vision from some of the most multi-modal and sensory diverse experiences that have been reported, the *paranormal* and *hauntings*. By synthesizing and deconstructing such phenomena, four novel opportunities to direct display design were uncovered, e.g., *intensity*, *familiarly*, *tangibility*, and *shareability*. A large-scale design probe, *The Living Room*, guided the ideation and prototyping of design concepts that exemplify facets of haunted design. By combining the opportunities, design concepts, and survey responses, a framework highlighting the importance of *objects*, their *behavior*, and the resulting *phenomena* to haunted design was developed. Given its emphasis on the odd and unusual, the haunted design metaphor should great spur conversation and alternative directions for future display-based user experiences.

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INTRODUCTION

Weiser’s vision for computing describes a world in which “the highest ideal [should be] to make a computer so embedded, so fitting, so natural, that we use it without even thinking about it” [45]. Over the last decade, advances in gestural interaction have enabled the ‘natural’ to become reality, however the ‘embedded’ and ‘fitting’ have yet to truly come to fruition: smartphones, smart watches, and screens have a rectangular form factor, bezel, and blinking LEDs for status or notification, and auditory displays employ sounds and tones that are synthetic and unnatural, disrupting the auditory landscape of a space or environment. While more soothing sounds or pleasing blending methods could blend could be used, these are but temporary solutions. We fear that if designers do not break away from their reliance on conventional designs, spaces will eventually become completely void of the elements that evoke personality, tangibility, and memory. The juxtaposition between the design of objects and products, and the languages of our spaces and possessions, invites the question: how do we fully realize the embedded nature of Weiser’s vision if beliefs regarding displays remain unchanged?

Others have identified the need to challenge the metaphors guiding product or interaction technique design. The most provocative and stimulating of this work looks towards unfamiliar ideas and domains for inspiration. Anderson et al. utilized facets of magic and misdirection to enable new input and display concepts for subtle interaction [3]. Yu and Nam [48] analyzed existing ‘humorous’ products to uncover design properties useful for bizarre and unexpected interactions. Virolainen and colleagues uncovered not only the technical challenges of working with materials such as ice, but also considerations for semi-temporary interfaces [44]. These viewpoints’ reliance on defamiliarization [4] created mindsets that encouraged deviation from desires for increased efficiency, functionality, and optimality [11, 34, 36]. The present work harnesses this by utilizing the paranormal and hauntings as inspiration.

Paranormal or *haunted phenomenon* are experiences in which the ‘witness’ perceives an event whose explanation falls outside traditional scientific justification. For example, objects suddenly fall to the ground, strange sounds are heard, or ghostly figures and spirits appear. Such experiences are rare, but universal in their perceptibility, ignoring gender, socioeconomic status, and culture [40]. They occur at night and during the day, target individuals or groups, and play with the senses to shock, surprise, or instill fear. Their tangibility and reliance on real-world objects makes them ripe for application to HCI, as they can add physicality and weight to the events, notifications, and data that feed displays. The unpredictable nature of the haunted and paranormal makes them a rich viewpoint from which to reexamine notions of display.

Using a combination of elicitation survey responses, design probes and concepts (Figure 1), and the research through design methodology, this work contributes the notion of *haunted design*, the application of the unusual and unknown to the design of experiences and displays. We synthesize haunted and paranormal phenomenon, highlighting the role of tangibility, familiarity, intensity, and shareability. We then detail the use of *The Living Room* as a design probe, and five design concepts that exemplify haunted design. We conclude with a framework to assist the development of displays and objects that harness the unknown. The work should spur discussion, and be of interest to the designers of artifacts, interior spaces, and themed-experiences, along with those who suspend disbelief, such as magicians or psychics.

RELATED WORK

Reimagining the display requires reflection on the present design of displays and technology for everyday life, along with an eye towards work that has utilized the paranormal and hauntings as inspiration. Research from these areas is reviewed to provide context for our exploration.

The Paranormal and Haunted as Design Inspiration

Facets of the paranormal and supernatural have been a source of inspiration for developers and engineers before. Agarwal and colleagues created ‘phantom presence’ visualizations of

remote user’s hands [1], whereas TouchGhost provided users with visualizations of possible actions within a multi-touch system [42]. Schmidt and colleagues created a virtual bulletin board to harness déjà vu [35]. Recent work by Dong, Ackerman, and Newman utilized the concept of *Phantoms* as representations of past occupants of a home to illustrate potential uses of activity traces [8]. Work by Marshall [25], Svanaes and Verplank [38], and Marshall, Benford, and Pridmore [26], explored how techniques used by magicians and illusionists can be applied to computer-aided performance, tangible user interfaces, and collaborative interaction, respectively. Each project explored only one haunted or paranormal experience, however their success underscores the potential of utilizing the totality of such a metaphor to reexamine display and interaction.

Designing Displays for Domestic Life

With the ubiquity of technology, many have focused on issues relating to the integration of technology with domestic life. There has been much research into alternative ways that displays can be used in the home, most from the domain of ambient displays. These ‘displays’ are often new objects or installations that are *added* to an environment and borrow heavily from art and design, using form, space, and movement [28] to draw attention or display information, alerts, or notifications. Although plants [7, 16, 19] and abstract forms and artwork [9, 18, 24] are common, other form factors including tables [6], power cords and outlets [12, 14], mirrors [10, 20], and fish tanks [31] have also been used. There have also been projects focused on adding collections of ambient displays to an environment (e.g., ambientROOM [17], Ambient Kitchen [31], and so on). While these projects explored a multitude of form factors for notification and alerts, the majority make use of light and color to convey information. Unlike the present work, they do not challenge how constructs such as fear, the unusual, or uncanny can be used for display nor do they stimulate all the senses.

Coupled with the design of ambient displays has been the development of principles, taxonomies, and frameworks to follow when designing such displays. Many have suggested characteristics such as aesthetics, intrusiveness, interactivity, abstraction, location, modality, and consistency [2, 28, 29, 41]. Although some dimensions are found across multiple taxonomies (e.g., abstraction and notification), overall, they lack a focus on elements crucial to domestic objects, such as the behavior and original use of objects, opportunities for augmentation, or goals aside from visual output. The tangibility of the haunted and paranormal allowed for these, and other dimensions to be explored, along with disengagement from conventions of domesticity and functional fixedness.

DISRUPTION OF DOMESTIC LIFE

Although the elements of the haunted and paranormal could be used to direct design choices for any domain or technology, the focus within this work was narrowed to identify their applicability to domestic situations. We

specifically focused on the space and contents of rooms that have dynamic activity and occupancy patterns such as living rooms. To ground the appropriation of the paranormal and hauntings within the home, an 18 question elicitation survey was administered on a crowdsourcing website. Respondents completed open-ended and Likert-type questions about the activities and décor of their living room (e.g., family room, den, and so on). Forty North Americans responded (M = 38 years, range of 21-64 years, 24 female) and were compensated \$10 for their participation.

The results revealed many insights into materialism and aesthetics. For most, living rooms were spaces for watching television, playing video and board games, surfing the internet on cell phones, and socializing with others (88%). Over half of respondents also viewed them as multi-functional spaces that included elements of an office, bedroom, home gym, or dining room. Functional objects such as couches, coffee tables, bookcases, televisions, video game consoles, and laptops were most common (i.e., 98% reported some combination of these). Wellness (e.g., salt lamps, yoga balls, water fountains), aesthetic (e.g., mirrors, artwork, plants), and sentimental (e.g., a painting of Bruce Willis, a ceramic pineapple dish, pictures of family and friends) objects were also popular. These diverse activities and objects, while contradictory to Venkatesh et al.'s view of domestic spaces as distinct rooms [43], illustrate how blended the social, technological, and physical are and suggest many avenues for new concepts of display.

Many reported that the look and style of their living room was important (Median Response: Very Influential) and ultimately viewed this an extension of themselves, e.g., “my room reflect[s] my style and what I love”. Others noted that décor “gave [their] room a distinct character” and that they wanted their living rooms to be *friendly*, *warm*, *personal*, and *attractive*. Sentimental value was important for ninety percent of participants (Median Response = Very Influential), with many describing the origin and story behind their most precious items, unprompted. This attachment and self-reflection speaks directly to issues found with devices today: they provide functionality but do not fit in because environments and contents are so unique and personalized. Although they invoke emotional reactions, the infrequent use and movement of sentimental objects also emerged, i.e., “while I like having things around, they usually just sit there and take up space”, “once I put it on the shelf, it doesn’t move and I often forget about it”. This lack of interaction with our possessions indicates that there is a need and space to reconsider how such objects can be used for more than simply reflection and remembrance.

The tension between materialism and minimalism was also poignant. While respondents enjoyed having décor “to make sure there was something and it wasn’t bare”, many ask

themselves “if an item adds or overwhelms the current items in the room” to make sure that they “don’t have too much clutter”. This tension echoes Lynggaard, Peterson, and Hepworth’s interviews with luxury homeowners [23] but contradicts popular thinking, wherein the addition of new objects into an environment is trivial, as it is the added functionality that is most important. This tension speaks directly to the difficulties of integrating new elements within established environments, while desiring to create consistent aesthetics and opportunities for remembrance.

The totality of responses highlights the ever-changing role of the living room in domestic life. Given the diversity and meaningfulness of objects in one’s space, viewing domestic objects through lenses inspired by alternative phenomenon should allow for new considerations regarding the fusion of functionality and display methods and forms.

THE UNKNOWN AND UNEXPLAINABLE

Many have experienced unusual sensations or events such as chills running up their spine, doors closing unassisted, or hearing footsteps. The *uncanniness* or confusion about these situations is typically low, as source stimuli can easily be found (e.g., an open window, a draft in a room, etc.). On the other hand, seeing a ghost, feeling as if someone is watching you, or having an out of body experience are uncanny and difficult to explain. While these unexplainable events may be attributed to mystic beings or paranormal transfers of energy, anomalistic psychology has focused on understanding the scientific basis governing such experiences. In reality, these experiences are largely hallucinations or confusion regarding source stimuli and sensations [33], the result of high levels of susceptibility in witnesses [15, 40], or electromagnetic events within the brain [5, 33]. The present work focuses on how displays can benefit from the contexts, sensations, and reactions surrounding haunted experiences.

As the paranormal and haunted is infrequently studied, literature from anomalistic psychology, blog posts, and online forums were reviewed, in addition to films and documentaries (e.g., from top movie lists on Forbes, imdb, and so on)¹. A list of haunted and paranormal experiences that were reported or used cinematically was compiled for each source. A thematic analysis using affinity diagramming was then undertaken to understand the circumstances surrounding the events, the modalities implicated, and the reactions reported. Through this process, many unique themes regarding haunted-focused design emerged. The four most prevalent are presented below.

Tangibility

There is a continuum along which tangibility influences the experience. Some experiences relied on *objects* to catalyze the senses: books, doors, keys, lamps, pets, branches, etc. Such *high* degrees of tangibility make experiences less

¹ Publications within the Journals of Exceptional Experiences and Psychology, American Society for Psychical Research, Neuropsychiatry and Clinical Neurosciences, Perceptual and Motor Skills, and so on over the

last ten years. Postings on Unexplained Mysteries, ParanormalSoup, Talk Paranormal, DMOZ Paranormal, Anybody There, and so on.

uncanny, as once the initial shock of the stimulation is over, one can easily attribute the experience to its source. Experiences with *moderate* tangibility, however are the by-product of *environmental* factors such as air pressure, temperature, air flow, and so on. The lack of an explicit sensation-source pairing decreases one's ability to find an explanation for the sensations perceived, thereby increasing confusion. The least common, albeit most memorable, experiences were those that were *intangible*. These experiences were entirely *cognitive* in nature (e.g., déjà vu, psychometry, being possessed) and were the uncanniest of all. The manner and degree to which the tangibility of our objects, mementos, and spaces can be harnessed for display thus opens many exciting avenues.

Familiarity

The reported experiences seem to suggest that one's degree of comfort, history, and knowledge with a space or object influences the occurrence and memory of the experience. In most cases, witnesses were very *familiar* with the environments where haunted or paranormal events occurred (e.g., in their bedroom, the house they grew up in, their place of employment, and so on). This exemplifies desensitization, as it is when we become accustomed to certain collections of stimuli that we are better able to filter them from the environment and make way for the detection of, and attention to, anomalies. As one's comfort and ease within an environment and space is often neglected by developers and designers, this theme challenged us to reconsider how the familiar can be made unfamiliar, or how the unfamiliar can be used to camouflage and obfuscate display.

Intensity

A prevalent theme that emerged was the intensity and nature of the stimuli that surround paranormal experiences. Phenomena perceived to be *less* intense involved predictable elements that stimulated *one* or *two* senses (e.g., a change in temperature or pressure, an object appearing in a new location). Others, such as near death experiences or being shoved, involved a *multitude* of sensory stimulation (e.g., haptic and audition) and were disruptive in a *highly* intense manner. More intense experiences appeared to be more memorable. This complements familiarity, as repeated presentations of intense experiences increase opportunities to find stimuli sources, eventually decreasing uncanniness and impact. However, this theme places emphasis on the sensations and modalities themselves, rather than situations and contexts. Such multi-sensory experiences underscore the importance of considering the holistic experience attached to a display, not simply the look and feel.

Shareability

The social and communal nature of haunted experiences was very prevalent. If something brushes your arm, tastes unusual, or if you hear whispering, you are likely the only one to perceive such *private* events. Other experiences, such as watching a book fall to the floor or a space feeling musty and damp, are *public* and can be perceived by a *group*. Still others, e.g., seeing hidden messages or a picture slightly

rotated, occur in the *public* realm but are perceived by an *individual*. Unlike depictions in movies, our readings suggested that it is very rare for groups of users to experience the same haunted or paranormal event, or even in the same manner, i.e., being asked "did you just see that?" was commonly reported. The possibility for information to be sensed and perceived in different ways, or targeted towards different users offers many opportunities for display and interaction, especially when the public-group versus public-individual distinctions are considered.

DESIGN INSPIRED BY THE HAUNTED

Given the desire for materialism that the online survey revealed and the variability of haunted experiences reported, haunted design was explored through a large scale design probe, *The Living Room*, and five design concepts.

The Living Room as a Design Probe

To lessen the limitations imposed when working within a space that doesn't exhibit mutability, a temporary installation, *The Living Room*, was constructed. The space was 5 m x 3 m in dimension and contained two free-standing walls that could be reconfigured or modified as necessary. The Living Room was modelled after the living rooms found in traditional North American detached houses (Figure 2). The space was filled with a variety of furniture (e.g., couches, end tables, TV stand), fixtures, décor, and objects to serve as probes and inspiration for our team.

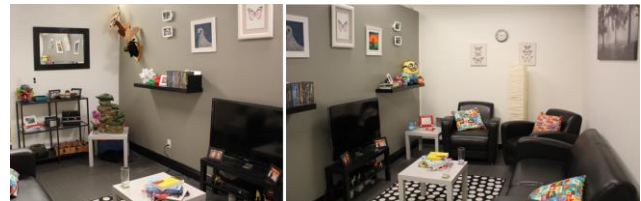


Figure 2. *The Living Room*, which served as the design probe for our exploration into haunted design.

It was deemed necessary to construct and work within such a space to allow for in situ ideation on activity patterns and traces, occupancy, and usability. The ability to augment, destroy, rearrange, remove, and add elements as necessary allowed for a holistic exploration of haunted design and uncovered possibilities otherwise constrained by pre-existing walls, furniture, and fixtures. Working individually encouraged reflection on form and tangibility, whereas with higher occupancy, we were naturally inspired to think about spatial location, line of sight, occlusion, subtlety, and so on. The inclusion of children's décor naturally encouraged us to consider all ideas, including the outrageous and whimsical.

Although guided by haunted experiences, less emphasis was placed on conceiving methods of display that could be construed as unethical, involve physical harm, or induce intense cognitive feelings (e.g., delusions, near-death experiences). As such, we explored concepts exhibiting moderate to high degrees of *tangibility*.

Haunted Design Concepts

After designing and working within The Living Room, many ideas and concepts were generated. In what follows, five concepts that best illustrate different facets of haunted design are explored. The first concept, *Awakenings*, explores how the tangibility and movement found with haunted experiences can be appropriated for display. The second concept, *Raising the Dead*, plays with the notion of the environment having a personality and using physical representations to convey dashboard-like information about a space. The third concept, *Séances*, explores communicating data through methods commonly used by the paranormal. The last two concepts, *Voices in My Head* and *Sensory Transduction*, explore how the intensity and transformation of sensory input can trick or confuse the viewer.

As physical prototypes and probes are important aspects of the design process for many, after inception, each concept was transformed into working prototypes. Numerous techniques and technologies were experimented with, not only to bring each concept to reality, but to allow for a further understanding of the implications of haunted design. Each concept used Arduino microcontrollers for control (i.e., Pro Mini, Duemilanove, Leonardo, or Mega R3) and ESP 8266 Wi-Fi modules for remote activation. While the aesthetics of the concepts may not exemplify cohesion across The Living Room, or fit within every household, we wanted to examine opportunities that covered a spectrum of design possibilities.

Awakenings

The awakenings concept is rooted in the *tangibility* that catalyzed many haunted experiences. If we consider the awakening and movements of a ghost or spirit through a room or space, such movements would cause objects to become slightly misaligned, fall off the shelf or table, etc. We argue that such events could become displays, making use of smooth, subtle, irregular, or jarring motions. Movements by a ‘ghost’ could result in a picture frame sagging to one side, or objects on a shelf becoming misaligned or falling to the floor, levitating in the air, or causing deviations (Figure 1, Figure 3). In prototyping such experiences, a variety of servo and vibrating motors were embedded within walls, shelving, and an artificial plant to create rotation, translation, or irregular motion.

Singular objects displaying these behaviors could allow for state-based information to be conveyed to an occupant, whereas collections of such objects could allow for ranges, or time-scales of information to be conveyed. In the case of entities falling to the floor, this could allow for action to be encouraged (e.g., “I have to clean this mess so I might as well go empty the garbage as well”), or dynamic notifications that increase in intensity over time (e.g., DVDs could slightly push out of alignment to indicate that supper will be ready soon, then later fall to the floor to indicate it is ready). This concept plays with notions of *shareability* and *familiarity*, as visitors to a home may not notice small changes such as a picture frame rotating a few degrees, however would notice

papers, books, or DVDs falling to the floor, and further notice, and comment on, something that began levitating.

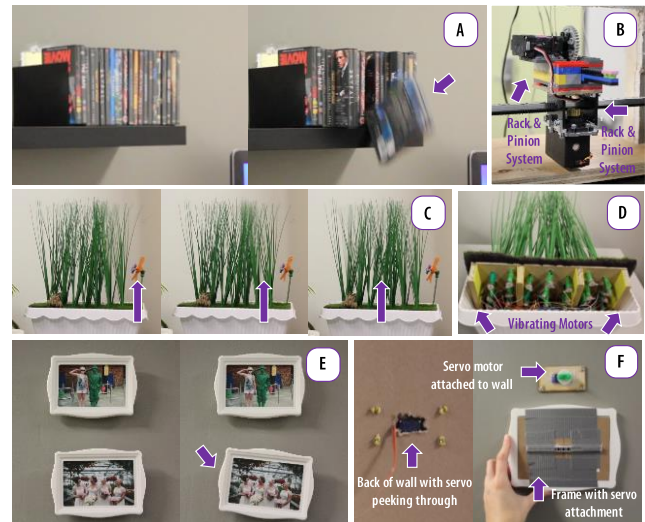


Figure 3. Prototypes of the *Awakenings* concept: (a,b) objects falling, realized with rack and pinion motor systems, (c,d) deviations in grass caused by vibrating motors, and (e,f) misaligned picture frames via servo motors.

Raising the Dead

The ability for inanimate objects to come to life has long been a tenant of films such as *Chucky* and *Harry Potter and the Sorcerer’s Stone*. The personification of inanimate objects creates a parallel to the information and data we often wish to have available. Instead of each object ‘coming alive’ via sensing, reaction, and information display, we imagine that one entity or dashboard could represent the personality, feelings, and status of the whole room or space. Similar to Amazon’s *Alexa* or Samantha in the film *Her*, homeowners could develop a close relationship with such an entity, however, bringing such a form to life via a physical, characterized representation personifies information, and data in ways that digital entities cannot.

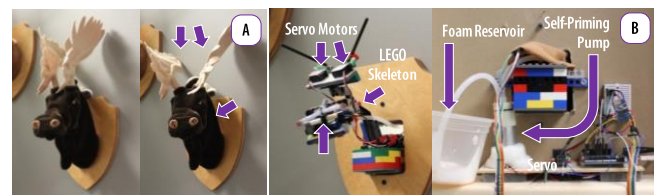


Figure 4. The (a) taxidermy moose explored *Raising the Dead* via (b) servo motors and self-priming pumps.

Inspired by audio-animatronics, we experimented with different methods that an inanimate object, i.e., a plush, taxidermy moose head, could come to life and be used for display (Figure 1, Figure 4a). While we do not believe that homeowners would literally have an animatronic moose head, the taxidermy head acted as a metaphor for objects that represent remembrance (e.g., a deceased pet) or story-telling (e.g., share stories of the ‘big catch’ or ‘lucky shot’). Using servo motors, self-priming pumps, and sensors (Figure 4b),

different points of articulation were mapped to information sources (e.g., snout movement, antler movement), combinations, timings, and *intensities* of motion represented different types of personalities depending on the occupants of the room (e.g., slow thoughtful movement to exemplify an older, wise space; quick and jerky motion to show an energy efficient, green location), and degrees of disgust and whimsy were realized via snot and bubbles coming from the snout. Proximity sensors and a speaker allow the moose to relay ‘secrets’ or sensitive information to nearby users.

Séances

The appearance of text, codes, or images on mirrors or walls is often thought to be the result of paranormal entities such as ghosts or spirits trying to communicate with the living. The Séances design concept harnesses such methods of communication to convey textual and pictorial data to witnesses. We imagine a scenario where the surfaces of one’s house are utilized by the dead (i.e., other smart objects or external data sources) to provide information to occupants. This concept plays with notions of *familiarity*, via the usual becoming the unusual, and *intensity* by exploring variable levels of noticeability. We constructed two prototypes to communicate with the ‘dead’.

In the first prototype, a mirror capable of displaying letters, numbers, or simple graphics via fog was built using a humidifier and an array of Peltier pads (Figure 1, Figure 5a). When the humidifier was turned on, a ‘message’ was displayed by selectively condensing or evaporating moisture using the polarity of the Peltier pads (Figure 5b). Such a design allows for the normal usage of the mirror for reflection and primping, while also allowing for selective data and information communication with the living.

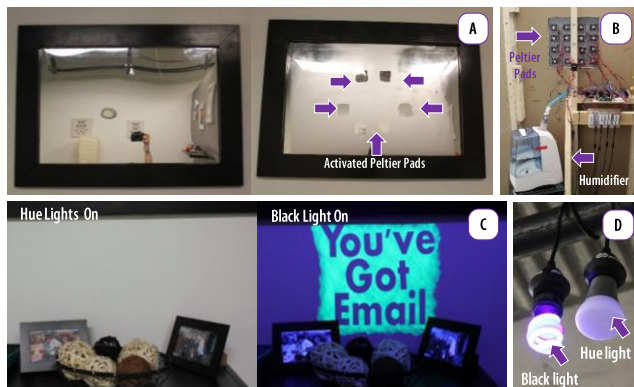


Figure 5. Examples of the Séance design concept: (a,b) a foggy mirror communicates between the dead and living using Peltier pads and a humidifier and (c,d) messages appear on walls using UV Paint with Hue and black lights.

Another implementation of Séances utilized flickering and glowing lights to communicate information. Phillips Hue lightbulbs and black lights, in combination with GloMania UV Invisible paint on the walls, allowed textual alerts and information to be ‘strobed’ in subtle or *intense* manners (Figure 5c). As the messages were invisible in the daylight

and dark, this allowed messages to be hidden in plain sight, yet revealed selectively (Figure 5d). Locating messages above or behind certain locations in The Living Room allowed the message nearest the flickering light to become visible, catching the attention of some, but not all occupants.

These variants on séances and communication with the ‘dead’ exemplify the importance of exploiting of one’s *familiarity* with objects and the environment for display.

Voices in My Head

Many of the haunted experiences reported across were rooted in auditory stimuli, e.g., footsteps, dripping water, creaking and closing doors, and so on. To occupants of a household, many of these are the result of a house settling and changing over the years. To a visitor, however, they are creepy, unusual, and startling. The mere presence of such sounds could thus invoke reactions with visitors or provide information for homeowners or occupants. Modifying elements such as duration, timing, spatial location, and so on would allow for information to be encoded for the homeowner or a subset of occupants (similar to Anderson et al.’s Numerical Sonification of time [3]). The sonication of data in a way that utilizes typical, *familiar* occurrences in the house presents interesting opportunities to ‘display’ data.

A combination of traditional stereo speakers and directional speakers were used during prototyping. A byproduct of this process was the determination that directional speakers allowed us to further explore private versus public *shareability* levels of a display experience, due to the narrow sound field distribution (Figure 6). Such technology can provide selective awareness and information to users, especially if voices or whispering is used, akin to notions of ‘voices in one’s head’. Due to size limitations of the directional speakers we were unable to integrate them within couch cushions or existing objects, however such possibilities would allow for even more opportunities to provide context-aware or situational information, e.g., embedded in remote controls, lamps or reading lights, blankets, picture frames, coffee coasters, and so on.



Figure 6. The (a) Voices in My Head concept uses (b) directional speakers to selectively provide information.

Sensory Transduction

The last concept was inspired by the aftershock reported with most experiences, i.e., questions of “what really just happened” and “was that real”? The doubt that haunted and

paranormal experiences generate in one's mind creates an incongruence between sensory stimulation and one's interpretation of this stimulation. The Sensory Transduction design concept exploits the tendency to doubt one's self by creating sensory stimulations that are so odd and unusual that one has no choice but to attend to, and reflect upon, them.

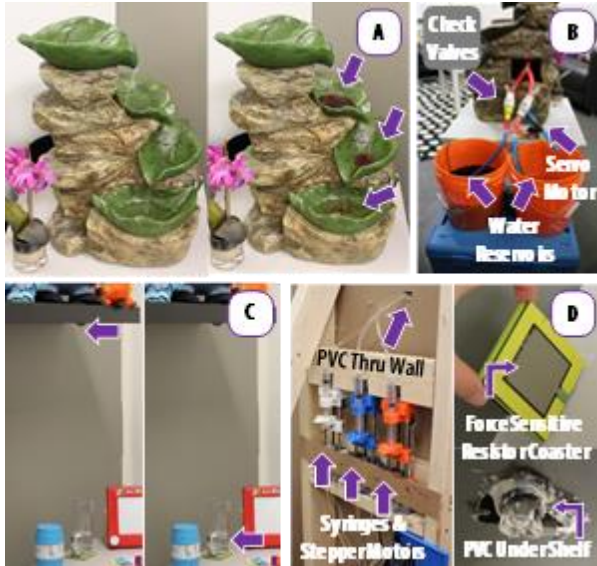


Figure 7. Examples of the Sensory Transduction concept: (a,b) a blood fountain using a water pump, (c,d) the aftertaste prototype uses syringes and PVC tubing.

The experimentation initially began with witness reports of water spots or blood appearing in houses and homes that were haunted. We initially prototyped a *shareable* analog to this, the idea of blood running down the wall of a room. Technical and practical challenges prohibited this from becoming a reality, so instead, an indoor water fountain was sourced and controllable water pumps switched clear water to ‘bloody water’, and then back to clear (Figure 7ab). This bloody fountain not only causes confusion and doubt in *public* space, but plays with speed and urgency (e.g., quickly turning water to blood versus a slow, trickling change over time) and could map information to time. The auditory feedback generated by gushing versus drops of blood further aids in confusion (e.g., leads to double-takes) and reflection about the data source it is mapped to.

Once the bloody fountain was developed, we were further intrigued by the use alternative materials, such as fluids or edible foods, to ‘display’ state-based or temporal data, in possibly *private* manners. Using three modified syringe pumps [46] and food-safe silicone tubing, we experimented with liquid-based flavors to recreate the metallic aftertastes commonly reported after seeing ghosts. Placing the pumps behind a wall and feeding them through the bottom of a shelf, out above a glass under the shelf, allowed for the ability to unobtrusively and undetectably change the aftertaste of one's drink (Figure 7cd). This design enabled different flavors, flavor combinations, and flavor intensities to be added to beverages. As the additional ingredients are invisible, they

cause the drinker to question what they tasted and why it was different. Although we do not advocate for literally dropping elements into drinks, using liquids and foods as a *tangible* metaphor for urgency (e.g., something is upcoming [sweet] versus you are late [sour]) or state-based information (e.g., the current smell in the bathroom as pleasant [umami] or rank [bitter]) is interesting to consider, especially given the *private* nature of such an experience.

While the fountain and beverages are but two examples of displays that cause the user to question perception, they could change the way we approach *shareability*, in addition to aqueous display interfaces and food-based display.

Discussion

As our design concepts illustrate, there are many opportunities for designers and developers to critique the metaphors and goals guiding their processes, and the objects they design and their situation within existing environments. While we do not envision a future in which all possessions are smart, actuated, or augmented, the notion that personally meaningful objects could hold alternative functionality yet still be ‘embedded’ and mesh with aesthetics and landscapes has yet to be given deep ideation and exploration.

Throughout the implementation process we were surprised by the lack of support current hobbyist and electronics platforms provided in terms of actuation, control, and support for materials such as fluids. As it is trivial to add sound, sensing, or LED output to objects, integrating motion (e.g., rotating a picture frame) and controlling fluids (e.g., blood fountain, aftertaste, foggy mirror), required custom solutions complete with engineered servo mounts, support structures, waste solutions, heat dissipation techniques, and so on. There were no off-the-shelf solutions to make these concepts a reality. Challenges also arose when cabling or support structures needed to be camouflage in the environment. The color schemes, form factors, and dimensions available today are insufficient to blend or hide elements of a design. Extending authoring tools such as *Jigsaw* [13] and *Modkit* [30] to support an end-to-end pipeline from design to physical object integration (3D scanning of pre-existing forms), to testing, and implementation, would greatly decrease the installation burden and allow for even richer and dynamic concepts and experiences to be realized.

The implementation process also revealed challenges with the integration of actuated and motion-based elements within large-scale environments. Similar to Woo and Lim [47], integrating devices within a space, even as open as ours, was difficult. We were fortunate that our process afforded drilling and cutting into walls, deconstructing tables, shelving, and light fixtures, and painting. Within existing spaces, this is next to impossible. Although not all implementations or applications of haunted design would go to the extremes we did, without *The Living Room* many of our ideas would not have been possible. There is thus a need determine where in the design and construction process haunted design should

Design Concept	Object						Behavior					Phenomenon		
	PURPOSE	LOCATION	FORM FACTOR	MOBILITY	CAMOUFLAGE	INDIVIDUALITY	GOAL	METHOD	MODALITY	NOTICEABILITY	FREQUENCY	SHAREABILITY	UNCANNINESS	INTENSITY
Awakenings <i>DVDs, Shelf</i>	functional	shelf	medium, compact	fixed	visible	group	compel	motion	visual-auditory	hidden (fall) -overt (r ove)	infrequent	grp (fall) -ind. (r ove)	low (fall) -med. (r ove)	moderate
Awakenings <i>Artificial Plant</i>	aesthetic	on table	small, compact	mobile	accentuated	singular	inform + remind	property change	visual	emphasized	repeated	group	high	moderate
Awakenings <i>Picture Frames</i>	sentimental	wall	small, compact	fixed	visible	group	notify	motion	visual	hidden	repeated	group	low	gentle
Awakenings <i>Wall, Car, Key Tray</i>	functional	wall	small, compact	fixed	concealed	group	compel	motion	visual	emphasized	infrequent	group	high	moderate
Raising the Dead <i>Taxidermy Moose</i>	sentimental	wall	medium, hollow	fixed	accentuated	singular	notify + remind + inform	motion	visual-auditory	emphasized	repeated	group	high	moderate
Séances <i>Wall, Foggy Mirror, Humidifier</i>	aesthetic-functional	wall	medium, compact	fixed	accentuated	singular	inform	spatial	visual	emphasized	repeated	group	high	moderate
Séances <i>Black Lights, Hue Lights, UV Paint</i>	functional	ceiling	small, compact	fixed	concealed	group	notify	property-spatial	visual	overt	repeated	individual group	medium	moderate
Voices in My Head <i>Directional Speaker</i>	aesthetic	ceiling	medium, compact	mobile	concealed	singular	inform	illusion	auditory	overt	repeated	individual group	medium	moderate-intense
Sensory Transduction <i>Fountain</i>	aesthetic	on table	large, hollow	mobile	visible	singular	inform + remind	property change	visual	emphasized	repeated	group	high	gentle - moderate
Sensory Transduction <i>Shelf, Glass, Coaster</i>	functional	wall-shelf	large, hollow	fixed	visible	group	inform	property change	gustatory	overt - emph.	infrequent	private	medium-high	intense

Figure 9. Examination of how each design concept exemplifies the dimensions of the Haunted Design Framework.

proximity to other objects, into account. When mindful of these factors, such as with the artificial plant, highly mobile, engaging experiences are possible.

Camouflage. The success of making something ‘haunted’ is influenced by how well its functionality can be disguised, i.e., can the technology be seen or discovered? Objects that are emphasized within a space are better suited to shared, gentle experiences (e.g., Awakenings concepts). Those that are hidden (e.g., UV painted messages, aftertaste) are better suited to private, personal experiences.

Individuality. Augmenting objects part of a group (e.g., rotating picture frames) creates more confusion, as there is uncertainty regarding each instantiation of the object (e.g., Do the picture frames work together to create one message, or do they each have their own?). Considering how to transition between individual and group membership also influences the repeatability and goal of an experience.

These six dimensions influence the suitability of a domestic object to be repurposed for interaction or display. Object purpose and form ensure that augmentation complements traditional usage patterns and believable behaviors. Location and camouflage dictate how easily an experience will be perceived, while offering varying degrees of technology obfuscation. Individuality allows for transitions between object memberships (individual to group), whereas device mobility influences repeatability, and possibly intensity.

Behavior

Once an interface has been selected, there are a variety of behaviors or effects that can be generated to create an experience. Similar to haunted experiences, a number of factors must come together.

Goal. As with any display, the intention of the interface dictates the behaviors that should be generated. If the goal is to alert, more intense, attention-grabbing behaviors may be appropriate, whereas to remind or provide awareness, subtle behaviors may be preferred. Encouraging immediate behavior or action is also possible if one plays upon obsessive tendencies or curiosity.

Method. The process that makes an interface ‘haunted’ can use a variety of methods including animation or motion, (optical, auditory, etc.) illusions, or harness temporal delays or spatial configurations [2, 41]. These categories shape the output and experiences perceived. Frequency or parametrization can also dictate the experience had, e.g., slow movement versus violent, irregular thrashing.

Modality. As haunted experiences encompass a multitude of senses, so too should displays, when appropriate. Care should be given to identify those that will work individually as well as in combination. As we explored, senses such as gustation offer unique opportunities to convey information, as do the use of fluids to catalyze sensation. Such modalities should be seriously considered in future designs.

Noticeability. Just as the displays can be camouflaged to varying degrees, so too can their behaviors and effects. Exploring elements such as speed, direction, intensity, duration [2, 27], and so on allow behaviors and output to be emphasized, overt, or hidden. This has a direct influence on how they are perceived by a viewer.

Frequency. Displays that afford multiple methods of output or make use of multiple processes to achieve output support behavior reuse and increased interactivity. The frequency of output influences the mapping between underlying data, its

urgency, and habituation. Infrequent presentation leads to a greater urgency and decreased habituation.

The factors governing behavior allow for an expansive set of actions and breadth of experiences. Simply changing the goal can influence the modality, methods and noticeability of the interface. Careful consideration must be given to how behaviors are designed and implemented, so as to not distract from the interface [7] or other décor.

Phenomenon

Although the experiences, feelings, and reactions that result from an interface are dependent on each individual and their susceptibility, three characteristics mediate these reactions.

Shareability. Phenomenon perceived by a lone individual create personal bridges between the user, display, and information (e.g., talking moose). This adds secrecy, dimension, and importance to messages. Due to the placement of the interface, not everyone may perceive an experience, or not everyone will have an overt reaction. This can thus be harnessed for shared or hidden experiences.

Uncanniness. Phenomenon vary in how odd or unusual they appear. When the interface is completely camouflaged and the behaviors exhibited are unusual, uncanniness will be high, as there is a mismatch between the source stimuli, expectations, and sensations one experiences. When perfectly fused, this will encourage overt reactions, reflectance, and curiosity.

Intensity. The reaction to phenomena is mediated by how intense stimuli are. Experiences that stimulate multiple senses, endure for a long time, or use an uncommon set of modalities, draw attention and increase the likelihood of overt responses. The most intense responses will be found when combinations of stimuli rouse multiple senses or cognitive dissonance arises.

The combination of uncanniness, intensity, and shareability enable the phenomenon aspect of the framework to generate and support many reactions. Uncanniness works hand in hand with intensity, and when fused properly, could create experiences that seem paranormal. The shareability of an experience, however, does not directly dictate the intensity.

Discussion

Exploring haunted design within the context of domestic environments, grounded the work and forced social space such as living rooms to considered as rich, living, breathing environments. However, the work is not constrained to only this space. One could imagine haunted vehicles, lecture halls, museums, and so on. Exploring haunted design forced us to reconsider the relationship between the object, its behavior, and output to view the design of displays from a new perspective. Although attention was not given to input or the manipulation of objects, haunted design could be further extended in this vein, especially to consider those phenomena that are cognitive in nature.

Many within the field of anomalistic psychology have studied the relationship between susceptibility and the likelihood of perceiving paranormal phenomena [15, 20, 21, 40]. Individual characteristics such as conservatism, hypnotic suggestibility, creativity, and religiosity have been found to impact susceptibility and could thus influence the degree of uncanniness found with any haunted experience. It is thus important to be mindful of the varying degrees of susceptibility users may have when designing haunted experiences, as some experiences, while tame to one, may be shocking or overwhelming to others. Although the present work did not explicitly draw parallels between susceptibility and experience design, the framework provides many dimensions along which such work could be conducted.

The framework was inspired by the haunted and paranormal, but many elements are generalizable outside this sandbox. For example, the dimensions of uncanniness and camouflage question a need for cohesion amongst various displays within a space. Although previously identified dimensions such as intrusiveness and interactivity are important when designing experiences, so too are the (haunted) dimensions of familiarity, shareability, and intensity. Through haunted design, elements normally considered to be implementation details such as form factor, method, and tangibility, can be used to create a stronghold over the emotions and reactions users have to displays and interactive spaces.

CONCLUSION

Within this work, a multi-sensory and engaging set of experiences, the *haunted* and *paranormal*, were used as an exploratory sandbox to challenge notions regarding 'displays'. This inspirational domain allowed for ideation about displays to occur unbounded by thoughts of efficiency and optimality. Though an analysis of reported haunted and paranormal phenomena, *tangibility*, *familiarity*, *intensity*, and *shareability* were identified as ways information displays could be enhanced. Guided by these themes, the reported phenomena, and the utilization of *The Living Room* as a design probe, five design concepts exemplifying haunted design were explored and implemented.

The ideation, design, and implementation processes helped form the Haunted Design Framework. This framework, emphasizes the role of the *object* (i.e., display), *behavior* of the object, and resulting *phenomenon* on the design of methods and techniques to convey information to users. When these factors come together, dynamic, uncanny, remarkable experiences can result. Although the framework was grounded in haunted experiences, many of the elements extend to non-haunted interface design and should encourage one to reconsider how objects they have in their home could be additionally used for interaction and display.

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