BEST PRACTICES FOR DESIGNING USER EXPERIENCE FOR INTERNET OF THINGS AND VIRTUAL REALITY

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This paper is focused on the principles of designing user experience (UX) for Internet of Things (loT) and virtual reality (VR) and creating effective user interfaces that incorporate wearable technology and rapid prototyping tools. New lean models will help to develop and cultivate new design processes and solve problems for products. It will emphasize product coherence among multiple devices including future Ul design trends such as augmented reality, virtual reality and emotional design. Conventional interfaces are no longer adequate means for interaction and the traditional computing paradigm will be replaced or complemented by new forms of interaction. From a certain perspective, VR and loT are two of the most important technologies to arise in the past decade or more. Taken individually, each technology represents a significant change. It is the confluence of these two developments, though, that offers the most promise and opportunity of all. VR and loT share a similar basic philosophy and purpose. Both are about the merging of the physical and digital realms, though they approach the task from opposite directions. Where VR is about making the digital world seem real, largely through head-mounted displays, the loT is about making real-world objects manageable in the digital. Designing for VR should not mean transferring 2D practices to 3D, but finding a new paradigm. Designers should expand their expertise to different fields, such as psychology, architecture, sound design, lighting design and physics, in order to be able to create fully controlled experiences, guiding users in VR by shaping the virtual environment in such way. This paper aims to conceptualize the foundations of design and implementation of 21st century interactive technologies and make an overview of the best practices. While contemporary Ul design techniques have been developed for the era of the PC, modern user interfaces are much more diverse and have to be designed for challenging contexts such as embedded and wearable computers and intelligent robotics. Designing in such context requires expertise in a large and diverse set of domains ranging from hardware-level sensor design all the way to user experience aspects. This paper addresses the vision that these requirements go largely beyond traditional Ul design techniques, calling for next generation tools that can integrate all of them in a unified manner. Our research is based on the literature exploring various solutions in different fields like education, research, industry and gaming.

Introduction

Internet of things and virtual reality are both emerging technologies, and combining the two into a fluid and seamless experience can be a real challenge. In both cases, designers need to overturn many longstanding ideas that have served them well for traditional PC setups. It's also an incredible opportunity – the chance to experiment and create in ways that previously existed only in the pages of science fiction. This paper is focused on the principles of designing user experience (UX) for Internet of Things (loT) and virtual reality (VR) and creating effective user interfaces that incorporate wearable technology and rapid prototyping tools. Conventional interfaces are no longer adequate means for interaction and the traditional computing paradigm will be replaced or complemented by new forms of interaction.

Best Practices in VR

Daily interfaces follow a common pattern that allows engagement, cultivation of identities, accomplishment of goals, and disengagement. These may be deep, prolonged sessions or momentary fly-bys. Some

interfaces help users to adapt to the surrounding world. Some interfaces require adaptation. Immersive experiences share the same core components as the interfaces users can encounter every day - naturally and directly.

Immersive experiences naturally lend themselves to longer, deeper sessions. This prolonged period is essential to achieve flow, where the user is no longer concerned with self and is fully engaged with the story and space. The sensory details of experience can serve to immerse the user further or pull them up and out of it. Both may be desirable as designers transform from interface experts to world creators and storytellers. In this chapter five key areas of design insight that will boost engagement with immersive experience are described.

Bring the World to Life

World-building is the foundation for developing successful VR interactions and interfaces. Letting the user step into a complete and believable environment allows them to suspend disbelief and engage freely with their surroundings. Creating this type of immersive world is about more than just ambient sound and scannable scenery. The physics of the world must be established as well. The more a user buys into the world they are in, and the rules it adheres too, the more immersive and enjoyable the experience has the potential to be. It is the creation of a deep and purposeful environment that is key in building trust with the user, as it allows the environment to grow and change as the user exists within the virtual space.

While many VR experiences are reliant on storytelling and from-scratch world creation, this is not always the case. Medical and engineering applications, for example, are likely to not contain any narrative element. They will, however, still require their own worlds built on rules, architecture, and navigational means to be successful.

A world experienced in virtual reality does not have to be complex to be convincing. Even the simplest of spaces is capable of evoking emotion and having a strong impact on the user. It is worth keeping this in mind when creating content for the VR space, and to carefully consider the effect of these experiences on a user's vulnerability, focus, and expectations.

Enrich with the Right Senses

A VR designer is a director orchestrating the senses. When a user has the freedom to look in any direction within a large world with seemingly limitless options, being able to focus the user's attention towards the next objective or narrative moment is key. Providing this focus imbues the user with a sense of purpose (to explore, to act, to witness, etc), which leads to greater immersion and a more seamless experience.

One challenge with design for virtual reality today is the variety of input options that must be considered when creating a virtual experience. Some hardware solutions rely on sight alone, others allow for hand movement or game controllers, and others take advantage of a free range of motion. Virtual experience designers must consider a "responsive" solution to gracefully downgrade for user's available sensory inputs and outputs.

In designing responsive experiences, the goal should be to keep a users look movement free and not rely on head movement to navigate or select. For varying hardware configurations, the pairing of sight, audio and voice as a minimal requirement would still make for a very compelling experience.

When thinking about touch, haptic feedback serves to orient the user, alerting them of changes in the environment. In addition, thermoception (temperature) or mechanoreception (vibration) should be considered. Paired with in-experience visuals, the smell of something burning in the air may lead participants forward if such were a relevant clue in the narrative. Vestibular senses (balance) and proprioceptive senses (the orientation of body position and movement of limbs) should also be considered. When experiences fail to consider these, the user experience greatly suffers.

As a best practice, the experience should be oriented to the user when beginning a VR experience. They should never put on the headset and realize they're looking at the wrong field of view and have to move their chair/body position to make the experience work. Physical comfort is key. For seated experiences, placement of story points and objectives should be within a comfortable angle to a user's field of view. This also becomes a useful tool in creating meaningful moments pushing a user to look behind them or to feel lost in a space.

With all of these options available to VR designers as methods for directing users through their experience, the art is really in the combination and composition (even exclusion) of these senses to seamlessly move the user through the experience and evoke the desired response.

User's Avatar is the UI

The user's avatar is an important reflection of who they are and their capabilities. It is used to teach the user, always aligning those with available hardware inputs and outputs. Tools and menus should be

considered as part of the user avatar. Of all parts of the avatar, the hands are the most important and can still prove valuable even if disconnected from an avatar body.

There will be a moment in the virtual experience where your user will look down. Whether motivated by curiosity or seeking to better understand their role in this virtual world, looking down and finding no avatar body can be disorienting and unsettling for many. If possible, user should be able to customize their avatar to improve immersion. Gender, body type and skin color may be profoundly personal. For some users, having a virtual body that is different than one's own can be liberating. It may allow a user to shed their inhibitions, instilling a sense of bravery and adventure that they otherwise would not have felt. It may allow them to disconnect from real-world limitations or maladies. Virtual experiences have the opportunity to be better than reality.

Allowing users to look around without attached UI elements and to instead use their hands to interact with the virtual world is the most important aspect in developing presence. A user needs to inhabit their avatar to feel empowered to take action. Users need the freedom to physically look in any direction without unnatural consequences. The now common practice of doing away with traditional HUDs allows the user to focus on the experience and frees designers to create new modes of interaction. Nothing should be attached to a users look control unless carefully placed into a narrative. Some experiences that have a reticle in the center of the screen should only have it available when it's most needed.

Selection, movement, and aim should shift from head movement to a user's hands. Ideally, hands act independently and are not tethered to a single controller. They should be visible within the virtual space at natural angles to head movement. Hand and tool actions in virtual space are mapped directly to user movements in the physical world. Showing the controllers, tools or available UI elements rendered with (or instead of) hands can orient a user to their abilities. Using gestures to show options is effective way to reveal menus and tools but still feels part of the experience.

Design for Personal Space with Social Connections

As users gain agency in a virtual environment, social connections are a natural step to sharing worlds and experiences. As a spatial medium, the feeling of loneliness may become pronounced. If this feeling is undesirable for your narrative, populating the space with other characters, or potentially, other participants should be considered.

With a greater sense of presence inside a virtual body there is also an increased awareness of personal space. Proximity to others becomes more affecting and directional sound makes 'face to face' conversations quite compelling. This becomes a powerful tool for enhancing game and social experiences, however, a user can also feel vulnerable. Allowing a user to control their distance in relation to others is key for comfort and security.

Personal space also extends to perceived "ownership" of virtual territory. Allow users to build their home environment and dictate terms of social engagement. Establish trust between users with clear spaces for different levels of engagement and vulnerability. For example, a group that often games together may have a common space where they meet and share in addition to public spaces or personal spaces.

Design for Multitasking

Acknowledging a user's tech-centered life in a VR environment allows for a more seamless integration into a user's life. Having access to phone calls, text messages and other forms of communication is important not only for convenience, but to maintain immersion in the VR space. Having to pause an experience to answer a call or quickly return a text from within the environment is less immersion-breaking than having to remove the headset and headphones to find phone or desktop. If a colleague or coworker needs to get user's attention while in VR, VR experiences should demonstrate awareness of the "outside" world and provide meaningful feedback to the user. Users should be able to virtually "lift the visor" while still in the VR headset by using the forward facing camera to project an image of what is directly in front of them. The headset can adjust lighting and use augmented reality elements to orient the user and ease the transition between virtual and physical worlds. This allows a user to pause an experience without removing or adjusting hardware. This could be triggered by a gesture as an easy shortcut to blend the worlds.

When someone is done with a VR experience and returns to the physical world, there is often a few seconds to a few minutes of re-acclimation after they remove the headset. This resurfacing should be considered in the development of experiences and use a combination of "lifting the visor", reintroducing sound and orientating a user as to where they are in the room. The currently cumbersome nature of the hardware should be redesigned to anticipate a user's

intent and smooth the transition back to the physical world.

Best Practices in IoT

What the IoT unites is data, interactions, and the physical world. Connected devices and infrastructures introduce their own unique complexities that often create new friction to user experience. Many manufacturers have struggled to bring connected products to market because of just how complicated development and management are, never mind the risks of botching customer relationships as a result.

Connected products are not singular objects, but inherently require a system to function. They tend to exist within much larger networks of devices, many of which originate from different manufacturers. In consumer contexts, this might be a connected door lock interacting with other in-home products like lightbulbs, a security system, and smart thermostats. In industrial or municipal environments, this could include thousands of streetlamps which need to be integrated with parking meters, environmental sensors, traffic systems, and so on. Even at the most basic level, most IoT services include one more devices, a gateway device, an associated cloud service, and some range of applications running on other devices in order to function as intended. When each part of the system is working, the system is invisible, but even when one part falters, the laps can significantly impact UX. The design of these systems is now synonymous with the design of the connected product.

The simultaneous proliferation of form factors, interaction modalities, software and hardware intelligence - particularly when juxtaposed against consumers' increased expectations, apprehensions, and waning attention spans - means that businesses of every type must embrace UX as a fundamental strategic component across any digital initiative.

User Interface

The role of interface is no longer exclusive to the aesthetic, touch, or feel of a physical product. In a world in which data are generated by interactions, interface becomes the interactive and tangible part of a far deeper and intangible whole. Interface becomes the means through which companies aggregate and deliver value. When poorly configured, it undermines the interaction, convenience, even trust users have in the brand delivering the experience.

As a result, businesses must begin by re-defining user interface in the context of their product or service. 'Tip of the iceberg' a useful metaphor for conceptualizing the function and future of user interface. What is visible, tangible, perceivable is the user interface, experienced through the five senses. Yet what sits below the waterline are a range of elements that develop and deliver the user experience of any connected object. These elements fall into the following eight categories:

- **Hardware & Firmware:** The physical technology (hardware, firmware, sensors) embedded in the object that power its function
- **Services & Transactions:** A company's ability to deliver service interactions and/or enact transactions by interacting with the device
- **Updates & Configurability:** Software used to deliver new features to the device's experience, security, mobile app, or power consumption.
- **Connectivity:** The protocol(s) and hardware (e.g. gateway, router, etc.) required for the device to connect to the Internet or other network(s)
- **Integration & Interoperability:** How and to what extent data and functionality from the device are shared or accessed via other devices or third parties, and vice versa (i.e. how third party device data are used by the device)
- **Identity & Privacy:** The object's ability to recognize individual user personas/avatars and associate interactions with their unique profiles, preferences, protections, and individual context
- **Security:** What safeguards hardware, firmware, software, code, or otherwise comprise the security of the device itself
- **Data & Content:** Data generated by interacting with the device and/or its associated mobile app; this also includes the resulting content that data trigger or generate

These eight core elements underlie user experiences and interactions any connected product. They define the parameters of any user experience development, whether a manufacturer designing a wearable, an automotive brand developing an in-car experience, or anything else. Furthermore, the sum of these tangible and intangible parts - hardware, software, firmware, code, integrations, services, and content - is dynamic, and dictates the evolution of the experience over time.

User Centricity

In design, everything starts and finishes with the user. As more devices, software applications, and data comprise a greater portion of the services to which consumers allocate their attention, ensuring true user-centric experience at every touch point is essential. Companies that fail to meticulously design for users' ever changing needs risk overwhelming or annoying customers, or altogether abandonment. In an age when customers expect personalized and (near) real time service, designers at every level simply must account for more contexts.

User experience may begin, include, or end with product, but it also includes all touch points connected and otherwise experience at every touch point is essential. Companies that fail to meticulously design for users' ever-changing needs risk overwhelming or annoying customers, or altogether abandonment. In an age when customers expect personalized and (near) real time service, designers at every level simply must account for more contexts.

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Context includes traditional 'customer journey' mapping characterizations, but also requires companies anticipate contexts from the user lens - that is, what users want and need to satisfy their context-specific objectives.

If connected products, environments, and channels are designed as vehicles for interactions, content and integrations become the elements of dynamic service design. Designers must work with multiple teams (e.g. marketing, creative, sales) to ensure consistency in look, feel, terminology, and tone in messaging, as well as product aesthetics. For example, if a physical product has red and green buttons and a blue dial, the mobile app may mirror such features to foster familiarity and usability across channels. When considering UX across touch points, designers must also think about which touch points support which capabilities. Product designers will, for instance, prioritize certain features for a mobile app and instead of designing them into the connected product in order to keep hardware costs down. Orchestration of content, integrations, technology, and systems architecture requires product and service designers work together in lock-step to surface technological opportunities and constraints while preserving user-centricity.

Understanding and building for such an integrated context is no easy task, but designing connected products and environments to support 'right-time' service delivery is an essential to any UX strategy.

Decreasing Steps between User & Objective

As connected form factors and interaction modalities grow more diverse, designers must constantly assess how they can ensure interaction is as simple as possible. Some environments are simply ill-suited for robust lists or feature sets. A smart watch is no place for extensive scrolling or search; driving in a car is no time for cumbersome selections or branded promotions; watching a movie is not the time for in-ear alerts. Many product companies make the grave mistake of over-complicating connected versions of their products. Too many buttons on a screen, too many levels to tap through to accomplish a task, too many features in an app, too much computation required, too many sensors (and not enough value) to justify a low battery life…

While companies should be applauded for progressively embracing (not ignoring) emerging technologies, they should only incorporate them into product design to support greater simplicity and superior ease of use. Innovation for innovation's sake risks adding more friction to usability.

The best designs coordinate technologies to drive simplicity. The objective is to harness complexity to deliver ease, even intuition. Prioritize interoperability and, where appropriate, machine learning techniques to reduce the mental overhead of dealing with more technology.

More options do not equal more intelligence. More bells and whistles do not always mean more value. Use these tools not for the sake of their luster or cool-factor, but to drive the simplest, most seamless user experiences possible. Incidentally, fewer steps (to move or tap through a workflow) typically drive greater conversion and success rates. Although simplicity seems obvious, it is often difficult to preserve when orchestrating software, mobile apps, integrations, and human-centric inputs.

For example, while driving, phones are a dangerous and terrible option for interaction. While the stakes for mobile phone use are lower at home, most people consider the home the environment for socializing with family, entertainment, preparing meals, recharging themselves— objectives for which phones are not ideal. Voice has, thus, emerged as an optimal interface in the home, where heads-up, hands-free, more social interaction is just easier. The same environmental cues can also inform software and graphical user interface decisions. Connected in-home products must, for example, prioritize data privacy controls, defaults, sharing, lighting, and child-safety given their inherent context. While in public, voice interaction is less ideal and in-ear or on-screen interaction may make more

sense. Wearable alerts sent while users are not moving may serve different needs than those delivered while walking or running.

Keeping the user's context central to the design process forces companies to de-prioritize technology for technology's sake. Embrace emerging technologies to simplify user experience, not overcomplicate it.

Customer Support Programs Alongside Products & Services

Although products and services are trending toward ever more autonomy, the reality is connected devices and services will require significant support from providers for the foreseeable future. Companies that have deployed connected products point to ongoing support and service as one of the top challenges they face. It's not just that connected products are prone to various quirks, connectivity hiccups, or other bugs, it's that new features and data-driven use case evoke new questions. For many, interacting with a connected object introduces friction that is absent in 'the old way' of doing things, thereby undermining other shiny features in the process.

While design can help streamline usability, machines rarely work perfectly all of the time, and issues are sure to arise that require human intervention and training. Connected product initiatives can fall flat if proper support structures, including people, budget, training, and incentives, are not in place. A connected hot tub manufacturer, for instance, found that its product's ability to delight users sank when it forgot to train and equip field service teams with the appropriate protocols and communications when the product failed.

Our research found this a common theme across product lines and industries, not only at the customer level, but across business partnerships as well.

Finally, some organizations and IoT platform providers recommend developing 'relationship maps.' These are akin to technology stacks and may even include technical and systems architecture, but also map relationships to devices in integration, support, administrators, etc. During both development and ongoing management, these can be valuable tools for partners to understand who has access to what information, permissions, devices, applications, and who makes changes when it comes to the most critical phase of IoT product management: data management.

Problem-Solve

In a world of 'smart' products and connected environments, businesses must view design as a useful vehicle for insights and problem solving. Alongside connected products, businesses must harness software intelligence and integrations to improve assets over time.

One way to think about this is to consider every data stream a voice. Through interactions, users are communicating their preferences, signaling intent, even expressing needs through action, inaction, or abandonment. Compared to traditional market research modalities like solicited focus groups or surveys, this real-time and 'in-the-wild' information is gold for companies committed to serving and anticipating their customers' needs.

The key is connecting how data transmitted through interactions offer solutions for core product, service, and business challenges. By monitoring sensors attached to products, environments, or customers, and analyzing interdependencies across data sets, companies can ascertain ideas for improvement. One place to start is to look for current 'blind spots' when it comes to users, such as their great pain points during product set-up, where troubleshooting fails, or how users dispose of their products.

Testing

It is of critical importance to test products 'in the wild.' Critical nuances in UX only surface when designers take the time to consider them. It is in both user and businesses' best interests for product designers to immerse themselves deeply in the end-user experience to see, think, feel, and discover the way their users do. For devices without a screen, this is even more important to avoid abandonment. Usability testing and meticulous analysis of every aspect of user interaction from the perspective of the end-user is the only way to evaluate the designer's own assumptions and adapt the solution.

What manufactures and product designers must continuously remember is that they think differently than their users, indeed users themselves think differently than other users. Avatars, or user archetypes remain an essential framework used to inform product, service, and content designs. Many of those interviewed assert the importance of segmenting and testing each avatar's interaction with products and using insights to inform avatar-specific R&D.

Users think differently at different phases of the product's lifecycle. For example, the moment of ripping into the packaging to set up a product for the first time has an entirely distinct emotional backdrop and tolerance level than does the moment when the product fails.

The following tips for testing connected product's UX should be considered:

- Test hypotheses
- Test different aesthetics and surfaces
- Test different patterns in workflows
- Test product use with and without mobile app
- Provide prompts to some user groups and no prompts to others; compare findings
- Ask users their assumptions after product testing
- Observe user tendencies for problem-solving
- Test different testing methods
- Use both online and offline channels for testing
- Solicit feedback from users as much as possible
- Integrated Context & Interoperability

What designers must understand is that interaction with connected products and infrastructure will inevitably be a fraction of contextual signals across a far deeper ecosystem of events and interactions. Imagine a world of no technological, no brand, and no interoperability barriers. Removing the barriers of interoperability multiplies the value any one device (or brand) can achieve, but it's not easy. Designers will have less control over the broader experiences they enable as interfaces will manifest over an increasingly vast ecosystem of touch points and channels.

What businesses must overcome is the temptation to design connected products as a product, and instead re-imagine and re-calibrate what value they offer within a broader system. When designing for systems, the goal is coherence across all touch points. Think of coherence as an umbrella, under which consistency, composition, and continuity fall.

At the most basic aesthetic level, UIs across all devices, platforms, and content should feel consistent, not identical per say, yet intuitively familiar and resembling of fellow touch points. Composition accounts for which devices or UI are best suited for which functionality. For instance, a wearable may be packed with sensors, but minimal in form factor and altogether screenless. More complex interactions or customizations might be handled on the device's associated mobile app. Continuity is the flow of interactions and data in a coherent sequence across devices. This is essential for UX design in IoT because connected products will rarely be the singular endpoint for interaction. This is about handling interstitial states gracefully; designing for the spaces between devices.

For example, if a user requests a transaction or change of state via one device, designers must consider how to convey the verification of the command versus the execution of the task on another device while accounting for variables like:

- Network connectivity
- Latency
- Gateways and routers
- Multiple devices working together to complete the request
- Classic usability (e.g. reflecting/responding to request)
- Critical vs. trivial nature of use case
- Data ownerships and proprietary limitations

The longer-term goal for UX design is less about each connected objects, device, home, car, or otherwise, rather it is about coordinating intelligent assistants and integrated contexts. Interactivity delivered so seamlessly and intuitively, it is all but invisible. At the time of this report's publication, there is still a dire need for adequate standards, connectivity speed, and device reliability to truly deliver this level of experience, although a variety of companies are advancing rapidly towards this objective.

To illustrate what this does not look like, consider the current state of the so-called 'Smart' Home. Wi-fi or Bluetooth enabled door locks, coffee-makers, light bulbs, and hundreds of other appliances barely provide more value than their analogue counterparts. What 'wow' factors do exist are all too often undermined by the lack of interoperability between all these smart appliances. Each of these 'parts' hardly constitutes a better UX whole.

Instead, consider how all businesses in this scenario must re-imagine their value in a systems context to deliver a superior user experience, to achieve a whole, coherent experience that is greater than the sum of the parts. Integrations between all in-home devices, systems, mobile, and environmental data help the home itself anticipate user needs. Using voice, motion detection, and gestures, the user enjoys, confirms, or corrects prompts the home offers (e.g. lighting, airflow, and temperature based on weather, season, time of day; music, audio, news based on preferences; greater security; services only as desired. Through voice or a tap or two on a smart watch, a user could control locks, security system, and communications with family. Such orchestration of contextually integrated, sensitive, and personalized experience delivery is only possible through interoperability, scenario design and recognition, and ecosystem integration.

Conclusion

In this article, the best practices of VR and IoT UX design have been presented. Even if seemingly apart, VR and IoT are getting closer and closer thanks to developments in both areas. In the following years increasing integration of smart things within virtual simulations, for uses ranging from education, industry or entertainment are expected. The vast amount of data being generated by sensors around the world, connected to virtual worlds and simulations, will be the basis of a new understanding of our surroundings.

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