# Immersion Mental Model White Paper

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# Applying High-Definition Haptics to Influence Mental Models for the Mobile User Interface

As human beings, we have a very sophisticated ability to perceive the world around us through touch, sight and our other senses. Despite the sophistication of our sensory systems, our perceptions are supplemented and enriched by associations we've developed from previous experiences. These prior associations help us interpret the world around us even if we lack full understanding of a particular situation. Without the ability to associate prior experiences with new ones, people would be hopelessly unable to function.

In the field of cognitive science, these perceptual associations are referred to as "mental models."[1] Without even being fully aware of it, we are continually creating and discarding mental models as we interact with external stimuli. The mental model we have for a particular experience guides our response to new situations and compensates for information or context that the current situation may not provide. If the mental model is incomplete or inaccurate, our response to a new situation can be misguided, faulty, or inadequate.

When software designers create new products or applications, they are expressing ideas that they believe will stimulate specific end-user experiences. The idea is known as a "conceptual model" and when properly executed in the product design, it will match a mental model that typical end users have and recognize.[2] Good products are able to make this connection reliably and intuitively and these products, most often, provide end-user satisfaction or pleasure. Products that are not able to make this connection reliably and intuitively are typically perceived by end users as cumbersome or confusing because the users have no way to relate to or predict the experience.

The purpose of this paper is to discuss the importance of mental models to the mobile user interface and the role that new technologies, such as high-definition haptics, can play to enhance a consumer's mental model of a specific mobile application and their appreciation of it. The paper will illustrate ways designers can use HD haptics to influence mental models for mobile applications to make virtual activities more realistic and engaging for the user and to differentiate their products in the marketplace.

# 1 Mental Models in Everyday Life

Over and over again during the course of everyday life, a person will use the mental models they have developed for given situations to inform and guide their responses to new experiences.

Let's say that someone wants to pick up a box. He or she probably has a mental model—based on their visual perception of the size of the box; whether it is made of cardboard, wood or metal; their previous experiences with similar boxes or materials; and their understanding of its contents—that helps them determine how much physical effort is needed to lift the box. The person's mental model automatically supplements the information he acquires from looking at the box. This mental model is verified when he first touches the box and it helps guide him to a successful experience of picking it up.

Sometimes the mental model a person attributes to an object turns out to be erroneous, and this can undermine the actual physical experience it should have enhanced.

Let's say that someone plans to pick up a suitcase. It is his understanding that someone else has packed the suitcase and that the contents are fairly heavy. He applies a fair amount of strength to pick it up, but he is immediately startled and nearly falls down because the suitcase had not been packed after all; it is actually empty and very lightweight. The person's startled reaction occurred because his mental model of the experience was incorrect.

# 2 Mental Models for Touch-Based Mobile Applications

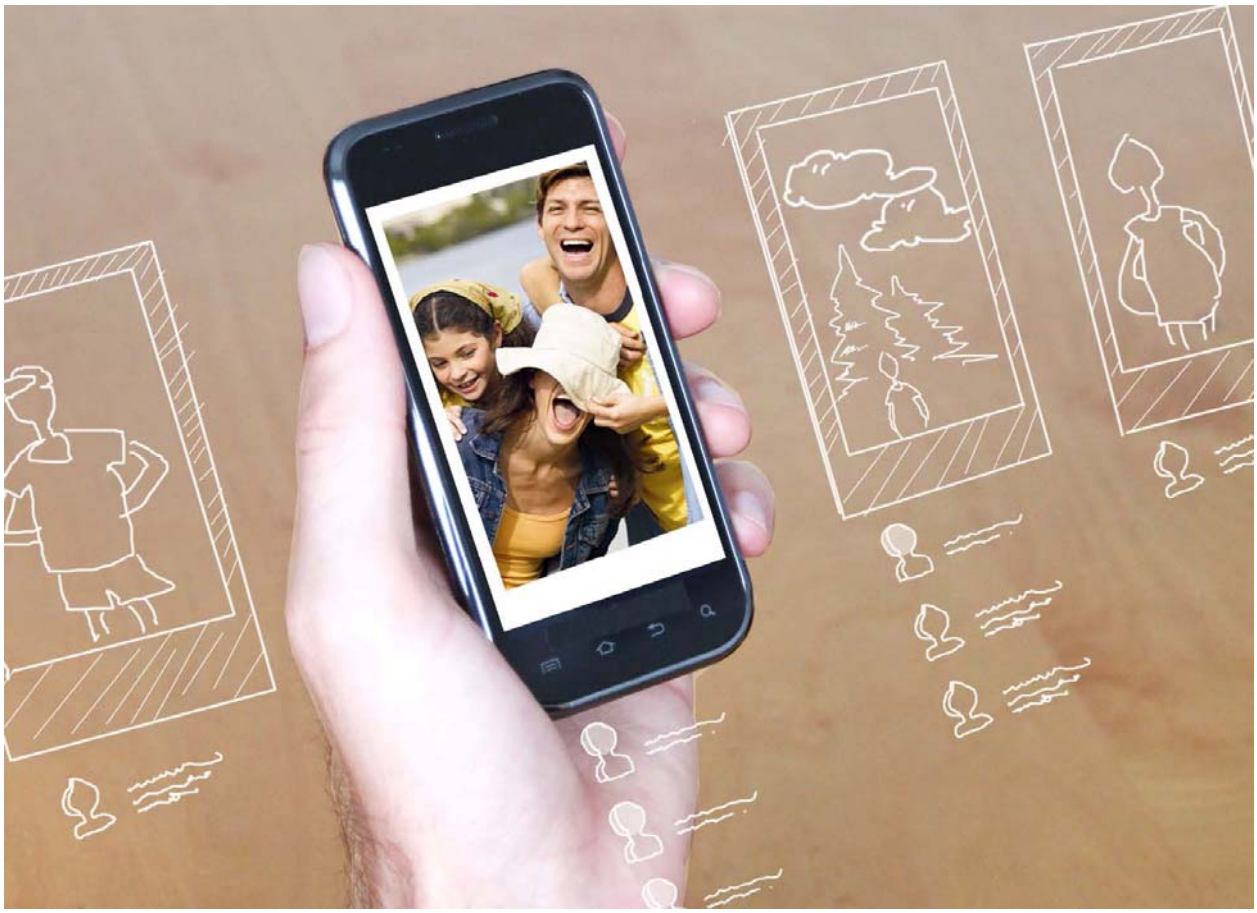
When it comes to mobile devices such as smart phones and tablets that use a touch screen, consumers have mental models that they use to supplement the experiences they have when they interact with their software applications.

For example, consumers often employ a mental model of a physical keyboard when they use the touch-based soft keypad on their mobile devices. The mental model can be noticeably reinforced if haptic technologies, which enable consumers to perceive touch sensations when interacting with their devices, are added to the keypad application to create the sensation that the keys are actually pressing down when touched.

Unless haptics are employed for a touch-screen interaction, however, the sensations that touch can evoke are absent from most consumer interactions that take place via the mobile user interface. In fact, UI designers have lamented that, by itself, the glass surface used for mobile displays cannot add the context of touch to a touch-based interaction. Bret Victor, a UI expert and designer of the Apple iPad user interface concept, refers to this as **"pictures under glass."** As he describes it, glass is a barrier that produces an "interaction paradigm of permanent numbness." [3]

Mobile device designers and application developers who are seeking to improve the user experience for their products can, in fact, use haptic-based touch technologies in ways that guide users' mental models to overcome the limitations of the glass interface and enhance the mobile device user experience. In particular, high-definition haptic technologies, which are now available for mobile devices, can provide highly nuanced touch-based effects that can create realistic physical sensations and mental models that generate very favorable reactions from consumers (see Figure 1).

**Figure 1: Touch-Based User Interface Evokes Mental Models for Smartphone Photos**



**HD haptics can be used to allow customers to "feel" attributes associated with photographs displayed on the glass screen of their devices. The haptic sensations can be tailored to suggest the number of comments on a photo or whether the user is tagged in a particular image.**

# 3 Immersion's Studies of HD Haptics and Mental Models for the Mobile UI

Immersion has conducted several consumer research projects that reveal how HD haptics can be used in mobile devices to create more realistic touch experiences and enhance the mental models consumers have for touch interactions.

## 3.1 The Immersion HD Design Principles Project

Immersion worked with the world-renowned design firm, Smart Design, to gain a better understanding of how consumers respond to applications enhanced with HD haptic feedback and to find new ways to design valuable applications that use HD haptic technology. The project included a central-location ethnographic study of Android smart phone customers who represented a diversity of end-user groups. The researchers evaluated the consumers' responses to a selection of new smart phone user experiences and conceptual models that were enabled on the devices with HD haptic technologies.

The study revealed that conceptual models created with HD haptic technologies can indeed produce effective mental models for touch-based devices by replicating sensations that feel distinctly physical to the end user. The study showed that HD haptic sensations can effectively bridge the barrier that the glass surface imposes on the touch experience and that the technology can even introduce new forms of expression to the mobile device. Further, the mental model, once established, can leave a lasting association for the consumer. This lasting association is important because it can create the type of "stickiness" that can influence loyalty for the product, strengthen the product's customer base and enhance its brand.

## 3.2 Rolling Ball

Immersion developed a simple demo of a HD haptic-enabled virtual ball that rolls around on a black screen on an Android device. The ball employed HD haptics to create tactile sensations that enable the user to feel the virtual ball as it rolls around and collides with the boundary of the screen. The ball's motion is governed by the tilt of device, as would occur if a marble were rolling around in a box. Research subjects were asked to hold the device, and while they could feel the virtual ball rolling around and colliding with the screen boundary, they were not shown any visual image of the ball or given any auditory feedback. They were then asked to describe the mental model they associated with the experience. For comparison, they were also asked to perform a similar test with a virtual ball that used a commonly available haptic-enabled actuator found in many mass-market devices.

The participants reacted strongly to the HD-haptic demonstration and cited easy-to-recognize mental models for the rolling sensation. One participant said, "It feels like a marble inside my phone!" Another said, "It's almost like it's in HD! It's really vivid!"

The test conducted with the traditional haptic technology did not evoke a strong mental model. The participants said the touch-based feeling was indistinct and "buzzy," but their feelings were not associated with any real-world experience.

## 3.3 Automatic Screen Rotation

Immersion developed a HD haptic-enabled automatic screen rotation feature to illustrate how the technology can be used to create new mental models for an application or replace traditional mental models that are ineffective.

Today, many users express frustration with the auto-rotate feature that shifts the image on a screen from portrait to landscape mode if the physical orientation of the device changes. Often when the image rotates, the transition is sudden, unexpected, and unwanted. Most phones will delay the rotation when the handset is making minor movements in order to prevent the display from constantly changing. Yet the delay is also frustrating to users because they must wait for it to return to the preferred orientation when they reposition the device. The users are frustrated with this device behavior because it often occurs when they are not expecting it and the auto-rotating function is not logical to them.

Immersion expanded on the rolling ball mental model to develop a mechanism that would make the auto-rotate function more transparent and accessible to consumers and even expected by them. The HD haptic technology simulates a ball rolling around inside a specially shaped box to track the rotation of the device. Since the ball is sensitive to the orientation of the device, it rolls when the device is tilted significantly and the users can feel the rolling motion. By correlating the position of the rolling ball with the orientation of the device, users are able to anticipate that the UI will auto-rotate unless they reorient the device. In this implementation, the virtual ball is never shown to users visually; the user is aware of the rolling ball only because they can feel it. As in the rolling ball use case, the high-fidelity haptic effects in this test, created by HD haptic feedback, are interpreted by consumers according to a real-world mental model that suggests there is a "marble in the device." This implementation goes further, however, because the marble's motion alerts the consumer that the screen is about to rotate.

Participants who tested this feature responded very favorably to it. One participant, excited by this feature said, "I know what's about to happen before it happens!" The reaction indicates that the user was able to construct a mental model of the experience and use the mental model to predict the behavior of the device.

## 3.4 Scrolling List

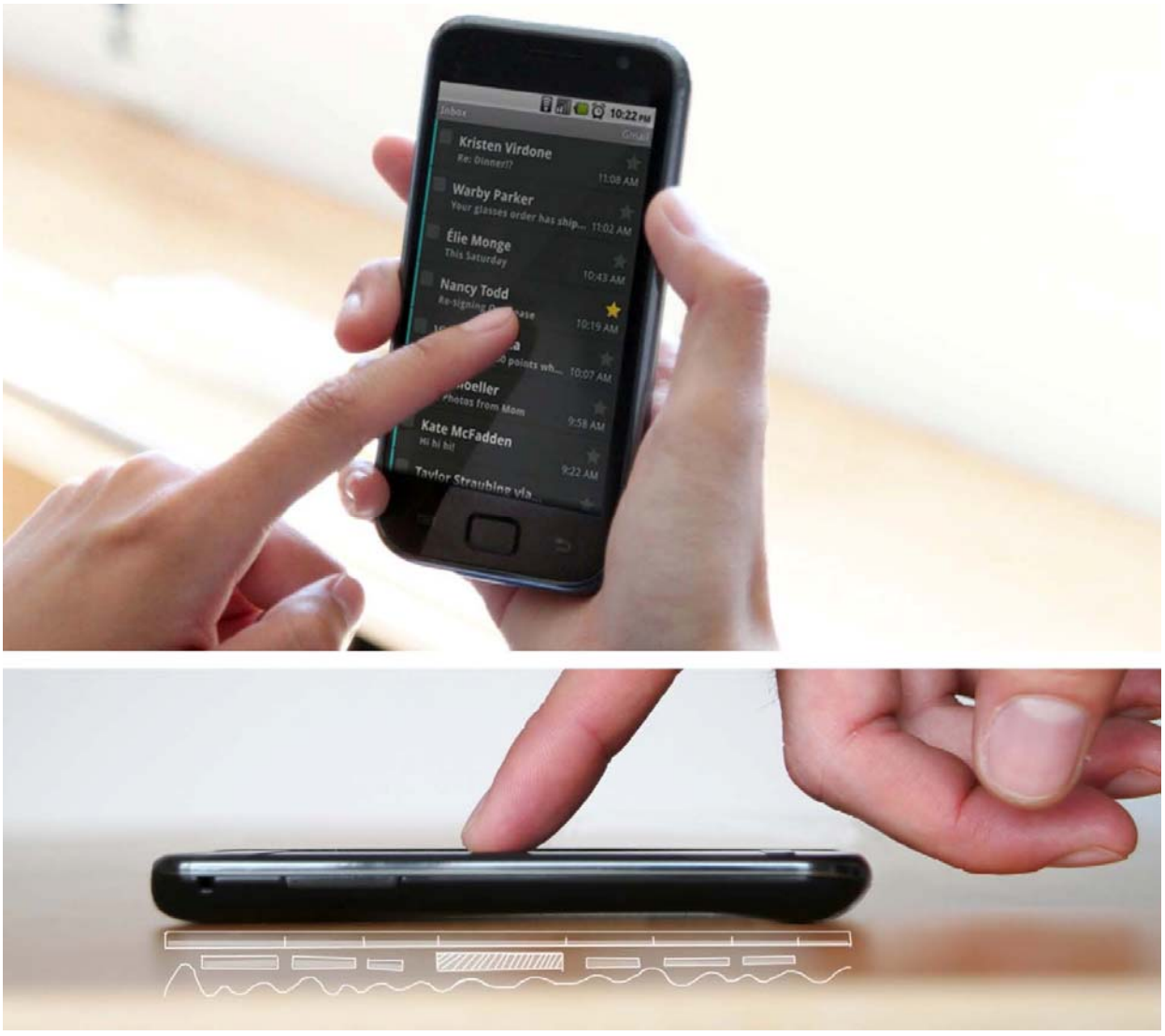
HD haptic-enabled touch sensations can be used to attach mental models to common swipe-based gestures, such as scrolling through lists.

Immersion employed HD haptics to convey physical sensations of lightness or heaviness for specific items in a list depending on the significance of the item. With this application, important or unread emails felt

heavier to the touch than the other emails in the list. The mental model made navigation through the list easier and more efficient because users could scroll through the list without looking at it (see Figure 2).

When tested with consumers, most participants responded immediately and understood the mental model. In fact, the mental model was so strong that the users even believed that the scrolling motion slowed down when important items were on the screen, even though this was not the case.

**Figure 2: HD Haptics Add New Layers of Information to Swipe Gestures**




**HD haptics make it possible to add emphasis and meaning to gestures. An important or unread email can feel heavy or different from other items in the list, allowing users to scroll through content with minimal visual attention.**

## 3.5 Uncluttered UI

HD haptic-enabled touch sensations can be used to provide mental models that characterize the availability and types of digital content available on a device, even if it that content is not displayed on the device screen.

Immersion used HD haptics to create a mental model that could be used to reduce the amount of clutter on the device screen. In one application, HD haptics were employed to allow consumers to "feel" attributes associated with photographs while they scrolled through photos that were displayed in full-screen mode (see Figure 1, above). The HD haptic feature provided a touch sensation that varied in intensity depending on the number of comments attached to a photo. It also indicated if the consumer was tagged in a photo. The association of the touch sensation with social media made it possible for users to feel additional information about content they couldn't see.

Participants who tested these features responded very favorably to the mental models that characterize off-screen information.

## 3.6 The Immersion HD Integrator Study

The Immersion HD Integrator Study was an ethnographic longitudinal research project conducted to evaluate the effect of HD haptics on consumer responses after the subjects used the products in their everyday lives for a long period of time. The study participants were all Android users and extreme consumers of smart phone applications.

Each participant was provided with an HD haptic-enabled test phone that was preloaded with their own SIM card, applications, games and social data. The participants used the test phones as their regular, personal devices for six to 10 days. At the end of the test period, subjects performed an exit interview and participated in a usability study designed to capture their qualitative and quantitative responses to the device.

The phones used by subjects were equipped with Immersion's HD Integrator, which deeply integrates haptic feedback throughout the Android user interface. With more than 125 different haptic effects, the HD Integrator can associate tactile elements with nearly all user interactions. In addition, the devices included HD Reverb technology, which automatically creates haptic sensations to accompany audio in games and media tracks.

Participants in general became very satisfied with the far-reaching tactile feedback offered by the devices. Most notably, subjects expressed strong preferences for subtle tactile feedback in common UI features such as scrolling lists, the notification bar and the home screen. These findings indicate that, beyond traditional uses such as keyboard-touch confirmation, tactile feedback generates positive responses when it is used to create a real-world mental model of the mobile UI that the consumer associates with prior experiences. Also, many participants reported telling and showing their friends about haptics in the UI and the HD Reverb feature. Many subjects indicated that they viewed haptics as a luxury or high-tech feature.

A key observation that emerged from this study was that the consumers developed an appreciation for HD haptic effects, and their associated mental models, which evolved over the course of the project. Some said they didn't appreciate the value of the effects initially but they reacted more positively to the features as they gained more experience with them. Their abilities to distinguish subtle differences in the effects also increased over time. Subjects also developed a vocabulary, based on their tactile interactions, to describe the sensations they experienced. They used words like "rough," "smooth," and "heavy," for example, to describe their tactile sensations. The users formed real-world mental models of their mobile interfaces that reinforced the graphical animations already present on the devices.

# 4 Implications of HD Haptics for End-User Mental Models

HD haptics introduce the capability to create dynamic tactile sensations that are extremely realistic. As a result, it is now possible to incorporate tactile industrial design into the core interactions of mobile devices with the expectation that users will find these designs to be both pleasing and informative and that the designs will allow them to formulate mental models quickly and easily.

Immersion's HD Integrator product has been developed to capture the infrastructure necessary to enable this level of design for next generation mobile devices. Figure 3 delineates some of the interactions it can enable.

**Figure 3. HD Haptic Effects Created by Immersion's HD Integrator**

| | Type | Haptic Model | Example |
|---|---|---|---|
| Passive | **Touch Gestures:** | | |
| | Pinch | Doppler Shift | Zooming out in Maps |
| | Spread | Doppler Shift | Zooming into Maps |
| | Press and Drag | Magnetic Snap | Dragging icons to Home |
| | Drag | Texture, Magnetic Snap-to-Grid | Dragging icons to Home Screen |
| | Flick | Flywheel | Rapid scrolling through a list |
| | Rotate | Indexed knob | Rotating a photo or map |
| | **Motion Gestures** | | |
| | Rotate | Indexed knob | |
| | Shake | Weighted spring | Shake to shuffle songs |
| | Point | Indexed knob, Geiger Counter | Maps POI |

**Immersion's HD Integrator can create very realistic and practical tactile sensations for a wide range of UI interactions and applications.**

# 5 Conclusion and Recommendations

HD haptic technologies give product designers a new opportunity to build compelling touch-feedback experiences and new mental models that can enrich the experiences consumers have when interacting with their mobile applications via the glass screen on their devices.

Effective mental models created with HD haptics will combine appropriate haptics that the consumer can relate to with well-synchronized visuals and sounds. Designers should employ HD haptics in ways that reinforce and facilitate the creation of mental models that give users satisfaction and pleasure when using the UI. The stronger a mental model is, the longer it will hold meaning for the user and the greater will be their confidence in the device.

A strong mental model should also be able to stimulate the user's imagination about their mobile content and activities even if the content or activity is hidden from the screen. The thought process accompanying these applications, which allows consumers to "fill in the blanks" on the screen with their imaginations, can invoke a strong emotional response that leaves a lasting positive impression about the mobile device's overall experience.

It is important that the HD haptic effects and mental models for the mobile UI incorporate nuances and subtleties so that the consumer's enjoyment of the features will increase over time. The process of adapting to new sensations can be compared to the process involved when learning how to appreciate fine wine: Once a customer acquires a certain measure of appreciation, they continue to seek that level of appreciation in subsequent experiences, become more discriminating consumers, and keep coming back for more.

**Notes**

1. "Mental Models and Thought," by P.N. Johnson-Laird, in *The Cambridge Handbook of Thinking and Reasoning,* edited by Keith J. Holyoak and Robert G. Morrison, Cambridge University Press, 2005, pages 185-208.

2. "The Secret to Designing an Intuitive UX: Match the Mental Model to the Conceptual Model," by Susan Weinschenk, in *UX Magazine*, April 8, 2010, http://uxmag.com/articles/the-secret-to-designing-an-intuitive-user-experience

2. "A Brief Rant on the Future of Interaction Design," by Bret Victor, published on Nov. 8, 2011 at

http://worrydream.com/ABriefRantOnTheFutureOfInteractionDesign/

## HD Integrator

The HD Integrator is a build-time OEM software tool that harnesses the capabilities of Immersion's TouchSense 5000 and high fidelity actuators to deliver new haptic interactions based on the dynamic content and UIs of next-gen handsets. The resulting experience uses thoughtfully designed and fast response HD haptic effects to: 1.) Communicate new and relevant information via haptics and 2.) Transform mobile UIs and content such as mobile games and video into multi-modal experiences that fully engage the senses.

HD Integrator is only available to OEMs using high fidelity actuators along with Immersion TouchSense 5000 software. The solution hinges upon the ability for the embedded haptic solution to deliver fast response times and effects across a broader frequency range, which is only available through high fidelity actuators. Learn more about HD Integrator at www.immersion.com/HDIntegrator.html

## About Immersion (www.immersion.com)

Founded in 1993, Immersion (NASDAQ:IMMR) is the leading innovator in haptic technology; the company's touch feedback solutions deliver a more compelling sense of the digital world. Using Immersion's high-fidelity haptic systems, partners can transform user experiences with unique and customizable touch feedback effects; excite the senses in games, videos and music; restore "mechanical" feel by providing intuitive and unmistakable confirmation; improve safety by overcoming distractions while driving or performing a medical procedure; and expand usability when audio and visual feedback are ineffective. Immersion's TouchSense technology provides haptics in mobile phone, automotive, gaming, medical and consumer electronics products from world-class companies. With more than 1200 issued or pending patents in the U.S. and other countries, Immersion helps bring the digital universe to life.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