Touch the Story: An immersive mid-air haptic experience

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***Abstract*—Haptic devices have often been used to enhance a variety of audio experiences such as listening to music, meditating, wayfinding, accessibility, and communicating. In most cases, the haptic interface is wearable or handheld and therefore suffers from limitations related to ergonomics or a limited palette of haptic sensation effects. In this paper, we present a touchless audio-haptic demonstrator experience that enhances the immersive narrative of an emotional short story. To do so, we have created an audio-haptic mapping that is semantically congruent and have synchronized the presentation of audio and haptic effects to the narrative timeline. The haptic effects presented to the user's palm are both spatially and temporally modulated so that they convey a rich palette of sensations (e.g., tapping, direction, rotation, rain, electricity, etc.) that are triggered by keywords or events in the story.**

Keywords— audio, haptics, storytelling, immersive, sensory.

I. Introduction

The use of interpersonal touch to elicit an affective response and promote emotional wellbeing is well known. For example, Gallace and Spence [1] describe how touch can be used to "enhance the meaning of other forms of verbal and non-verbal communication. Meanwhile, many handheld and wearable haptic devices such as pillows, pebbles, wristbands, and vests have long been proposed to haptically enhance several audio experiences such as listening to music, meditating, wayfinding, accessibility, and communicating.

Ultrasound mid-air haptics technology has traditionally been used to deliver haptic feedback in response to some gesture input such as in a car, in VR, or when interacting with a screen (see recent review [2]). In this paper, we present an audio-haptic prototype experience where a user listens to a short story narrative while also experiencing a semantically congruent set of vibrotactile sensations delivered to their palm via a touchless mid-air haptic device [3]. We briefly motivate our demo, describe the setup and experience, and conclude by discussing future research directions.

II. Background and Related works

Bumatay and Seo investigated the role of haptic stimulation in mobile guided meditation tools [4]. In their study, they employed a vibrating pillow that would provide biofeedback to the person meditating with the aim to aid relaxation and decrease objective stress ratings. Hayens et al. recently echoed these results using a haptic (pneumatically driven) pillow after testing with 129 participants and concluded that haptic devices can be an effective alternative to mindful breathing practices and can reduce anxiety without the need for training or guidance [5]. Massung et al. prototyped handheld pebble devices to enhance remote storytelling to children [6]. The devices are paired so that the narrator can send a vibration to the listener's pebble by squeezing his/her pebble device. User feedback from their paper highlighted issues related to ergonomics (i.e., having to hold the pebble while reading) and the limited haptic sensation palette (rumble on/off). Finally, Israr et al. used a vibrating vest to enrich story listening [7]. Different feel effects (FEs) were designed (haptic vest patterns) and where then associated to as set of events and keywords through extensive user testing. Their study laid critical foundations for using haptic inputs to enhance semantics in narrative and learning environments not only for adults but also for younger children.

Figure 1: Demo setup showing a user interacting with the USX device while listening to the narrative via the headphones. The laptop is only used to make an initial selection of the narrative voice (male/female). The high table can be used for the user to rest their elbow, otherwise an armrest can be used instead.

In most of the state-of-the-art and literature, audio experiences are enhanced through wearable or handheld haptic devices. Some of the limitations arising from such interfaces relate to hygiene when shared by multiple users, a limited palette of haptic effects, ergonomics when having to constantly hold a device, and the increased setup time needed

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to put on or off the required haptic gear. We note that these limitations are not always a showstopper and can potentially be overcome through UX and product design considerations.

III. Mid-Air Haptic Technology

Mid-air haptic technology has been rapidly developing since 2010 [2]. The basic idea is that a collection of ultrasonic speakers is electronically controlled to create high-pressure points in mid-air that induce a vibrotactile effect when touched. Much of the technological development surrounding this core idea has been down to hardware improvements, the creation of software toolkits, deep psychophysical studies about touch, and a plethora of interactive prototypes that demonstrate the capabilities of the underlying haptic technology. The latter mostly includes haptic effects to accompany 3D holograms in AR/VR/MR during dexterous manipulation [8], and haptic feedback effects during gesture input in control interfaces found in cars [9] and kiosks [10].

The semantic-haptic space of ultrasound mid-air haptics has only recently been explored [11]. Similarly, a recent study looked at how biofeedback and biosignal transfer via mid-air haptics can enhance real-time affective communication [12]. Motivated by these findings, we propose here an audio-haptic demo that leverages touchless haptics in a story narrative. The experience presents for the first time and audio-haptic only demo (no visuals) that uses mid-air haptic technology thereby circumventing some of the limitations of wearable and handheld haptic devices noted in the literature [4]-[7].

Feel Effect (FE)	Description of FE	Semantic keyword / event
	Rotation	Look to the left/right; start/stop engine;
	Direction	Wind; driving forward; waves; slideshow;
	Focus / tapping	Cold; focus; knocking; steps; heartrate;
	Expand / contract	Open/close door; warm; enter/exit;
	Random points	Raindrops; ants; keys crackling; electricity;

Figure 2: Sample of the audio-to-haptic mapping table. On the left column are representations of the spatio-temporal haptic stimuli (aka Feel Effects (FEs)) presented to the user's palm as seen in Figure 1. Each FE can be simply described according to the middle column in the table. Finally, the right column gives the semantic keyword or narrative event that triggers the haptic FE.

IV. Demo Setup and Experience

The "Touch the Story" demo can be experienced while standing up or sitting down. An Ultraleap Stratos eXplore (USX) device is placed on a table and connected to a host PC, laptop or tablet (see Figure 1.). The user is first provided with studio headphones and then selects the preferred audio voice playback (male or female actor). A 2.5-minute audio story follows about a person who returns home to post-war Ukraine after a long absence with the intention to stay and re-build it. The narrative reveals the deep emotional and sensory experience journey while the hero drives back from the airport to his/her home and then finally arrives, enters, and sees it after many years. The voice narrative is accompanied by environmental sound effects such as rain, wind, airplane landing, car engine, door swinging, footsteps, keys crackling, heartbeat, etc. These sound effects as well as some of the narrative keywords are haptically presented as different semantically congruent haptic patterns (see Figure 2), analogous to the FEs in [7], onto the user's palm which is resting at about 15 cm above the USX device. The PC screen displays the transcription of the narration (optional) and at the end presents the credits. The haptic effects last approximately 1.5 seconds each and are in sync with the narration via an editable metadata transcript provided with the audio. Finally, it is worth noting that the audio-to-haptic mapping was heuristically constructed after much trial and error. Further research on the accuracy, dimensions and features of this mapping is currently underway.

V. Conclusions

Enhancing audio experiences through haptic feedback is an active area of research. We have presented a novel audio-haptic experience that employs touchless mid-air haptic technology and an audio-to-haptic mapping that is semantically congruent to the events and transcript of a short emotional story. The haptic effects displayed are extensive and benefit from a both space and time multiplexing, while not requiring the user to wear or hold any additional apparatus, thus overcoming some of the limitations observed in the literature [4]-[7]. We aim to use this demo setup and future iterations of it to study the haptic-audio semantic mapping method and accuracy, the possibility of reducing stress, improving memory recall and learning, and finally the possibility of automating the haptification of two-way audio experiences through generative and hybrid AI methods [13].

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