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POTENTIAL OF HAPTIC FEATURES IN MOBILE LEARNING: A CASE STUDY BASED ON A LANGUAGE LEARNING APP

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Abstract

The landscape of mobile language learning has expanded significantly, fostering global connectivity through the widespread use of mobile apps. However, despite the increasing integration of haptic features into mobile devices and applications, their potential within mobile language learning apps remains largely unexplored. This paper aims to bridge this gap by investigating the impact of haptic features on language learning outcomes and designing respective exercises. In particular, the goal of this paper is to explore the integration of haptic feedback into an Android-based language learning app, considering its implications for improved learning outcomes, engagement, reinforcement of learning, skill acquisition, and inclusivity in app design. To achieve this, we designed and implemented a language learning app featuring three haptic exercises for vocabulary training: vibration-based repetition, clicking for memory exercises, and drag-and-drop interactions. These exercises are discussed in relation to their practicality using the Jetpack Compose library in Android and relevant literature.

Keywords: *Mobile learning, interactive learning, language learning, haptic feedback.*

1. Introduction

Advancements in technology revolutionized language learning, evolving from audio tapes over CD-ROMs to smartphones. Each leap enhanced performance and diversified learning tools. The shift from Computer-Assisted Language Learning (CALL) to Mobile-Assisted Language Learning (MALL) became a standard (Davies, 2023; Godwin-Jones, 2011). Mobile learning granted learners' flexibility, enabling study anywhere, anytime, and at their own pace, empowering individual progress. The rise of mobile apps, dominating various aspects of life, supported mobile learning, leveraging mobility and wireless technology for active education. These trends fostered global interconnectedness, offering unparalleled opportunities to explore diverse cultures and languages through mobile language apps (Miangah & Nezarat, 2012).

This resulted in a plethora of language learning apps on the market today. However, one area of research that is widely overlooked is how the inclusion of haptic features such as clicks, swipes, drags, or vibrations, affects language learning outcomes, especially when implemented in a mobile application. Such apps typically strive to enhance and enrich the user's learning experience by leveraging the latest tools and technologies available for mobile devices, such as speech recognition, the use of auditory media to improve pronunciation (Joseph & Uther, 2006), or even machine learning (Kumar &Goundar, 2023; Chen et al., 2020).

The lack of research in this field is surprising considering that the development of haptic technology and its use in mobile devices has been steadily increasing over the last decade, see (IDTechEx, 2023; Statista, 2023). Haptics are nowadays used in increasingly sophisticated ways not only in games and other types of mobile apps, e.g., through drag-and-drop features for moving objects, but also in the operating system of mobile devices, e.g., through vibration feedback in response to user interactions, such as a button click. As the trend of incorporating such features into mobile devices indicates further growth, the most beneficial ways of using haptics for improved outcomes in mobile language learning should be explored.

The goal of this paper is to provide an overview of the potential of haptic feedback in the context of mobile language learning and in extension mobile learning in general. We will show how haptic features can be effectively integrated into mobile language learning exercises on Android while considering the latest studies and theories on (language) learning to improve learning success (Liu et al., 2017; Mohammad et al., 2021). To investigate the impact of adding a haptic dimension to enhance the learning experience, we designed and implemented a mobile language learning app with three haptic exercises. The three exercises are: a repetition exercise that uses vibration as a haptic component, a memory exercise that uses clicking as a haptic feature, and a drag-and-drop exercise. The exercises are discussed in terms of their practicability regarding the Jetpack Compose library in Android and the outlined literature.

The remainder of this paper is structured as follows: Section II introduces the use as well as advantages and limitations of haptic technology in educational contexts. Subsequently, Section III presents our design and implementation of a language learning app leveraging different haptic features. Section IV summarises the most important findings of this paper. Finally, Section V concludes the paper.

2. Haptic features to improve learning

Haptic technology for digital devices is a field of study that deals with the creation and manipulation of touch sensations in virtual or augmented environments. It is a bidirectional technology that facilitates the interaction between the user and these virtual representations by allowing them to apply force onto one another. This is analogous to our real-world interactions with physical objects as action-reaction pairs (Crandall & Karadogan, 2021). Haptic technology can be classified into two main types: tactile and kinesthetic. Tactile haptics refers to the stimulation of the skin receptors, such as vibration, temperature, or texture, while kinesthetic haptics refers to the stimulation of the muscles and joints, such as force, torque, or position (Liu et al., 2017).

Haptic technology has been widely used in various domains, such as gaming, entertainment, medicine, engineering, art, and education. In this paper, we focus on the application of haptic technology in education and learning, especially in the context of mobile devices. Haptic technology can provide a new human-computer interaction method, which allows the user to feel the motion and haptic information in virtual environments with haptic devices, and it is also a new kind of learning means (Liu et al., 2017; Crandall & Karadogan, 2021; Norouzinia et al., 2022).

2.1. Recent studies

The use of haptic technology in education and learning has been explored in various studies and theories. They have shown that haptic feedback can affect learning outcomes in different ways, such as engagement, motivation, reinforcement, performance, skill acquisition, accessibility, and inclusivity. For example, haptic feedback can increase the engagement and motivation of learners by providing a more immersive and interactive way of learning, which can stimulate their curiosity and interest (Liu et al., 2017, Hamza-Lup & Stanescu, 2010). Haptic feedback can also reinforce the learning outcomes by providing sensory feedback to the actions performed, which can help learners to consolidate their memory and recall. Furthermore, haptic feedback can increase the accessibility and inclusivity in learning apps by providing tactile input that can be felt by people with different abilities and preferences, such as visual or auditory impairments.

Several recent studies that in some form incorporate haptics base their work on the frameworks of cognitive psychology. In particular, the Embodied Cognition Theory (ECT) as proposed in (Atkinson, 2010) and the Cognitive Load Theory (CLT) developed in the late 20th century (Sweller, 2010) were mentioned in this context. The ECT assumes that sensory and motor systems have an impact on cognitive processes. More specifically, physical activity is suggested to positively influence the understanding of abstract concepts. Examples that support this theory are counting on one’s fingers or rotating puzzle pieces to see if and where they fit. The idea behind this theory is that physical actions that accompany cognitive processes aid in freeing up cognitive resources, which in turn enables higher focus on the task at hand, since the working memory is not burdened to keep all information active at once.

This leads to the CLT, which proposes that the working memory only has limited capacities. Alternative expressions used for cognitive load are processing load or mental effort, and they each refer to the amount of work the working memory needs to deal with when met with a specific task. If the working memory’s resources are exceeded, learning is suggested to be obstructed, or worse, prohibited. Therefore, the cognitive load should be considered in the design to achieve optimal results for learners.

The combination of the two theories leads to the assumption that the working memory may be able to offload mental processes onto the environment through physical actions of the body. Thus, it is speculated that the restrictions of the working memory may not pertain when it comes to processes that are supported by embodied actions (Crandall & Karadogan, 2021).

2.2. Studies focusing on mobile language learning

Although this phenomenon is not fully understood yet from a neurological standpoint, several studies have indicated positive results for language learning when haptic features were incorporated, which may be taken as supportive evidence for the discussed theories. For example, Xiong et al. (Xiong et al., 2013) conducted a study to investigate the results of haptic, visual and haptic-visual training methods for Chinese handwriting with French students by the aid of a tablet and a haptic arm. The best outcomes were revealed for the haptic-visual group in terms of air time (i.e., pausing during writing) and overall performance. The researchers also found evidence suggesting that information provided only through the visual modality may aid in learning writing shape, while haptic information may support the skill transfer of shape learning.

Similarly, another study (Teranishi et al, 2018) explored the results of a haptic guidance system including a pen-like stylus designed to develop Arabic hand writing skills in participants unfamiliar with the language. The results showed the most effective method for this scenario to be partial guidance from the stylus, which encourages learners to draw actively on their own and only redirects by corrective force feedback if the reference trajectory has been exceeded too far. This is in contrast to full haptic guidance, where the learner is fully led by the system and follows the movements passively.

There is very limited research to specifically investigate the effects of haptic features in mobile language learning. In (Sheshadri et al., 2020), the results of a study on foreign vocabulary recall when learning was accompanied by free-form digital annotation on a mobile phone touchscreen are presented. Overall, participants showed better performance on tests when their learning process included free-form digital annotation compared to the control group, which was only presented with new words and their meaning, but they did not get the option of annotating. An additional objective of the study was to explore the influence of vibrotactile features during the annotation and encoding process, which was shown to have a significant positive impact on immediate free recall. In a similar vein, a systematic literature review of studies relating to mobile language learning apps in general was published in 2022 (Kumar & Goundar, 2023) which only amounted to a total of 47 studies. Yet, the authors proclaim mobile language learning to be an emerging field of research, and this paper shall be a hallmark in this direction.

The use of haptic technology in education and learning also faces some limitations and challenges, such as the cost and availability of haptic devices, the compatibility and interoperability of haptic software and hardware, the design and evaluation of haptic interfaces and interactions, and the ethical and social implications of haptic technology (Crandall & Karadogan, 2021; Ley & Rambukkana, 2021). Therefore, there is a need for further investigation and experimentation on how to effectively and efficiently integrate haptic features into mobile language learning apps, while considering the latest studies and theories on (language) learning.

3. Design of a mobile-language learning app

This section describes the Android mobile application “Kanji Memory” which we have designed and developed to facilitate language learning, specifically the acquisition of Japanese characters (kanjis), with English as a source language. The words, i.e., characters, used for this purpose were beginner level kanjis known to be part of the N5 level of the Japanese-Language Proficiency Test (JLPT), which is the first of five levels (JLPT, 2023).

The design of a mobile language learning app focuses on vocabulary training, which is reported to be the most common field of research in mobile language learning (Kumar & Goundar, 2023). We designed and developed this app for Android using Jetpack Compose. Jetpack Compose is the recommended toolkit for native Android UI development using Kotlin. Since its launch in July 2021, it has been steadily growing both in technical features as well as its community of Android developers who are using it daily. Jetpack Compose offers a quick and easy way to build screens in a declarative and straightforward way. In our ”Kanji Memory” app, we implemented the following four exercises:

- A *scrollable* list of all items included in the three exercises. The list shows all kanjis and their respective English translation.
- A *Repetition* exercise with vibrational feedback where the user is shown a random kanji and a text field that the correct translation should be typed into. Regardless of the user input, the next random kanji will be shown as soon as the user clicks the “Check translation” button. If the answer was correct, a toast will pop up displaying a congratulating message, whereas it will show a message containing the correct translation if it was wrong. Additionally, the user receives haptic feedback via two different kinds of vibration patterns depending on the correctness of the answer. This exercise was intended as a spaced repetition system, where kanjis would reappear for translation after increasing intervals depending on when and how often they have been translated correctly.
- A *Memory* exercise, which was the first exercise implemented in this project. Upon entering the exercise, 10 clickable cards are shown across two columns, which contain 5 random kanjis and 5 matching translations each. To introduce a level of difficulty, the items are shuffled so as not to appear matched directly next to each other. Therefore, the user needs to identify and click the correct pairs of kanji and translation until each of them has been matched. Then, another set of 5 randomly shuffled kanji-translation pairs will appear.

- The aim of the *Drag and Drop* exercise is to match one out of five random draggable kanjis correctly with the translation shown as a drop target. Only if the correct kanji is dropped onto the translation, a new set of 5 random kanjis and one translation will appear. In either case, a toast will appear to let the user know whether the item was matched correctly.

The architecture of the "Kanji memory" app follows best practice standards in that several components are configured to manage the handling of data between the UI layer and the data layer, see (Android Developer, 2023). The main components of our architecture are: Room Database, KanjiRepository, ViewModel and User Interface.

4. Discussion

The exercises proposed in this paper vary in difficulty for learners, with the Drag and Drop exercise assumed as the easiest since only one out of five kanjis match with the translation it is to be dropped onto, and the number of possible attempts is infinite. Therefore, the exercise can be solved by process of elimination, which results in a maximum of 5 attempts for each set. Moreover, the user is provided with feedback via a toast message on each try. An improvement of this exercise could be the implementation of vibrational feedback as in the Repetition exercise. Furthermore, it could be designed to alternate between matching kanji to translation and matching translation to kanji.

The next level of difficulty would be the Memory exercise. While the process of elimination can also be applied in this exercise, the maximum number of attempts needed for this exercise is increased to 15. Although the cards appear greyed out upon being matched correctly, more visual feedback could be implemented for this exercise, such as a colour change upon selection. The study conducted by (Xiong et al., 2013) supports the notion of combining the visual and the haptic modality, which in this case is implemented via button click.

Finally, since the Repetition exercise requires active knowledge of the correct meaning of a word instead of passive recall, this exercise is deemed to be the hardest one out of the three. Upon entering a translation for a kanji, the user is provided with feedback both via a toast message and through vibration, which is used to signal a correct response in the form of a short effect, and an incorrect response through long vibration. Since (Sheshadri et al., 2020) found positive results for digital annotation while incorporating vibrotactile feedback, a next step to improve the Repetition exercise could be to incorporate digital annotation, for example by the use of an external library specifically designed to be able to draw on a Canvas in Jetpack Compose, such as provided by (Brysbaert, 2019). Once combined with vibrotactile feedback, this exercise would correspond with the notion pointed out in (Sheshadri et al., 2020) that spaced repetition combined with vibrotactile feedback may lead to effective learning outcomes.

Future exercise implementations involving haptics and their research should also involve other areas of this field, i.e., listening, writing, pronunciation, grammar etc. for a more holistic language learning experience. Further, more varied, and complex exercises could be implemented, which may also include the use of different kinds of media, such as auditory, or AI components to allow for speech recognition. Additionally, the device's motion sensors could be used, e.g., to learn directions. A possible implementation could be to show a direction word, i.e., front, left, right or back, and the goal is to rotate/tilt the device in the indicated direction. A next step toward further research in this field could be an evaluation of the exercises outlined in this paper or similar ones. For this purpose, (Nielson, 2023) recommended 40 test users for statistically reliable results from a user experience viewpoint, while (Brysbaert, 2019) argued for much larger numbers in psychological studies to ensure a high-power statistical analysis, i.e., finding true effects that exist in a population. For example, (Brysbaert, 2019) suggested a minimum of 52 participants for a repeated measures t-test and 200 participants for a between-groups comparison (100 participants for each of the two groups). A possible study design for repeated-measures could be to analyse the number of words that can be recalled after certain time periods, while a between-groups comparison could be achieved by having one group use the application as is, and one control group to learn kanjis in a different modality, e.g., only providing visual input of a word in the target language and its translation. Participants could then be tested on the learnt words, and their results compared for differences. Further, a mixed-design analysis of variance (ANOVA) could be executed to investigate both within- and between-subject differences, though this would lead to an even larger number of participants needed.

5. Conclusion

Haptic features can be used to create a more immersive and realistic experience for users. This technology can enhance mobile language learning by providing learners with different sensory modalities to interact with the learning content and environment. In this paper, we present an approach for implementing haptic features into a mobile language learning app. In particular, we implemented three different exercises that support vocabulary training of Japanese characters with haptic feedback. Using Android Jetpack Compose the integration of such features is very straightforward. The haptic features implemented in the outlined exercises are not exhaustive. In future, additional exercises could be developed to also include swiping or scrolling, the latter of which was only used to display the list of kanjis and translations.

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