The title of the project: An experimental study on the spatial and haptic cognition in Agumented-LBS game. In summary, it allows users to add a digital layer upon the physical space, which means to introduce a new way of helping people to *understand* their cognitions about the space. This project aims to look into a various cognitive reactions from users based upon the memory and recall the information about the space *involved*, also the level of fixation on the digital contents, along with observing the different haptic modalities to try identifying the most appropriate settings for this AR game.

We researched on a series of historical references about Geo-based AR games, collectively, they used the information from location services, trying to let the users to create and explore in a hybrid environment which cooperates both physical and digital objects. Upon this, in order to measure the level of users’ cognition, we had an idea of creating a guessing panel to allow users to use their imaginations to figure out what virtual objects other people built there before, according to how they perceive the space around them.

Many existing AR apps(e.g., AR tour app,.., etc) have some problems of conveying a correct, meaningful and unambiguous information to the users. Diving this issue deeper, a significant fact is, people’s levels of cognition are varied, depending on reasons both from themselves and environment, by measuring the users’ behavior when using AR applications through the apps we made, we are able to analysis and improve the AR experience for them.

We had a plan for this, at first, we were understanding and exploring existing geo-based applications. After that, we developed an app to study and observe effects of different cognitive factors by tweaking the application as required. Later, using the app to conduct experiments to evaluate constructed hypotheses. And we collect the data and analysis from experiments. Finally, Drawing conclusions and inferences from them.

So, we set up a few digital contents(POIs) initially within a certain area to let users to explore with the app we gave them, each POI gets resolved when pointing a mobile device to it. We did a comprehensive experiment with almost 30 participants. upon a time limit(divided into 2 halves, 1st half without maps, while the 2nd maps are enabled) and how accurate they feedback with the answers, so that we can draw analysis about how users perceive the physical spaces and the digital layers upon them.

The results show that usually the first few POIs were not easily to be found, we researchers need to guide them with clear instructions, and as time goes, they could get a hang of it. However, roaming along a designated pavement, users often ignore the spatiality about and were unable to re-visit the lost sites behind them, which may suggest panning the device while moving would be a better chance to hit the right target. We also discovered that most of the time users turned on the maps system until they got close enough to the things they were exploring, and then they switched it to the AR interface. Apart from those behaviors, there were some issues when users were standing too close or even exactly on things they tried to resolve(step-into problems) and just couldn’t find the content, or content shapes or colors didn’t look exactly real which disrupted a correct judgement and so on. Finally, we investigated the haptic cognition by giving different ways of input for the users to try and evaluate even whether we should introduce a hybrid system that doesn’t break the relationship between the physical and virtual.

Finally, let me introduce you our group members: **Somasundaram, Sathish,** he is the project designer and director, also contributing to develop the AR function for the app, designing and managing the experiment process, and drawing analysis. **Tian, Zhenan**, she is theInterface and modeling designer, also helps to share the references to the existing map applications, AR modeling applications, which both works well in Unity(the app development environment), and also one of the experiment researchers. And **Yan, Xu,** he is the App developer, developed the map functions, collaborating with Latish to work through the AR functions, also participating in experiment as a researcher and assistant.

And here are the references we had:

1. Jeffrey Buckley,  Niall Seery& Donal Canty(2018).  *A Heuristic Framework of Spatial Ability: a Review and Synthesis of Spatial Factor Literature to Support its Translation into STEM Education*

2. Julian Keil, Annika Korte, Anna Ratmer, Dennis Edler,&Frank Diclmman(2020).  *Augmented Reality (AR) and Spatial Cognition: Effects of Holographic Grids on Distance Estimation and Location Memory in a 3D Indoor Scenario*

3. Brett E Shelton, Nick Hedley(2003).  *Exploring a Cognitive Basis for Learning Spatial Relationships with Augmented Reality*

4. Javornik A,  Kostopoulou E,  Rogers Y,  Fatah gen Schieck A, Koutsolampros  P, Moutinho AM&Julier S(2018).  *An experimental study on the role of augmented reality content type in an outdoor site exploration*

5. Ho Chih Yu,  Fong Gong Wu. *The Haptic Feedback Design of Augmented Reality Virtual Keyboard on the Air*

6. Lars chittka et al.(2019). *What is cognition?*

7. Samihah et al.(2017). *Factors Influencing the Acceptance of Augmented Reality in Education: A Review of the Literature*

8. Hennry Been-lirn Duh, Nai Li(2013). *Cognitive Issues in Mobile Augmented Reality: An Embodied Perspective*

9. *https://www.nytimes.com/2016/07/12/technology/pokemon-go-brings-augmented-reality-to-a-mass-audience.html*

10. *https://www.frameweb.com/article/can-minecraft-in-ar-transform-spatial-design*

11. *https://www.infoq.com/news/2020/10/android-ARCore-cloud-anchors*

12. *https://www.youtube.com/watch?v=Kp2Sm4Fibj0*