Model-Based Analysis of the Differences in Sensory Perception between Real and Virtual Space: Toward ``Adaptive Virtual Reality''

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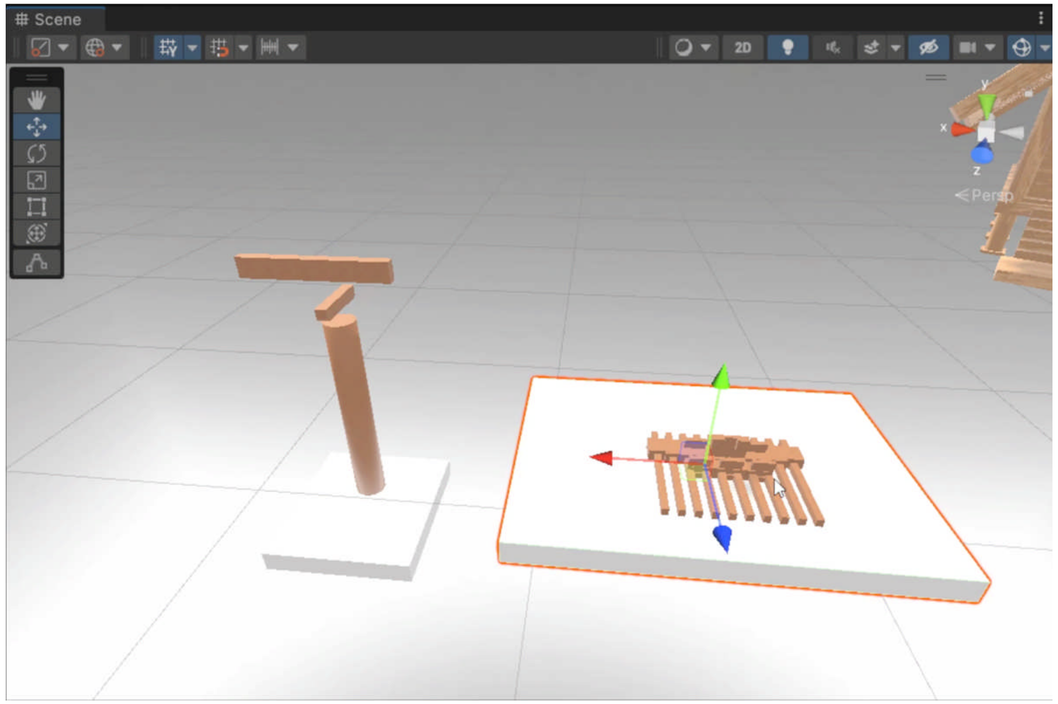
Resume

- Taichi Nakagawa
- a first year master's student
  at Nagaoka University of Technology
- interested in research related to VR
- I belong to a taiko club at my university.

Introduction

- **In recent years, with the development of VR technology and the popularization of HMDs, VR content has become easily available.**
- **It provides a more immersive experience than traditional content and is used not only for games, but also for a variety of other purposes, such as education, tourism, and simulations.**



VR educational content about traditional Japanese architecture (jinja shrine)
Developed by National University Management Reform Promotion Project

Introduction

- **There are many research approaches to VR contents and systems including research from the perspective of Human Computer Interaction (HCI), research on the differences in sensory perception between the real and VR, and research on "Adaptive VR" that incorporates individual adaptability into VR contents.**
- **Among the studies from the perspective of HCI, Mousavi et al. * integrate Emotion Recognition (ER) and VR to provide an immersive and flexible environment in VR.**
- **This integration can advance HCI by allowing the Virtual Environment (VE) to adapt to the user's emotional state.**

*S. M. H. Mousavi et al., "Emotion recognition in adaptive virtual reality settings: Challenges and opportunities," CEUR Workshop Proceedings, vol. 3517, jan 2023, pp. 1–20. [Online]. Available: https://sites.google.com/view/wamwb/

The purpose of this study

Challenges:

- The implementation of adaptive VR is becoming feasible.
- The main effects of its implementation on users should be understood based on a cognitive model.

Objective:

Studies have mainly focused on bottom-up content design with an awareness of adaptive VR, however, a top-down approach is also necessary.

1. We describe a model of the flow of information obtained by actual human perception through avatars in the VR space and the resulting human reactions

2. The degree of immersion predicted because of the integration of multisensory information is also discussed.

Understanding the role of multisensory information can enable us to design VR contents for individual users and how we can control sensory perception.

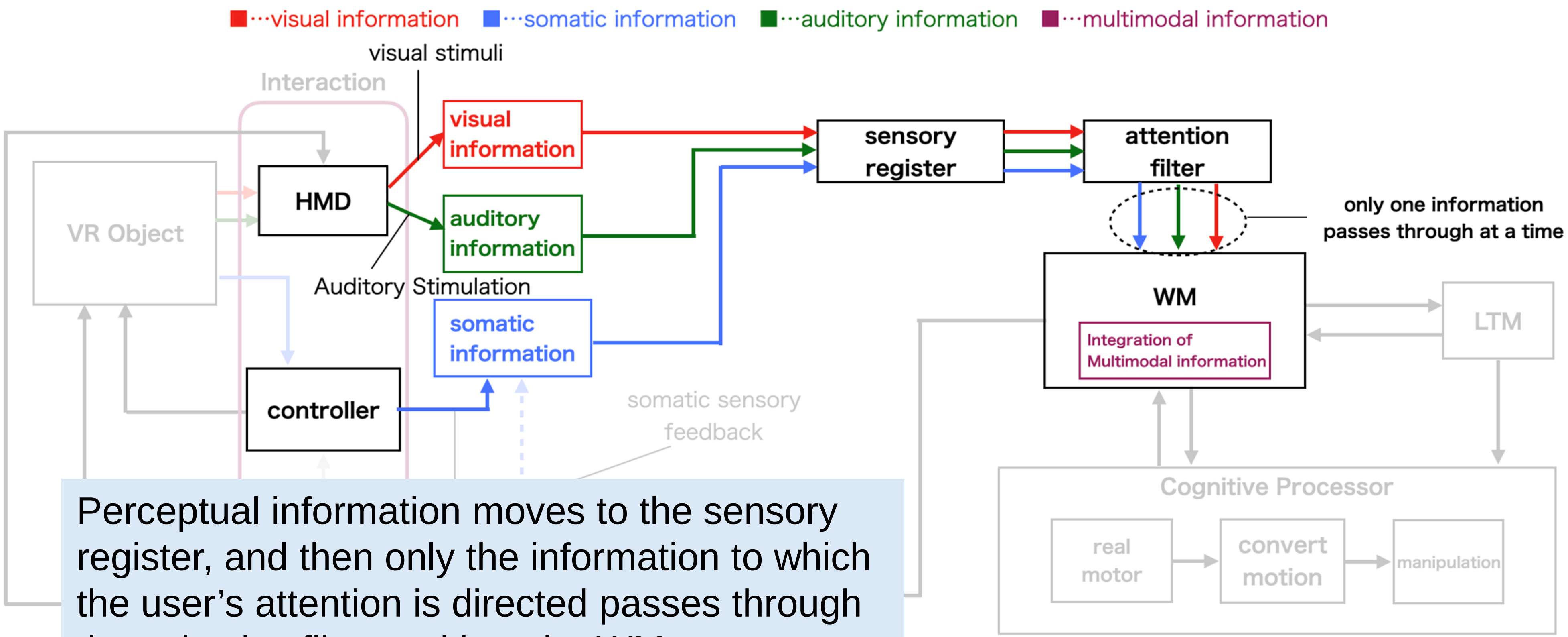
Cognitive processes of VR experiences using an HMD

The following items are present in the cognitive process of VR experiences using an HMD.

- **Perception of information**
- **Cognition of information**
  - **-Attention**
  - **-Cognition**
  - **-Decision**
- **Motor system based on perception**
  - **-Human body motion**
  - **-Interaction with VR objects**

Perception/Cognition of information in the VR Space

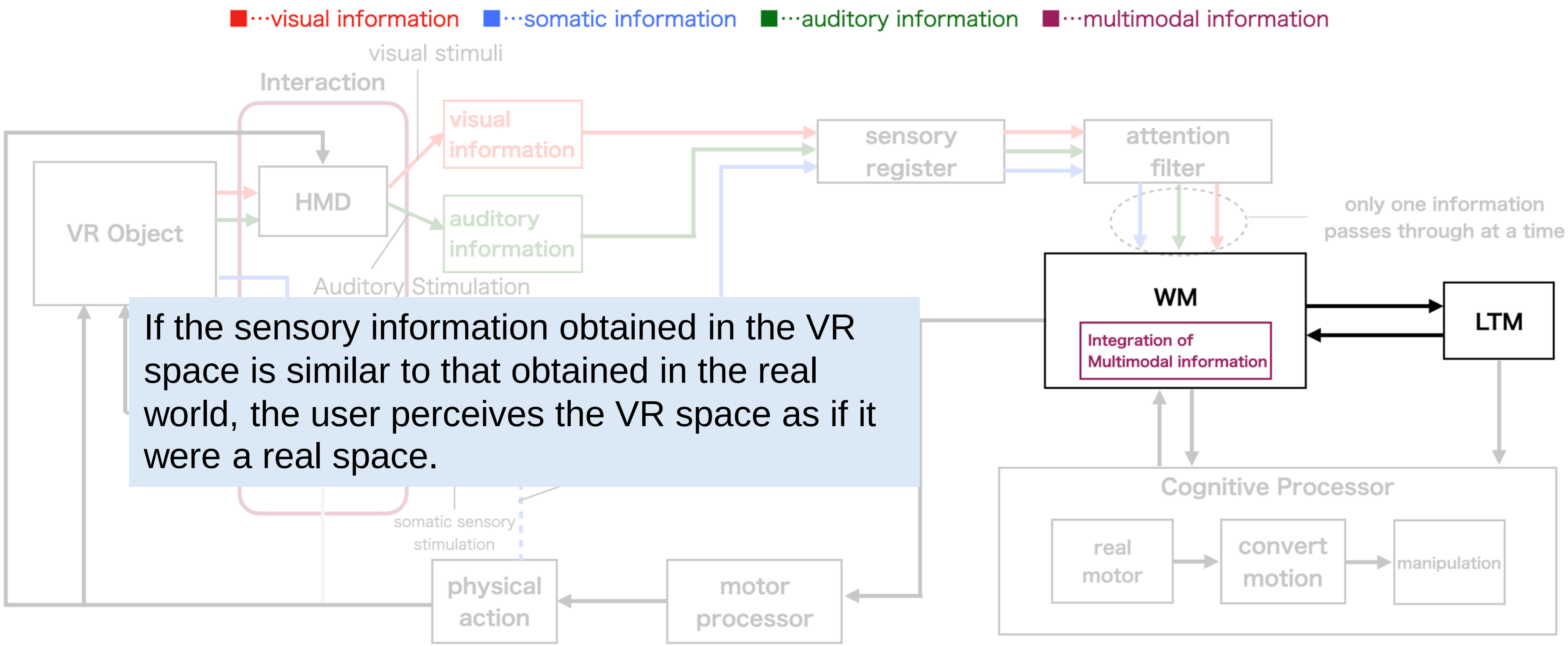
Attention



Perceptual information moves to the sensory register, and then only the information to which the user's attention is directed passes through the selective filter and into the WM.

Cognition of information in the VR Space

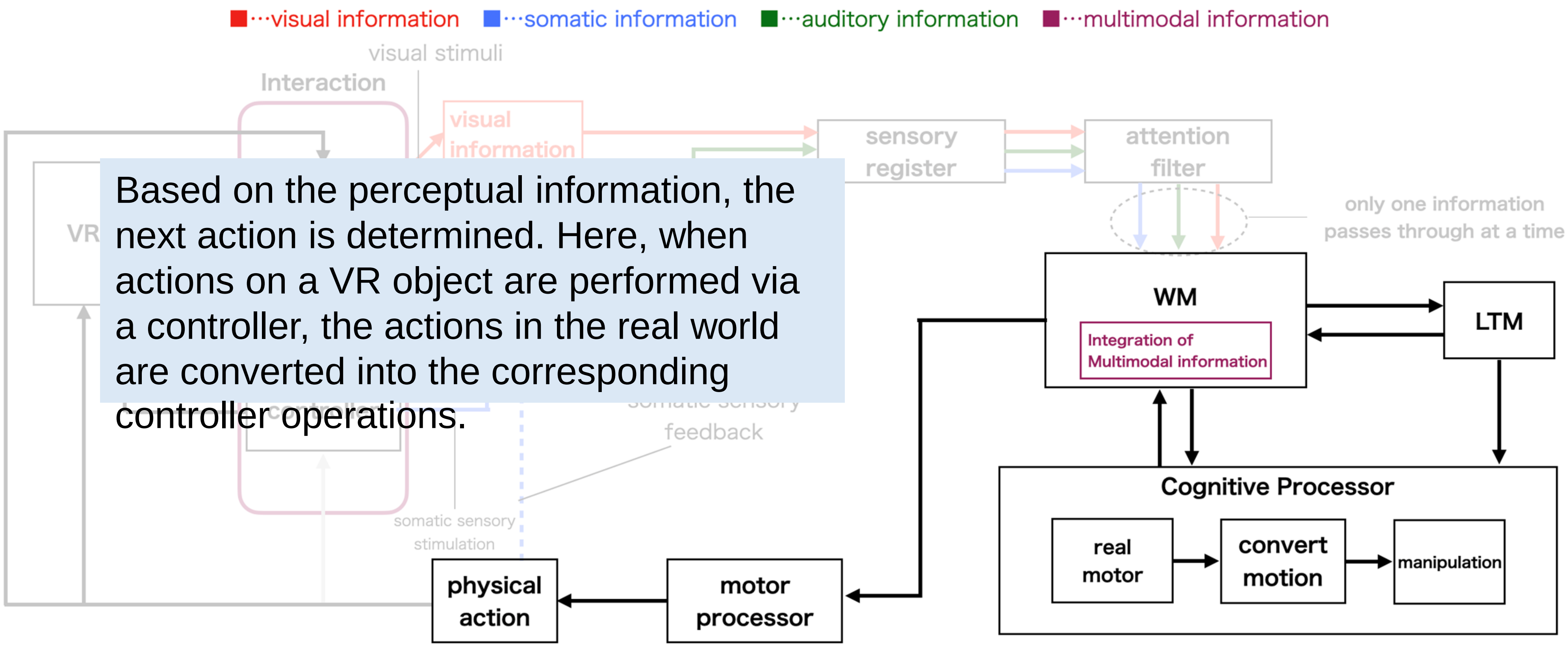
Memory



If the sensory information obtained in the VR space is similar to that obtained in the real world, the user perceives the VR space as if it were a real space.

Cognition of information in the VR Space

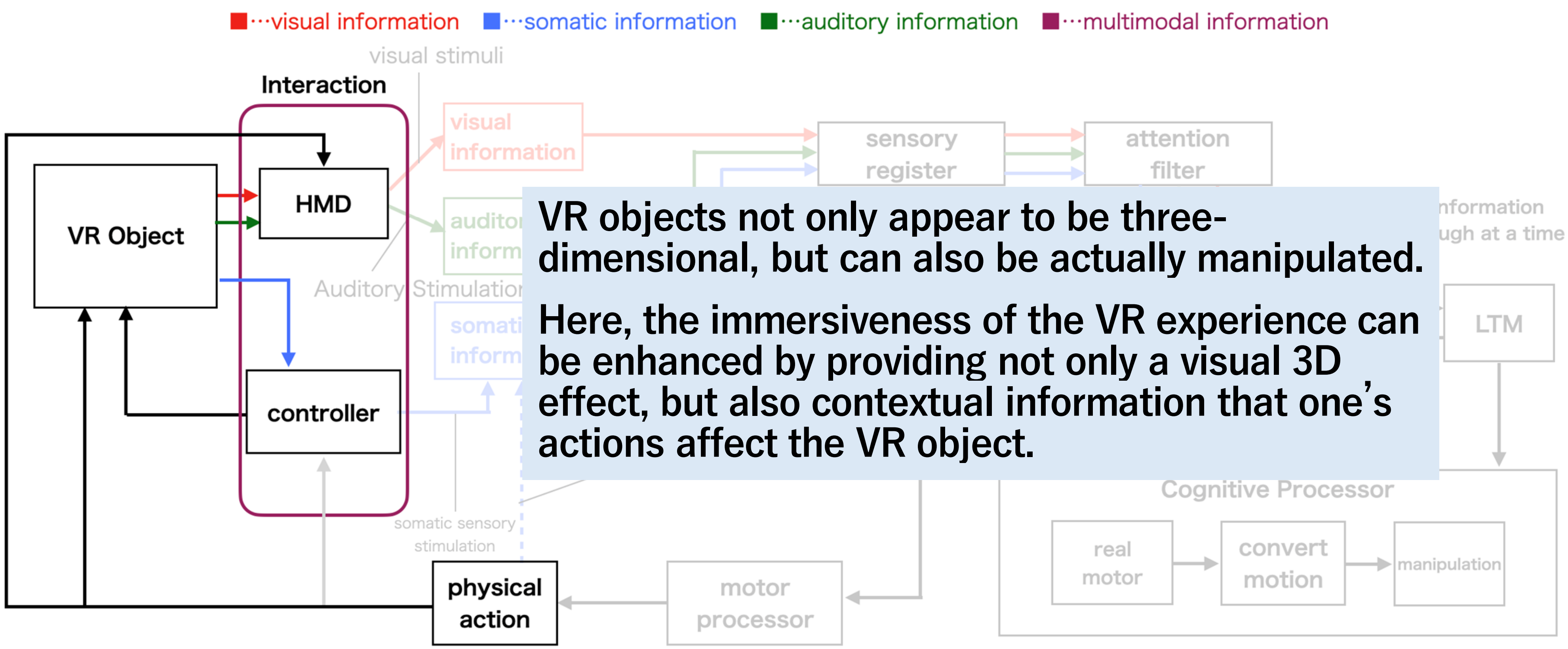
Decision



Based on the perceptual information, the next action is determined. Here, when actions on a VR object are performed via a controller, the actions in the real world are converted into the corresponding controller operations.

-Hand tracking
-Controllers

Body movement based on perception: Interaction with VR objects

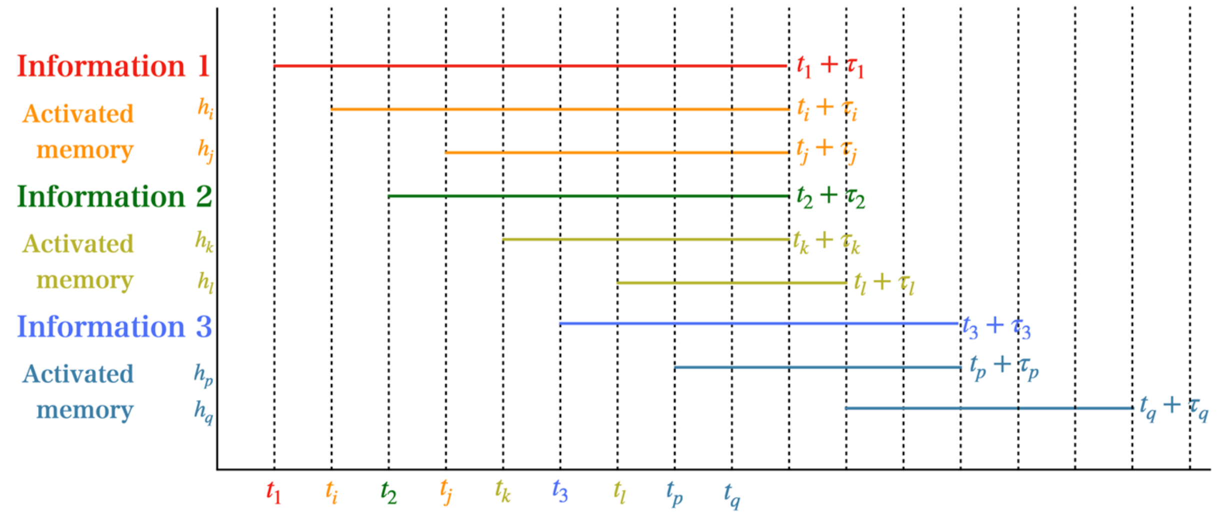


VR objects not only appear to be three-dimensional, but can also be actually manipulated.

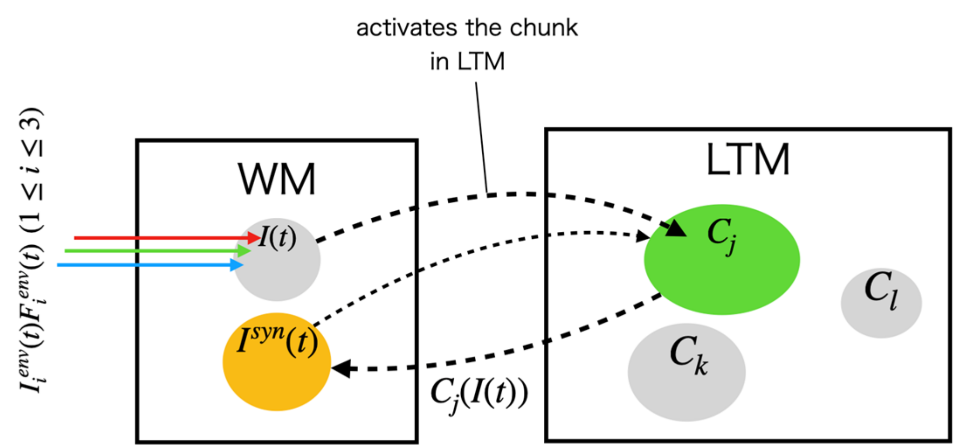
Here, the immersiveness of the VR experience can be enhanced by providing not only a visual 3D effect, but also contextual information that one's actions affect the VR object.

An Example of a VR Experience

Consider a situation in which the user plays *taiko* drums in a VR space.



Timeline of sensory information stored in the WM and information activated from the LTM.

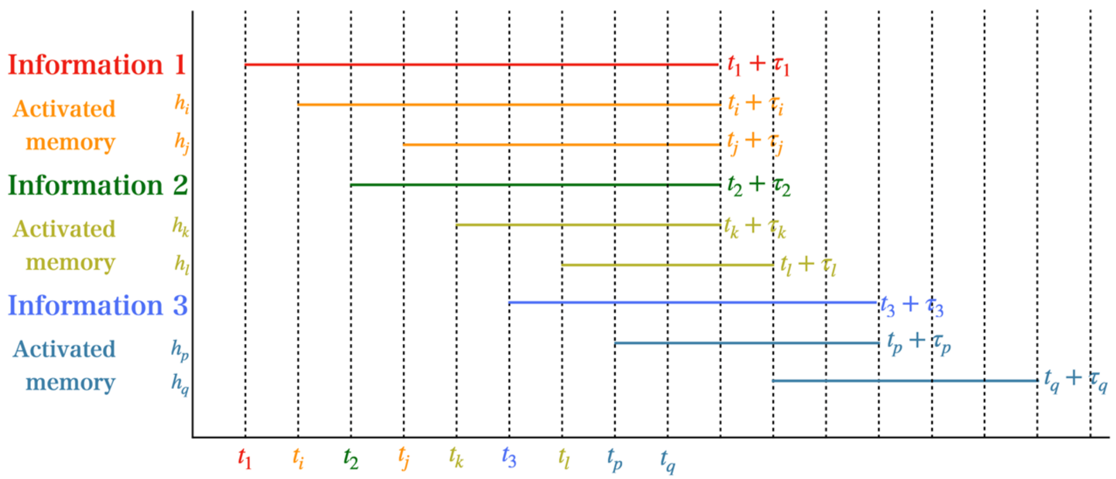


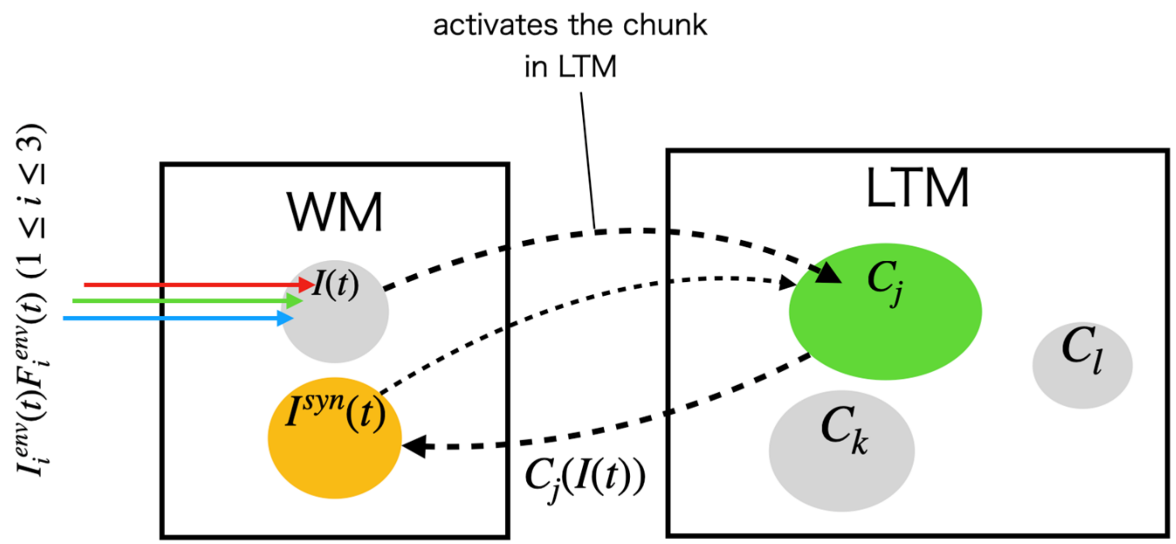
Perception in the Real/VR World

The chunk C_j stored in the LTM is constructed from the information group $I_i^{env}(t)$ obtained from sensory organ $i(1 \leq i \leq 5)$
Each $I_i^{env}(t)$ passes through the attention filter $F_i^{env}(\mathrm{t})$ via the sensory register.
The set of information obtained from each sensory organ is represented as follows:

$$I(t) \ = \ \{\boldsymbol{I} \mid I_i^{env}(t) F_i^{env}(t), 1 \leq i \leq 5\}$$

C_j contains the information obtained from each sensory organ as a set $I(t)$ and is denoted as $C_j(I(t))$.





Perception in the Real/VR World

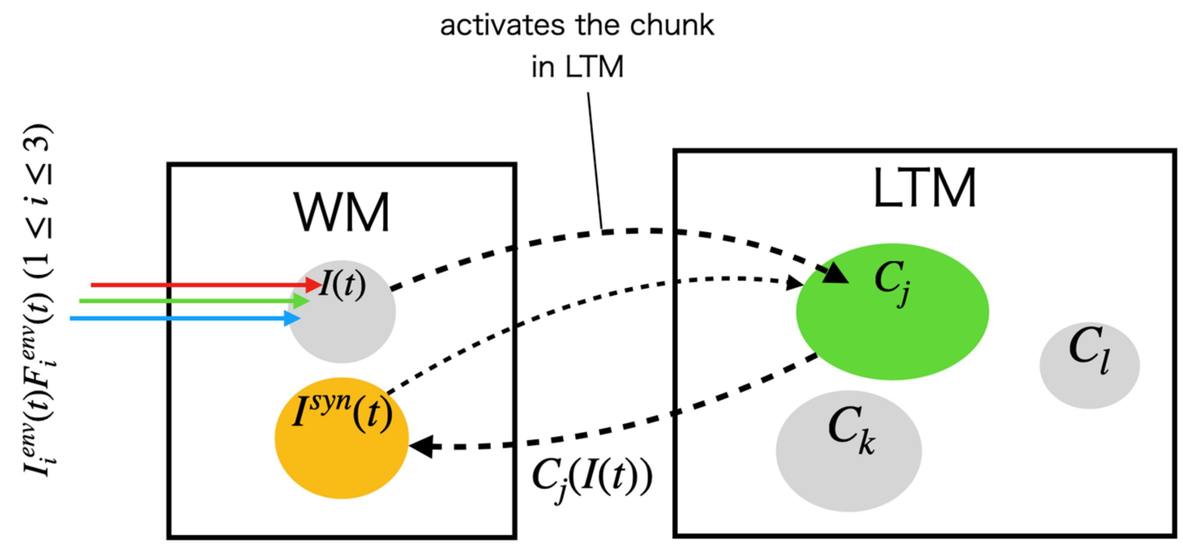
Here, we target three types of sensory information – visual, auditory, and somatic, and consider how these information $I_i^{env}(t)(1 \leq i \leq 3)$ flow.

The integrated information $I^{syn}(t)$ can be expressed as follows.

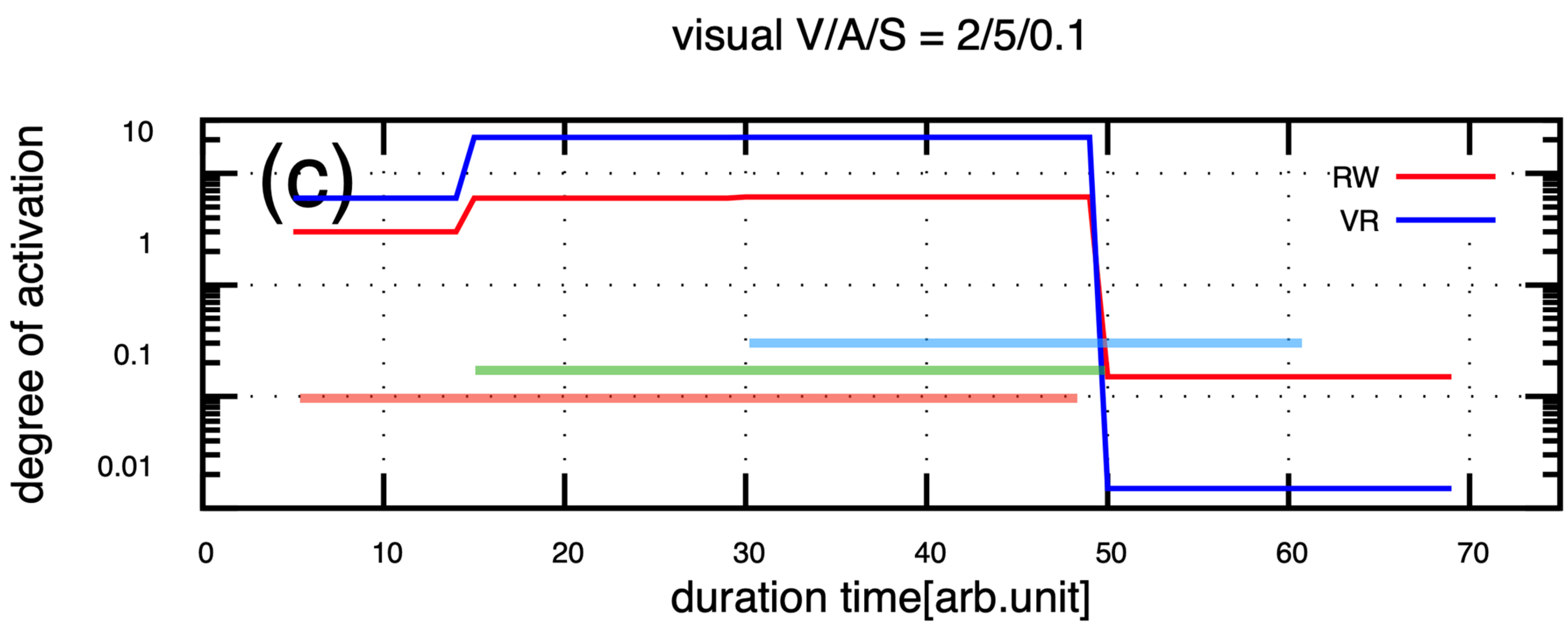
$$I^{syn}(t) \ = G\left(i,\ j,\ I_i^{env}(t)F_i^{env}(t),\ C_j\left(I(t)\right)\right)$$

For the sake of simplicity, we simply add the amount of information and the degree of chunk activation as follows.

$$G^{env}(t) \ = \sum_{i}^{n}\sum_{j}^{m} I_i^{env}(t)F_i^{env}(t)C_j(I(t))$$

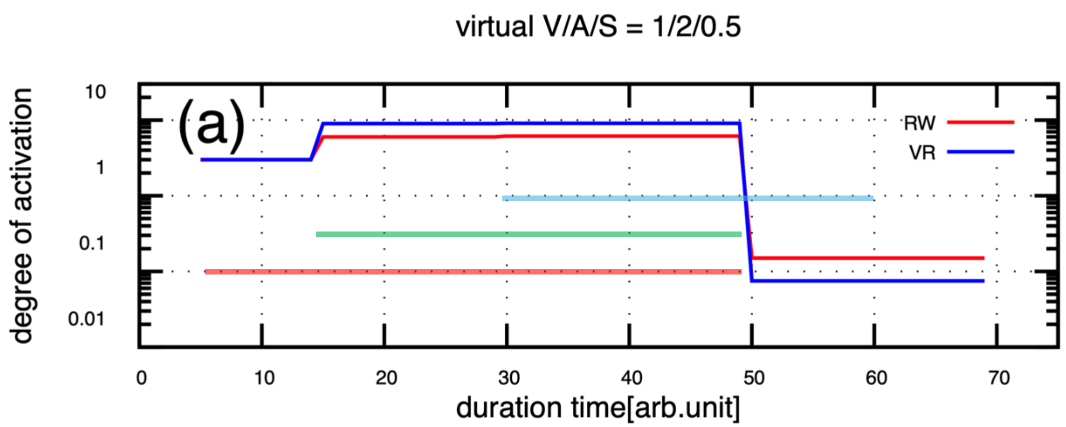


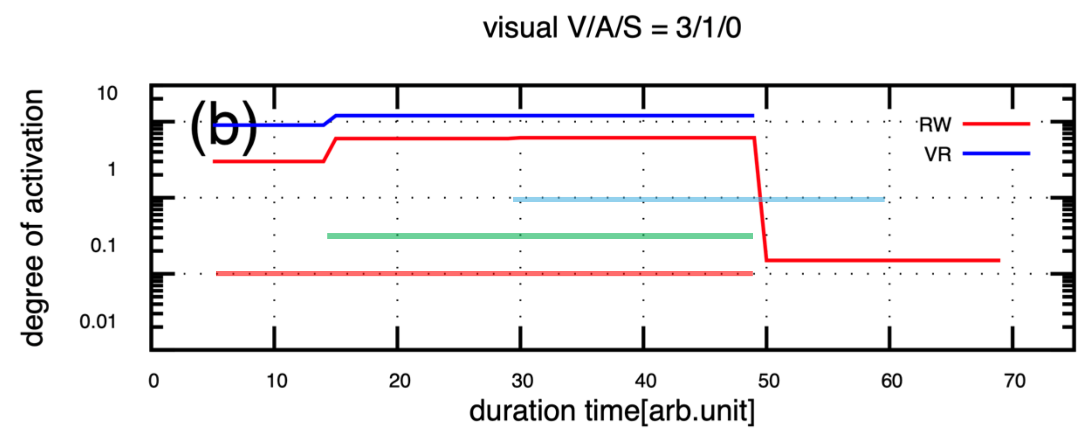
Chunk Activation Timeline

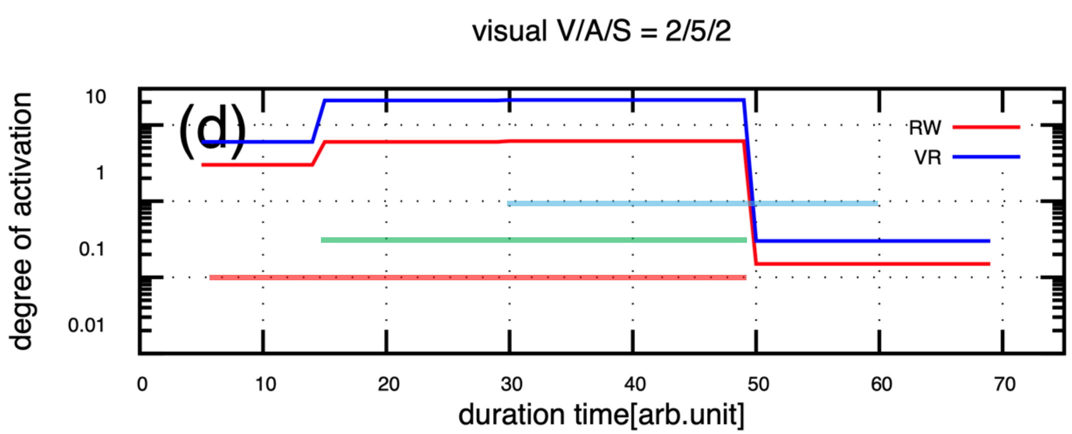


Visual/Auditory/Somatic

Chunk Activation Timeline







Visual/Auditory/Somatic

Discussion

- The intensity of human sensation is expressed as a logarithm according to Weber-Fechner's Law.
- Therefore, as shown in previous graphs , even if the difference in sensory information is very slight, it suggests that the human senses can distinguish this difference.
- The sense of "slightly different from the real world" felt in VR content is thought to be caused by such slight differences in sensory information.
- The sensory information obtained in the real space is not necessarily large, as shown in the example.
- However, it is easy to understand that these small differences lead to a sense of discomfort, which in turn indicates a decrease in immersive perception.

Conclusion

To realize adaptive VR…

- **we need to design deeper immersion resulting from human interaction with real/VR spaces.**
- **As a first step, this study described a sensory-cognitive model for VR spaces.**

This study describes…

- **Small differences in sensory stimuli can reduce immersiveness**
- **Understood how the VR space realizes the immersive effect, and suggested that it would be possible to design immersive content that is adapted to the individual user.**

Future work

- **In the present case, we only dealt with a very simple integration of information.**
- **To advance our understanding of human sensory perception and use knowledge in VR spaces, we should develop a new approach that uses operators, such as Adaptive Control of Thought—Rational (ACT-R) and Model Human Processor with Realtime Constraints (MHP/RT) which incorporate Two Minds, to integrate information in a cognitive architecture.**

Thank you for your attention.