Decoding passive tactile shape from functional MRI signals

Trung Quang Pham[1], Hoang Xuan Tran[2], Hiep Hoang Ly[3], Hiroki Ishizuka[4], and Junichi Chikazoe[1]

[1] Araya Inc., Tokyo, Japan
{trung_pham,chikazoe_junichi}@araya.org
[2] Ubiquitous System Lab, Toyohashi University of Technology, Toyohashi, Japan
tran.xuan.hoang.vg@tut.ac.jp
[3] Department of Mechatronics, School of Mechanical Engineering, Hanoi University of Science and Technology, Hanoi, Vietnam
hiep.lyhoang@hust.edu.vn
[4] Department of Mechanical Science and Bioengineering, Osaka University, Osaka, Japan
ishizuka1314@a3.keio.jp

Abstract. Decoding passive tactile shapes is a challenge in neuroscience. In this study, we extracted BOLD signals from three regions of interest, the intraparietal sulcus (IPS), the lateral occipital cortex (LOC), and the dorsolateral prefrontal cortex (dlPFC). All are known to be the shared areas between visions and haptics. Then we used a VDVAE (Very Deep Variational Auto-Encoder) to visualize the haptic information from these areas. This approach opens a new way for explaining the human tactile perception and possibly contributes to haptic-related diagnosis in future work.

Keywords: functional MRI · VAE · Neural Network · passive tactile sensation

1 Introduction

The decoding of information from the human brain has been a hot topic in recent years. The success of such a technique would give us feedback for improving the current human experience even if they could not express it verbally. Recent studies have achieved a good decoding from perceptions such as visions, and auditions. However, decoding tactile stimuli from the somatosensory areas remains a challenge.

The human somatosensory area covers the perception of the skin, the largest area in the human body. Since the somatosensory areas are very close to the motor areas, their neural activity could be influenced by arbitrary motions and top-down modulation. Thus, decoding the stimuli from the somatosensory areas is not straightforward.

Previous studies [1] have suggested that the visions and haptics shared a few common regions along the visual pathway, such as the intra-parietal sulcus

(IPS) and the lateral occipital cortex (LOC). These areas, hence become a good candidate for indirectly decoding the somatosensory information. In this paper, we demonstrate a novel approach in which tactile shapes are decoded from the visual pathway using a combination of magnetic resonance imaging (MRI) and a Very Deep Variational Auto-Encoder (VDVAE).

2 Methods

2.1 MRI Scanning and Processing

We asked 35 participants (male and female, 18-30 years old) for the MRI experiment. An MRI compatible haptic display [2] was used to stimulate the right hand of the participants with 10 types of 3×5 dot digits (from 0 to 9). During this, we captured their blood-oxygen-level-dependent (BOLD) signal using an MRI scanner (Siemens Verio A). Each digit was displayed from top to bottom at the speed of one row per second. The experiment was repeated for 3 runs. Acquired magnetic resonance data were pre-processed following the Human Connectome Protocols [3].

2.2 Decoding model

The original VDVAE was obtained from [4], pre-trained with the Natural Scenes Dataset. We replaced the original regressor and then re-trained the model with the data extracted from IPS and LOC. We also used the dorsolateral prefrontal cortex (dlPFC) because it is related to visual/haptic working memory. The masks for these regions of interest (ROIs) were determined using the statistical map obtained from a meta-analysis of NeuroSynth [5]. The decoding was performed by training VDVAE with two runs and testing with the other.

3 Results

Figure 1 shows the decoded images obtained using BOLD signals from ROIs (Fig. 1a). Interestingly, the decoded images from LOC and IPS are visually corrected to the complete concatenated form of the stimulus (Fig. 1b). Noted that all stimuli were displayed sequentially row-by-row, this result suggests that there must be an accumulation and visual encoding process of tactile stimulus in these areas. The worse performance of S1 is also expected. Although the decoding of dlPFC is worse than our expectation, this result suggests that there could be a more complex presentation of information in this area.

4 Discussion and Conclusion

Our current results of decoding the passive tactile shape are preliminary but relatively accurate (especially when using the BOLD signals from IPS and LOC

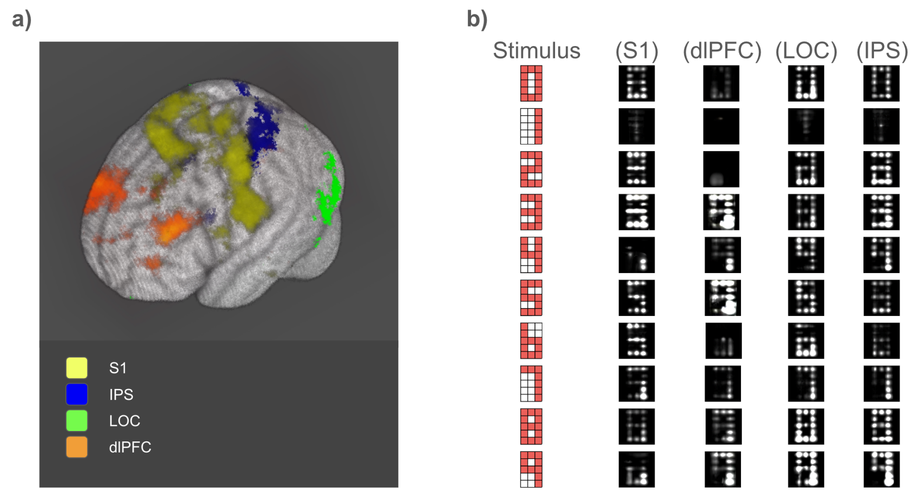

Fig. 1. (a) Visualization of ROIs. (b) Decoding example of a good performance participant.

areas), demonstrating the usefulness of the combination of VDVAE and MRI. In passive touch, the temporal change of information is controlled and hence could also be decoded, paving a novel way for investigating the spatio-temporal characteristic of tactile perception. The current decoding targets are relatively simple and small. We will test the decoding approach with more complex stimuli in future work.

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References

1. S. Lacey and K. Sathian, Visuo-haptic multisensory object recognition, categorization, and representation, Front. Psychol., **5**(2014)
2. T.Q. Pham, et al.,"Design of an fMRI-compatible pneumatic tactile array for spatiotemporal stimulation", *The 61st Annual Conference of the Society of Instrument and Control Engineers (SICE)*, 1343-1346, 2022.
3. M.F. Glasser, et al., "The minimal preprocessing pipelines for Human Connectome Project", *NeuroImage*, 80:105-124, 2013.
4. F. Ozcelik, R. VanRullen, Natural scene reconstruction from fMRI signals using generative latent diffusion, Scientific Reports, **2**(13), 15666 (2023)
5. T. Yarkoni, et al., Large-scale automated synthesis of human functional neuroimaging data, Nat. Methods, **8**(8), 665-670 (2011)