

# The invisible body

## Citation for published version (APA):

Zhan, M. (2018). *The invisible body: the neural mechanisms of non-conscious and conscious processing of emotional bodies*. Ipskamp Printing BV. <https://doi.org/10.26481/dis.20180516mz>

## Document status and date:

Published: 01/01/2018

## DOI:

[10.26481/dis.20180516mz](https://doi.org/10.26481/dis.20180516mz)

## Document Version:

Publisher's PDF, also known as Version of record

## Please check the document version of this publication:

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# Valorization

## Addendum

In this thesis, we explored the mechanisms of emotion and human body action processing, under conscious and non-conscious conditions, and with the use of virtual reality (VR). In studying the non-conscious processing of bodily emotions, we also compared our results from healthy participants under the CFS paradigm, to patient groups including blindsight, neglect, and hemianopia without blindsight. We explore the possible influence of our research in three domains: the general public, specific groups of users (especially the patients with visual cortex lesion), and the scientific researchers using fMRI as a tool.

## For the general public

Consciousness is a phenomenon that all of us experience in everyday lives. Even in mundane activities such as non-REM sleeping each night, we transit from a conscious state into a non-conscious state in sleep. When our body parts are in the colliding trajectory of obstacles such as furniture, we move to avoid them without consciously thinking how to carry out the actual movements.

Throughout the history, consciousness and the human brain in general have been attracting people's fascination, which not only motivated scientific researchers to perform various studies, but also stimulated the imaginations of the general public. Brain, consciousness, VR and artificial intelligence (AI)-related themes have been continuously and increasingly featured in numerous sci-fi novels and movies, from the very early *Frankenstein* (1918), to the more recent *Ghost in the shell* (1989), *Ex machina* (2015), and Dan Brown's new novel *Origin* (2017).

In the current society with more electronic devices, VR and AI have become increasingly accessible. For VR (and the related augmented reality), more and more first-person perspective video games support 3D viewing, effectively creating VR experiences, and large companies such as Google and Facebook (which acquired Oculus) has been actively developing easy-to-use VR and AR technologies. For AI, there are intensive discussions about whether AI algorithms could be conscious, whether they can make decisions, and whether they will take people's jobs soon.

Despite the enthusiasm and increasing discussion in the general public, and the development of the human brain science field for more than 100 years, the general public still holds numerous misconceptions about the brain. Some information is outdated, and some is plainly wrong. For this current situation, both the scientists and the mass media in the general public are responsible.

From the scientist side, the latest brain science results were not disseminated quickly and effectively. We are in the fast-developing subfield of cognitive neuroscience, with fMRI as one of the major research tools. However it is in 1993 that the fMRI technique was developed; and only from the 21<sup>st</sup> century on, the multivariate-pattern analysis (MVPA, or machine learning. The RSA method in **Chapter 6** is of this category) became more and more used in brain research. With such a short history, cognitive neuroscience has not got enough time to widely enter textbooks for the general public. Only a small part of undergraduate- and high-school-level textbooks contained information about cognitive neuroscience, while

most others contained mainly neurobiological (cellular and molecular) information. Also, these neuroscience-related contents are usually from studies done more than 40 years ago. In my own experience, I was trained in basic medical sciences and neurobiology as an undergraduate student, not much cognitive-neuroscience contents were included in my textbooks. Although studies of blindsight was already established in the 1970s, I still remember the shock, when I was told by the BBC documentary *Brain Story* (2000), that the conscious visual information is only a portion of the visual information received by us every day, while a large portion of the information is unconscious. Another problem is, not all neuroscientists are informed of the most up-to-date knowledge, which includes the methodological knowledge of their tools (e.g. proper fMRI data analysis), the knowledge of other subfields (e.g. about other brain areas and network systems), and the knowledge within their own subfield. This fact has led to the current discussions of a “replicability crisis” in the cognitive science field; we also discussed some other implications of it in **Chapter 8**. It is worth mentioning though, that the scientific community itself is constantly undergoing scientific debates, and is constantly developing and self-adjusting scientific theories. No absolute “truth” exists, which is especially true for the newest findings.

From the mass media side, whenever a study with potential social relevance is published, they tend to look for eye-catching titles, to over-interpret and over-generalize the research results (e.g. treating significant but small-effect-size results as having big effects), or they simply do not correctly understand concepts, details, and the research results. For example, the blindsight-related research by Prof. Beatrice de Gelder (the current PhD candidate’s supervisor) was dubbed the “sixth sense”, featured in a popular documentary *Through the wormhole* (2011), which was hosted by the famous actor Morgan Freeman. In the blindsight phenomenon, one side of some patients’ primary visual cortices was destroyed during stroke, leading to a blindness of one half of the visual field contralateral to the lesion, in both eyes. However in this documentary, the narration got this information wrong, by stating that the “left/right eye” was not able to see, instead of the “left/right visual field”.

Therefore, on one hand, although the general public is eagerly in need to be informed about the latest brain (cognitive) science developments, people could not discern, and do not have an easy access to many reliable information sources (scientists and mass media). On the other hand, disseminating latest and correct scientific information to the general public is also a demanding task for the scientists. As a result, brain-related myths have been abundant in the public mind for a long time, accepted by most people without further questioning, such as “only 10% of the brain is used”, and “the left and right laterality predicts whether you are good at logic, or art”. Various recreational games/apps were also created, based on these myths (including laterality-related ones). They boast to boost your cognitive abilities after you play them, without the support of any evidence in relevant research fields (See e.g. Kable et al., 2017).

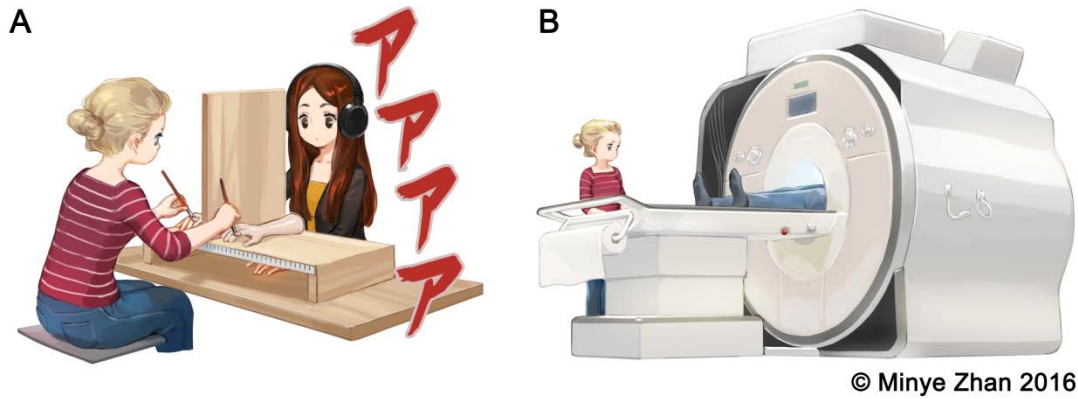
To deal with this situation, first of all, we should de-mystify the brain, and debunk the wrong concepts in the public mind. Take brain laterality for example, although previous fMRI research proposed lateralized univariate activation for face processing (in the right fusiform area), visual word form processing (in the left visual word form area), language processing (in the inferior frontal lobe of the left hemisphere), and tool perception (in the contralateral

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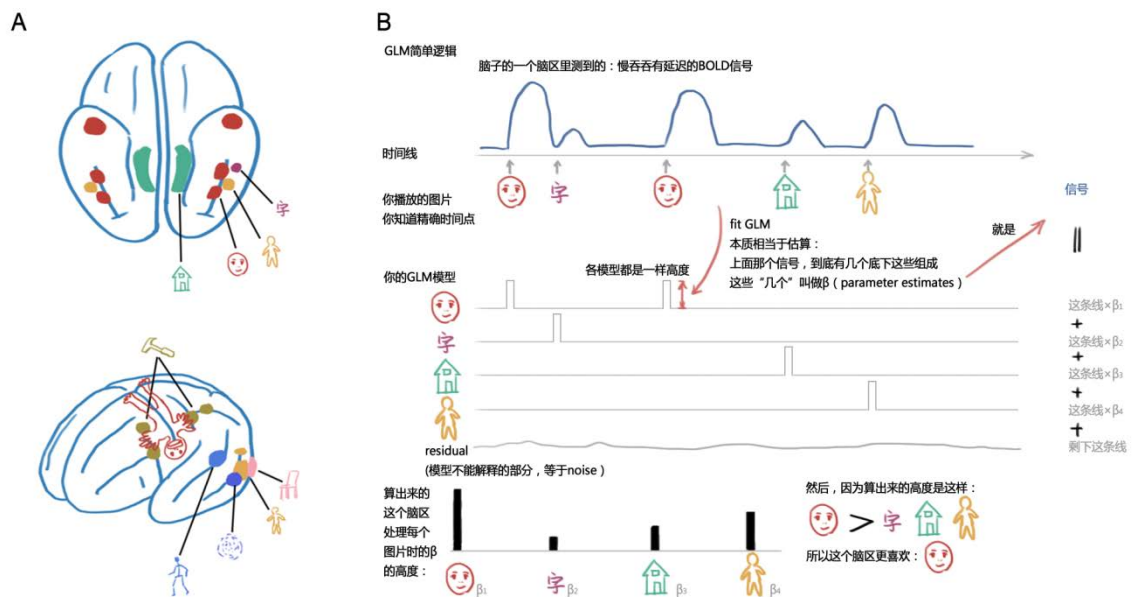
side of the dominant hand, which we also observed in **Chapter 5**, see **Figure 2** in that chapter), these lateralization were relative, and studies did show activated clusters in the other side now and then. Moreover, single-cell spikes are not fully correlated with univariate activation; recent MVPA studies also showed that, outside the activated voxels, relevant information could be recovered from voxels that does not activate above baseline. This indicates that univariate activation could not yet serve as the sole indicator of a brain area participating in certain processing (See a more detailed discussion in **Chapter 8**), and laterality is not an absolute concept. Whenever I see a laterality-myth-related post is being retweeted in the social media, I would/will continue to debunk it, and update the audience with the information above.

We should also routinely introduce to the general public our research results, and new exciting results from other researchers. As a starting cognitive science researcher, and also as a professional computer graphics painter with an outreaching audience in social media, this offered me additional opportunities to disseminate my research, and brain-science related facts. I would represent scientific information in a more accessible drawing style, as what I did for a talk by Prof. de Gelder in Japan, 2016 (See **Figure 1**). When the research article about CFS under fMRI (Chapter 5) was published, I wrote a 7000-word article in the Chinese social media *Weibo* (January 2018, <https://www.weibo.com/ttarticle/p/show?id=2309404197514260695242>, which received 955 retweets, 65 comments, 618 faves), describing our research, and previous research results that led to our study. The concepts mentioned there included attention, action perception, the brain, ventral/dorsal pathways, category-specific areas, fMRI, the general linear model (GLM) and MVPA, the intraparietal sulcus, extrastriate brain area, the MT+ complex, the CFS paradigm. To explain these concepts, I drew simple schematic pictures (See **Figure 2**). I also emphasized how our knowledge of the human brain is gradually built up by numerous studies, each of which tackled only a very small research aspect, and moved the knowledge boundary a little bit further. Up to the point of writing the current chapter, this article has been read for 204045 times. I received comments from the audience, that the article is “easy to understand” for them, that they are very intrigued by our research and the brain research in general, and would like to learn more in the future. Some audience also expressed that before reading this article, they did not realize the bit-by-bit nature of the real research process.

These comments made me realize and believe, that apart from disseminating scientific information and latest research results, it is more important for researchers to show the audience how proper research is done from a researcher’s perspective, and what evidence and thinking process are necessary to lead to a conclusion. For a certain piece of research result, we should provide the general public the most essential but rigorous reasoning chain to understand that result. Although not everyone in the general public is well armed with the critical thinking ability, showing them the actual logic links would give them examples to refer to, and to some extent guard them from easily believing a single piece of information without questioning.



**Figure 1.** Pictures painted by the current PhD candidate, for the presentation of Prof. Beatrice de Gelder (the current PhD candidate’s supervisor), Japan, 2016, in the “manga style” to be more accessible for the Japanese general audience. **A.** Tahnée Engelen (the current PhD candidate’s colleague) performing the rubber-hand experiment on Marta Poyo Solanas (another colleague), while presenting sounds with valence. **B.** Tahnée Engelen putting a participant into the Siemens 3T Prisma Fit scanner, Scannexus, Maastricht.



**Figure 2.** Schematic drawings to explain scientific concepts to the general audience, in an article in the Chinese social media Weibo, about our research (**Chapter 5**). **A.** The category-specific brain areas. **B.** The general logic of GLM (general linear model) analysis in fMRI data.

We also disseminated our research to the public through talks in an art gallery. In an event modulated by Prof. de Gelder (February 2018, <http://fundamentalresearch.org/2018/01/18/drawing-new-machine-age/>), I was invited to have a conversation with the artist Amelie Bouvier, to discuss the use of “drawing” in both art and brain science. When interacting with the audience, I talked about concepts including unconscious processing, machine learning, peri-personal space, and extension of limbs by tools. While keeping in mind my realization from the comments of the social media, I emphasized the subjectivity of the scientific research, e.g. the interpretation of a same result

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would be different by different researchers, and the same research group would update (and even radically change) their understandings across years. I also emphasized that the results we could see are determined and limited by our tools, a direct example would be the different resolutions under 3T and 7T fMRI.

These interactions with the general public stimulated interests and enthusiasm to the brain science, and more such interactions would be necessary. I would continue interacting with the general public, whenever there is an opportunity.

## **For specific groups of users (patients with visual cortex lesion)**

In **Chapter 3** of this thesis, we compared and discussed the similarities/differences of results obtained in healthy participants under the CFS paradigm, to blind patients with primary visual cortex lesion, which included blindsight patients who could perceive and react to events (although at a degraded level) in their blind visual field, and hemianopia (cortically blind in one visual field) patients without blindsight. Our CFS results bore more resemblance to the results from hemianopia patients without blindsight. Cerebrovascular accidents (strokes) are among the major causes for disability these days according to WHO ([http://www.who.int/healthinfo/statistics/bod\\_cerebrovasculardiseasestroke.pdf](http://www.who.int/healthinfo/statistics/bod_cerebrovasculardiseasestroke.pdf)), which impose blindness and disabilities to people when the affected sites are the primary visual cortex. It has been advocated that rehabilitation training would reduce the blind visual field to some extent, and trainings could potentially improve the visual abilities of the blindsight patients. Since the majority of the hemianopia patients are without blindsight, if a link of mechanisms between CFS and this kind of patients could be established, it would be possible to train healthy participants to utilize the unseen visual information suppressed by CFS, and later transfer the training to the group of hemianopia patients. To establish a link of the mechanisms, further research is needed.

In **Chapter 7** of this thesis, we examined the perception of emotional faces and bodies both before and after a domestic-violence VR scenario. The effect of this scenario was previously examined in a group of domestic violence offenders (Seinfeld et al., 2018). In normal male participants, we found that the VR experience induced a reduction of activity specific for fearful faces, in the fMRI run right after it. This indicated that the VR scenario is able to have impacts on people's thinking. Therefore, specific VR programs could be created to influence certain groups of users, for example changing people's perspectives. We should also realize at the same time, in the current society with increasing access to VR experiences, this ability of influencing people should not be misused, and the effect of commercial VR software should be evaluated more carefully.

## **For the scientific researchers using fMRI as a tool**

As mentioned earlier, there are heated discussions about a "replicability crisis" in the scientific community. This has been a recurring discussion in the cognitive science, particularly in the community that uses fMRI as a tool, where misuses of statistical inference

were abundant (Eklund, Nichols, & Knutsson, 2016). And already in the preprocessing stage, the flexibility for the researcher is huge, that multiple preprocessing options are routinely chosen by different researchers (Carp, 2012).

In the fMRI data preprocessing pipeline, I believe that the alignment of functional runs to each other is of the utmost importance. This is especially true for ultra-high field studies with very high functional resolutions (below 1.5 mm isotropic), including studies trying to analyze activity in different cortical layers. In such studies, a misalignment of two functional runs would make a same piece of cortex tissue ending up in different locations across runs, reducing the specificity and credibility of the results derived from the data.

Although of utmost importance, the alignment of functional runs received relatively little attention. The anatomical image (T1-weighted) is usually with high resolution, while the functional image (T2\*-weighted for BOLD images) is usually with much lower resolution, blurry, and with inverted image intensity comparing to the anatomical ones. When using a wide variety of fMRI data processing packages, most researchers align each functional runs to a certain anatomical run (and if necessary align multiple anatomical runs to each other across sessions), hoping that consequently the functional runs would in this way be aligned with each other. This usual procedure requires the alignment of two images that look very much different. When using this procedure, most of the researchers use automatic aligning algorithms provided by the software packages. One alignment algorithm with better performance (boundary-based registration, BBR) calculates the boundaries of different tissue types, and align these boundaries of the functional image to the anatomical image (Greve & Fischl, 2009). This and other alignment algorithms usually operate at the whole-brain level. Whether or not using BBR, after alignment is performed, most packages show the user a boundary of the functional image overlaid onto the anatomical image, which looks roughly fitting each other, and gives the impression that the alignment is successfully done.

However, for gradient echo EPI images, image distortion in the encoding directions is inevitable. Even with top-up distortion correction with scans of reversed encoding directions, distortions in different brain areas are different, which varies across runs due to the participant's head-position change in the scanner, and usually cannot be completely removed. This situation cannot be handled by BBR and other algorithms, thus requires the researcher to decide which specific area to align across runs, to implement manual alignments, and calls for careful visual inspection across different functional runs to check alignment quality (which few researchers actually do, to my knowledge). When manual alignment is performed, each time aligning the functional runs to the anatomical run will introduce human error, which accumulates across the functional runs.

To deal with this problem, for all the fMRI studies in the current thesis, we used a manual work-around aligning method in BrainVoyager, where we explicitly align the different functional runs to one of them. With this method, the image modalities (appearances) are the same across runs, and tiny translations/rotations could be observed with visual inspection, and be dealt with (to the precision of 0.1 unit translation/rotation that is operative in BrainVoyager). This method requires only one anatomical run, and could deal



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with across-session functional run alignments. Thus it is not necessary to acquire multiple anatomical runs across different sessions, which in turn saves scanning resources. For our data, we actually checked the alignments across runs until our satisfaction is reached, before proceeding to further analysis. With this method, we observed more robust activation in our data, than when processing with the traditional automatic/manual alignment methods.

We included the manual for our alignment method here. We hope that this will help our colleagues to achieve better alignment, save scanning resources, and at least we hope it would raise the awareness for checking functional run alignment quality.

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