

LEARNING FROM THE BRAIN

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Learning from the brain

*Best practices for the use of neuroimaging
data
in psychology research*

ACADEMISCH PROEFSCHRIFT

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aan de Universiteit van Amsterdam
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prof. dr. ir. K.I.J. Maex

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Awesome thesis title

Some funky subtitle of my
fancy thesis

Lukas Snoek

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CHAPTER 1

Introduction

The first chapter of the thesis, which introduces your PhD project. The filler-text below was created with the postmodernism generator¹.

1.1 Learning from the brain

When reading this thesis' title, some might think that it contains a typo. Scientists want to learn *about* the brain, right? Not *from* the brain. Well, yes, neuroscientists do. But I am a psychologist at heart, interested in human behavior, cognition, and above all, emotion. I'm interested in the mind, not the brain. I don't care about axons, neurotransmitters, and the basal ganglia. Sure, I do believe, like any proper scientist, that everything we feel, perceive, and do is instantiated in the brain, but I do not necessarily think that *just* studying the brain in isolation is going to teach us anything useful about the human psyche. Mind you, in this PhD you'll find several studies that analyze *brain* data, but realize that my ultimate goal has always been to understand the mind.

¹<http://www.elsewhere.org/journal/pomo>

CHAPTER 2

Shared states: using MVPA to test neural overlap between self-focused emotion imagery and other-focused emotion understanding

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Abstract

The present study tested whether the neural patterns that support imagining “performing an action”, “feeling a bodily sensation” or “being in a situation” are directly involved in understanding *other people’s* actions, bodily sensations and situations. Subjects imagined the content of short sentences describing emotional actions, interoceptive sensations and situations (self-focused task), and processed scenes and focused on *how* the target person was expressing an emotion, *what* this person was feeling, and *why* this person was feeling an emotion (other-focused task). Using a linear support vector machine classifier on brain-wide multi-voxel patterns, we accurately decoded each individual class in the self-focused task. When generalizing the classifier from the self-focused task to the other-focused task, we also accurately decoded whether subjects focused on the emotional actions, interoceptive sensations and situations of *others*. These results show that the neural patterns that underlie self-imagined experience are involved in understanding the experience of other people. This supports the theoretical assumption that the basic components of emotion experience and understanding share resources in the brain.

2.1 Introduction

To navigate the social world successfully it is crucial to understand other people. But how do people generate meaningful representations of other people’s actions, sensations, thoughts and emotions? The dominant view assumes that representations of other people’s experiences are supported by the same neural systems as those that are involved in generating experience in the self (e.g., Gallese et al., 2004; see for an overview Singer, 2012). We tested this principle of self-other neural overlap directly, using multi-voxel pattern analysis (MVPA), across three different

aspects of experience that are central to emotions: actions, sensations from the body and situational knowledge.

In recent years, evidence has accumulated that suggests a similarity between the neural patterns representing the self and others. For example, a great variety of studies have shown that observing actions and sensations in other people engages similar neural circuits as acting and feeling in the self (see for an overview Bastiaansen et al., 2009). Moreover, an extensive research program on pain has demonstrated an overlap between the experience of physical pain and the observation of pain in other people, utilizing both neuroimaging techniques (e.g., Lamm et al., 2011) and analgesic interventions (e.g., Rütgen et al., 2015; Mischkowski et al., 2016). This process of “vicarious experience” or “simulation” is viewed as an important component of empathy (Carr et al., 2003; Decety, 2011; Keysers & Gazzola, 2014). In addition, it is argued that mentalizing (e.g. understanding the mental states of other people) involves the same brain networks as those involved in self-generated thoughts (Uddin et al., 2007; Waytz & Mitchell, 2011). Specifying this idea further, a constructionist view on emotion proposes that both emotion experience and interpersonal emotion understanding are produced by the same large-scale distributed brain networks that support the processing of sensorimotor, interoceptive and situationally relevant information (Barrett & Satpute, 2013; Oosterwijk & Barrett, 2014). An implication of these views is that the representation of self- and other-focused emotional actions, interoceptive sensations and situations overlap in the brain.

Although there is experimental and theoretical support for the idea of self-other neural overlap, the present study is the first to directly test this process using MVPA across three different aspects of experience (i.e. actions, interoceptive sensations and situational knowledge). Our experimental design consisted of two

different tasks aimed at generating self- and other-focused representations with a relatively large weight given to either action information, interoceptive information or situational information.

In the *self-focused* emotion imagery task (SF-task) subjects imagined performing or experiencing actions (e.g., *pushing someone away*), interoceptive sensations (e.g., *increased heart rate*) and situations (e.g., *alone in a park at night*) associated with emotion. Previous research has demonstrated that processing linguistic descriptions of (emotional) actions and feeling states can result in neural patterns of activation associated with, respectively, the representation and generation of actions and internal states (Oosterwijk et al., 2015; Pulvermüller & Fadiga, 2010). Furthermore, imagery-based inductions of emotion have been successfully used in the MRI scanner before (Oosterwijk et al., 2012; Wilson-Mendenhall et al., 2011), and are seen as robust inducers of emotional experience (Lench et al., 2011). In the *other-focused* emotion understanding task (OF-task), subjects viewed images of people in emotional situations and focused on actions (i.e., *How does this person express his/her emotions?*), interoceptive sensations (i.e., *What does this person feel in his/her body*) or the situation (i.e., *Why does this person feel an emotion?*). This task is based on previous research studying the neural basis of emotion oriented mentalizing (Spunt & Lieberman, 2012).

With MVPA, we examined to what extent the SF- and OF-task evoked similar neural patterns. MVPA allows researchers to assess whether the neural pattern associated with one set of experimental conditions can be used to distinguish between another set of experimental conditions. This relatively novel technique has been successfully applied to the field of social neuroscience in general (e.g., Gilbert et al., 2012; Brosch et al., 2013; Parkinson et al., 2014), and the field of self-other neural overlap in particular. For example, several MVPA studies recently assessed

whether experiencing pain and observing pain in others involved similar neural patterns (Corradi-Dell'Acqua et al., 2016; Krishnan et al., 2016). Although there is an ongoing discussion about the specifics of shared representation in pain based on these MVPA results (see for an overview Zaki et al., 2016), many authors emphasize the importance of this technique in the scientific study of self-other neural overlap (e.g., Corradi-Dell'Acqua et al., 2016; Krishnan et al., 2016).

MVPA is an analysis technique that decodes latent categories from fMRI data in terms of multi-voxel patterns of activity (Norman et al., 2006). This technique is particularly suited for our research question for several reasons. First of all, although univariate techniques can demonstrate that tasks activate the same brain regions, only MVPA can statistically test for shared representation (Lamm & Majdandžić, 2015). We will evaluate whether multivariate brain patterns that distinguish between mental events in the SF-task can be used to distinguish, above chance level, between mental events in the OF-task. Second, MVPA analyses are particularly useful in research that is aimed at examining distributed representations (Singer, 2012). Based on our constructionist framework, we indeed hypothesize that the neural patterns that will represent self- and other focused mental events are distributed across large-scale brain networks. To capture these distributed patterns, we used MVPA in combination with data-driven univariate feature selection on whole-brain voxel patterns, instead of limiting our analysis to specific regions-of-interest (Haynes, 2015). And third, in contrast to univariate analyses that aggregate data across subjects, MVPA can be performed within-subjects and is thus able to incorporate individual variation in the representational content of multivariate brain patterns. In that aspect within-subject MVPA is sensitive to individual differences in how people imagine actions, sensations and situations, and how they understand others. In short, for our purpose to explicitly test the assumption that self

and other focused processes share neural resources, MVPA is the designated method.

We tested the following two hypotheses. First, we tested whether we could classify *self-imagined* actions, interoceptive sensations and situations above chance level. Second, we tested whether the multivariate pattern underlying this classification could also be used to classify the how, what and why condition in the *other-focused* task.

2.2 Methods

Subjects

In total, we tested 22 Dutch undergraduate students from the University of Amsterdam (14 females; $M_{\text{age}} = 21.48$, $s.d._{\text{age}} = 1.75$). Of those 22 subjects, 13 subjects were tested twice in 2 sessions about 1 week apart. Half of those sessions were used for the model optimization procedure. The other half of the sessions, combined with an additional nine subjects (who were tested only once), constituted the model validation set (see Model optimization procedure section). In total, two subjects were excluded from the model validation dataset: one subject was excluded because there was not enough time to complete the experimental protocol and another subject was excluded due to excessive movement (>3 mm within data acquisition runs).

All subjects signed informed consent prior to the experiment. The experiment was approved by the University of Amsterdam's ethical review board. Subjects received 22.50 euro per session. Standard exclusion criteria regarding MRI safety were applied and people who were on psychopharmacological medication were excluded a priori.

Experimental design

Self-focused emotion imagery task

The self-focused emotion imagery task (SF-task) was created to preferentially elicit *self-focused* processing of action, interoceptive or situational information associated with emotion. Subjects processed short linguistic cues that described actions (e.g., *pushing someone away*; *making a fist*), interoceptive sensations (e.g., *being out of breath*; *an increased heart rate*), or situations (e.g., *alone in a park at night*; *being falsely accused*) and were instructed to imagine performing or experiencing the content. The complete instruction is presented in the Supplementary Materials; all stimuli used in the SF-task are presented in Supplementary Table S1. Linguistic cues were selected from a pilot study performed on an independent sample of subjects ($n = 24$). Details about this pilot study are available on request. The descriptions generated in this pilot study were used as qualitative input to create short sentences that described actions, sensations or situations that were associated with negative emotions, without including discrete emotion terms. The cues did not differ in number of words, nor in number of characters ($F < 1$).

CHAPTER 3

How to control for confounds in decoding analyses of neuroimaging data

CHAPTER 4

The Amsterdam Open MRI Collection, a set of multimodal MRI datasets for individual difference analyses

CHAPTER 5

Choosing to view morbid information involves reward circuitry

CHAPTER 6

Using predictive modeling to quantify the importance and limitations of action units in emotion perception

CHAPTER 7

Comparing models of dynamic facial expression perception

CHAPTER 8

Summary and general discussion

Appendices

APPENDIX A

Supplement to Chapter 2

A.1 Stimuli used for SF-task

Class	Dutch	English translation
Action	Hard wegrennen	Running away fast
	Iemand wegduwen	Pushing someone away
	Iemand stevig vastpakken	Holding someone tightly
	Je hoofd schudden	Shaking your head
	Heftige armgebaren maken	Making big arm gestures
	Ergens voor terugdeinzen	Recoiling from something
	Je ogen dichtknijpen	Closing your eyes tightly
	Je ogen wijd open sperren	Opening your eyes widely
	Je wenkbrauwen fronsen	Frowning with your eyebrows
	Je schouders ophalen	Raising your shoulders
	Op de vloer stampen	Stamping on the floor
	In elkaar duiken	Cowering

	Je schouders laten hangen	Slumping your shoulders
	Je vuisten ballen	Tighten your fists
	Je borst vooruit duwen	Push your chest forward
	Je tanden op elkaar zetten	Clench your teeth
	Je hand voor je mond slaan	Put your hand in front of your mouth
	Onrustig bewegen	Moving restlessly
	Heen en weer lopen	Walking back and forth
	Je hoofd afkeren	Turning your head away
Interoception	Een brok in je keel	A lump in your throat
	Buiten adem zijn	Being out of breath
	Een versnelde hartslag	A fast beating heart
	Je hart klopt in de keel	Your heart is beating in your throat
	Een benauwd gevoel	An oppressed feeling
	Een misselijk gevoel	Being nauseous
	Druk op je borst	A pressure on your chest
	Strak aangespannen spieren	Tense muscles
	Een droge keel	A dry throat
	Koude rillingen hebben	Cold shivers
	Bloed stroomt naar je hoofd	Blood is going to your head
	Een verdoofd gevoel	A numb feeling
	Je hebt tintelende ledenmaten	Tingling limbs
	Een verlaagde hartslag	A slow heartbeat

	Je hebt zware ledematen	Heavy limbs
	Een versnelde ademhaling	Fast breathing
	Je hebt hoofdpijn	Headache
	Je hebt buikpijn	Stomachache
	Zweet staat in je handen	Sweaty palms
	Je maag keert zich om	Your stomach churns
Situation	Vals beschuldigd worden	Being falsely accused
	Dierbare overlijdt	A loved one dies
	Vlees is bedorven	Meat that has gone off
	Je wordt bijna aangereden	You are almost hit by a car
	Iemand naast je braakt	Someone next to you vomits
	Huis staat in brand	House is on fire
	Zonder reden ontslagen worden	Being fired for no reason
	Een ongemakkelijke stilte	An uncomfortable silence
	Alleen in donker park	Alone in a dark park
	Inbraak in je huis	A house burglary
	Een gewond dier zien	Seeing a wounded animal
	Tentamen verknallen	Messing up your exam
	Je partner bedriegt je	You partner cheats on you
	Dierbare is vermist	A loved one is missing
	Belangrijke sollicitatie vergeten	Forgot a job interview
	Onvoorbereid presentatie geven	Giving a presentation unprepared

Je baas beledigt je	Your boss offends you
Goede vriend negeert je	A good friend neglects you
Slecht nieuws bij arts	Bad news at the doctor
Bommelding in metro	A bomb alarm in the metro

Note: The stimulus materials presented in Table S1 were selected from a pilot study. In

A.2 Full instruction for the other-focused emotion understanding task

Translated from Dutch; task presented first.

In this study we are interested in how the brain responds when people understand the emotions of others in different ways. In the scanner you will see images that display emotional situations, sometimes with multiple people. In every image one person will be marked with a red square. While viewing the image we ask you to focus on the emotion of that person in three different ways.

With some images we ask you to focus on HOW this person expresses his or her emotion. Here we ask you to identify expressions in the face or body that are informative about the emotional state that the person is experiencing.

With other images we ask you to focus on WHAT this person may feel in his or her body. Here we ask you to identify sensations, such as a change in heart rate, breathing or other internal feeling, that the person might feel in this situation.

With other images we ask you to focus on WHY this person experiences an emotion. Here we ask you to identify a specific rea-

son or cause that explains why the person feels what he or she feels.

Every image will be presented for six seconds. During this period we ask you to silently focus on HOW this person expresses emotion, WHAT this person feels in his/her body, and WHY this person feels an emotion.

Before you will enter the scanner we will practice. I will show you three images and will ask you to perform each of the three instructions out loud.

It is important to note that there are no correct or incorrect answers, it is about how you interpret the image. For the success of the study it is very important that you apply the HOW, WHAT or WHY instruction for each image. Please do not skip any images and try to apply each instruction with the same motivation. It is also important to treat every image separately, although it is possible that you have similar interpretations for different images.

The three instructions are combined with the images in blocks. In every block you will see five images with the same instruction. Each block will start with a cue that tells you what to focus on in that block.

Each image is combined with all three instructions, so you will see the same image multiple times. In between images you will sometimes see a black screen for a longer period of time.

Do you have any questions?

A.3 Full instruction for the self-focused emotion imagery task

Translated from Dutch; task presented second.

In this study we are interested in how the brain responds when people imagine different aspects of emotion. In the scanner you will see sentences that describe aspects of emotional experience. We ask you to try to imagine the content of each sentence as rich and detailed as possible.

Some sentences describe actions and expressions. We ask you to imagine that you are performing this action or expression. Other sentences describe sensations or feelings that you can have *inside* your body. We ask you to imagine that you are experiencing this sensation or feeling. Other sentences describe emotional situations. We ask you to imagine that you are experiencing this specific situation.

We ask you to always imagine that YOU have the experience. Thus, it is about imagining an action or expression of your body, a sensation inside your body, or a situation that you are part of.

I will give some examples now.

For each sentence you have six seconds to imagine the content. All sentences will be presented twice. In between sentences you will sometimes see a black screen for a longer period of time. For this experiment to succeed it is important that you imagine each sentence with the same motivation, even if you have seen the sentence before. Please do not skip sentences.

Do you have any questions?

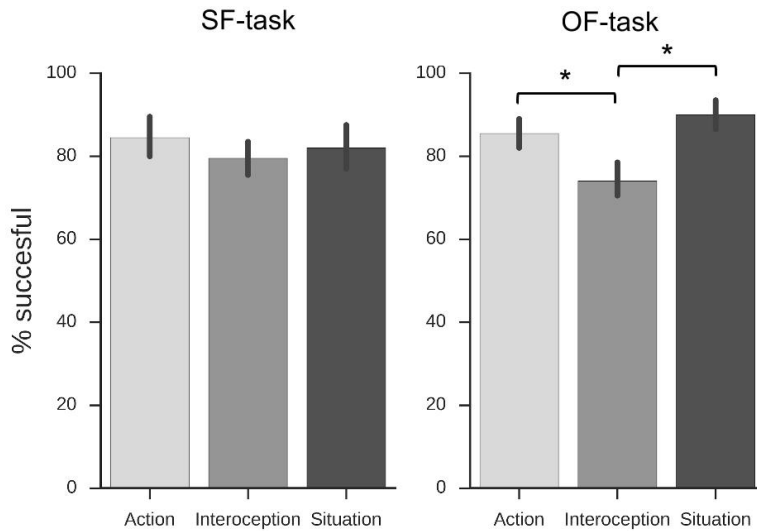


FIGURE A.1 Mean percentage of trials successfully executed for the SF-task (left panel) and OF-task (right panel). Error bars indicate 95% confidence intervals. A one-way ANOVA of the success-rates of the SF-task (left-panel) indicated no significant overall differences, $F(2, 17) = 1.03$, $p = 0.38$. In the OF-task (right panel) however, a one-way ANOVA indicated that success-rates differed significantly between classes, $F(2, 17) = 17.74$, $p < 0.001$. Follow-up pairwise comparisons (Bonferroni corrected, two tailed) revealed that interoception-trials ($M = 74.00$, $SE = 2.10$) were significantly less successful ($p < 0.001$) than both action-trials ($M = 85.50$, $SE = 1.85$) and situation trials ($M = 90.00$, $SE = 1.92$).

APPENDIX B

Supplement to Chapter 3

APPENDIX C

Supplement to Chapter 5

APPENDIX D

Supplement to Chapter 6

APPENDIX E

Supplement to Chapter 7

APPENDIX F

Data, code and materials

Bibliography

Contributions to the chapters

List of other publications

Alilović, J., Timmermans, B., **Reteig, L. C.**, van Gaal, S., & Slagter, H. A. (2019). No evidence that predictions and attention modulate the first feedforward sweep of cortical information processing. *Cerebral Cortex*, 29 2261–2278. <https://doi.org/10.1093/cercor/bhz038>

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Nederlandse samenvatting (Summary in Dutch)

Replace this with the Dutch title of your thesis

The summary goes here.

Acknowledgments

This section is optional, but theses typically include acknowledgments (*dankwoord* in Dutch) at the end. You may want to mix languages to thank people in their native tongue (though most Dutch speakers write it entirely in Dutch). But the standard language of the thesis template is English. You can switch temporarily by wrapping the text in language tags like so: [Your Dutch text here]{lang=nl}. This is important for things like hyphenation to work properly.

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