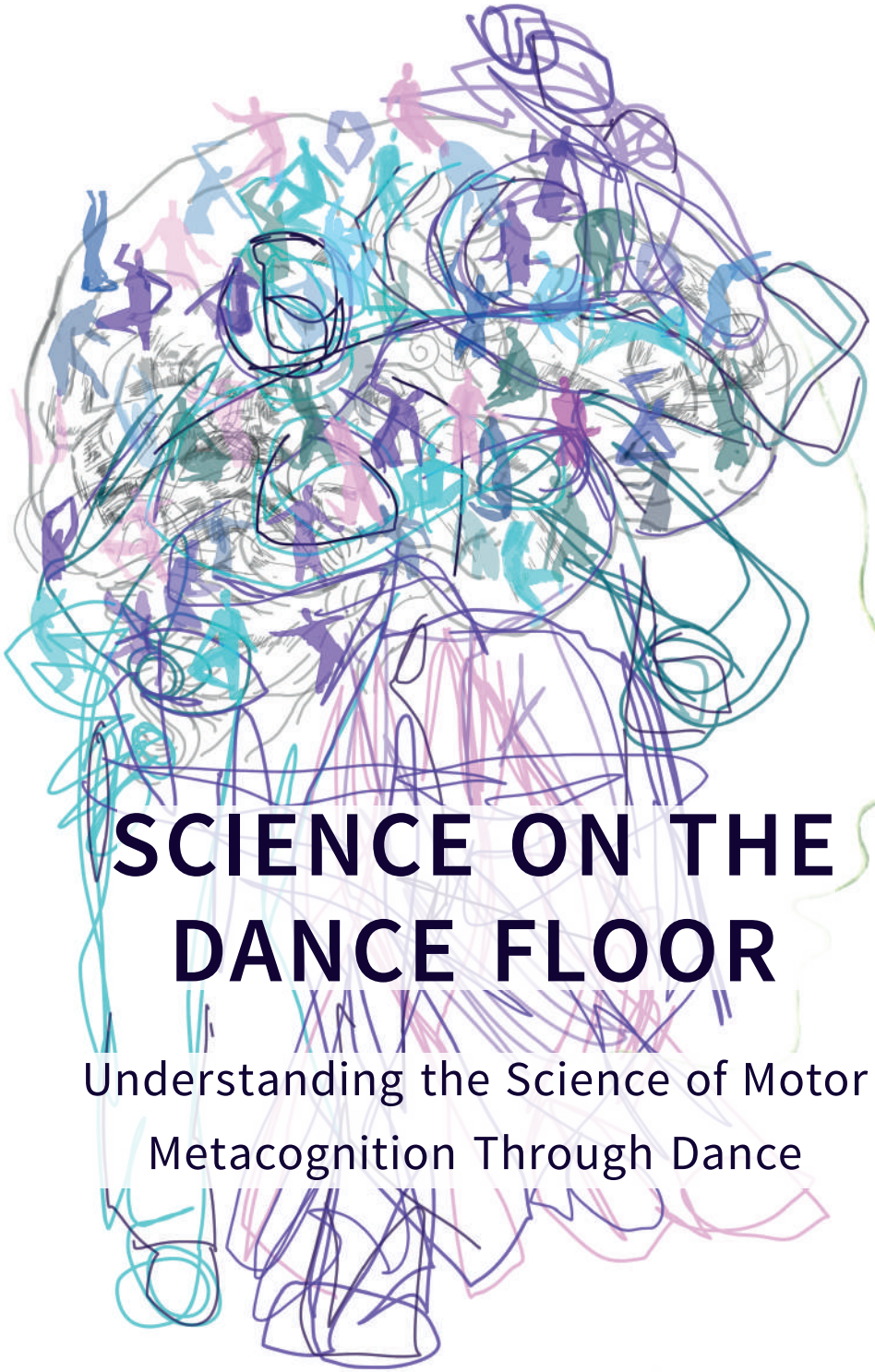

SCIENCE ON THE DANCE FLOOR

Understanding the Science of Motor Metacognition Through Dance

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Understanding the Science of Motor Metacognition Through Dance

This project has been possible thanks to funding for Science Communication from the Volkswagen Stiftung (Az.: 9E513). It was additionally supported by the Horizon Europe Marie Skłodowska-Curie Actions Doctoral Networks; under the "Confident Decisions” (CODE) grant project, agreement No. 101119647.

Contents

INTRODUCTION

There is movement happening,
and there is what I know about that movement,
and they are not the same thing.

What is dance?

The first intuitive answer that comes to mind might be: dance is movement to music. But is music necessary? Is every movement dance? When does movement become dance? Perhaps when it is felt. Perhaps dance is *felt* movement.

Dance takes many forms across cultures and historical contexts and encompasses a vast spectrum of human movement, from ritualistic practices, to codified techniques such as ballet, social dances, or folk traditions, and further to experimental forms in contemporary performance and choreographic research. Across this diversity, one thing remains constant though: *it is about the lived experience of being in a moving body.*

Somatic movement philosophy emphasizes the inner experience of movement - "from inside out" - understanding movement as something deeply connected to inner sensations. Within this perspective, sensation is placed at the center of movement and dance, approaching dance as an inwardly experienced process.
This approach, with its focus on bodily experience, intersects with the principles we explore in the project "Science on the Dance Floor".

What are we interested in?

Neuroscience has helped us understand in exquisite detail how our brain moves our body. But much of this work focuses on how the brain sends and corrects motor commands, forgetting our subjective experience of being in a moving body.

Why does it feel like anything at all to move our bodies? How does the brain consciously know how it moves our body? And, considering that much of our movement and postural muscle control is unconscious, how much can the brain consciously know about how it moves our bodies? Are there limits to our introspection? Can one train to consciously direct attention to normally unconscious aspects of movement?

We are interested in two approaches to probe (with the aim to understand) the experience of being in a moving body: A scientific approach, as external observers, and an introspective approach, as observers from the inside. We hope to invite better insights, and to invite dancers to become rigorous scientists of their inner experience.

What are the Science on the Dance Floor movement labs?

The movement labs "Science on the Dance Floor" are designed for movement artists, dancers, athletes, actors, body practitioners — anyone interested in movement — and aim to exchange tools and perspectives for movement practitioners to 'think like scientists' and for scientists to 'think like dance artists.' In these workshops, we invite participants to explore what cognitive science currently understands about movement, awareness, and bodily control; and just as importantly, what remains unknown. We want to encourage workshop participants to critically and experientially engage with the questions: What does it feel like to move? What in my movement is conscious — and what is not? Where are the limits of my awareness of my own movement and can one shift them?

In the guided labs participants are invited to move or dance attending to their inner sensations, introspect on their movement, and learn corresponding scientific terms, using them as tools to notice and articulate their experience. Together, we use introspection to explore subjective experience and tease it apart into its different aspects.

Guided by scientific work, we then name these different aspects with the common scientific terminology. This allows us to bridge two ways to understand conscious experience; introspection and scientific enquiry. Equipped with a shared vocabulary, we discuss whether dancers and movement practitioners, through their training, may have gained a particularly clear sense of their bodies in motion. And if — and how — they can help others improve that same skill. Ultimately, what we set out to do is not to find answers, but to share questions and help shape a kind of interdisciplinary research culture, that values exchange and brings together different forms of expertise.

Structure of a movement lab

The movement labs take place in various studio settings. Each one unfolds following the same structure: Several blocks build progressively upon one another — each of them relates to one idea or question. Participants are invited to explore these questions first through dance and then through a scientific lens. After each task, they report on their experience using the digital app (https://www.scienceonthedancefloor.com/downloads) or the handbook.

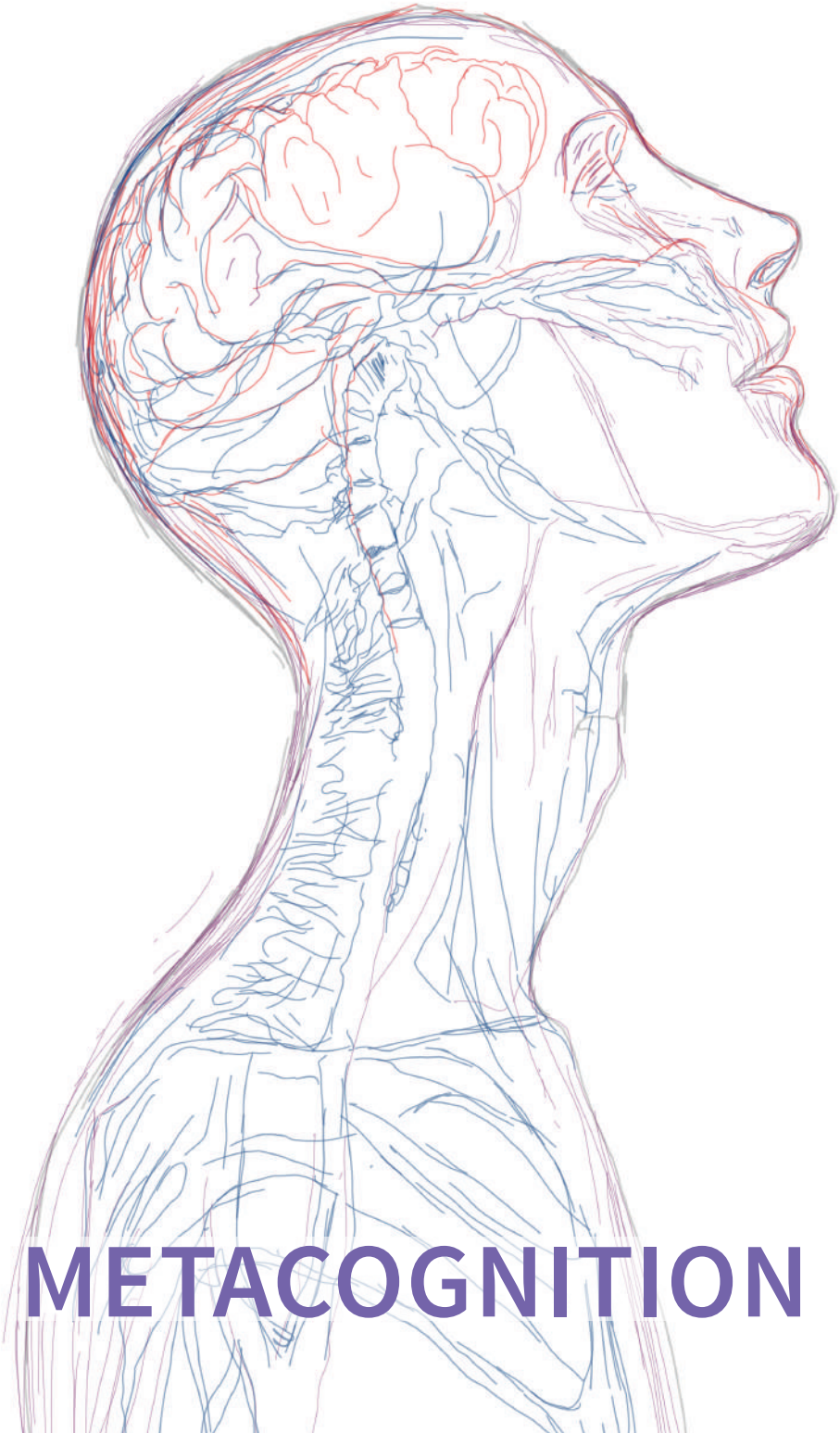
This workshop is not intended to help participants to master movement, but to make us reflect and relate differently to experiencing and knowing movement. **The focus is not on the quality of movements, but rather on the quality of the subjective experience of those movements.**

Structure of the handbook

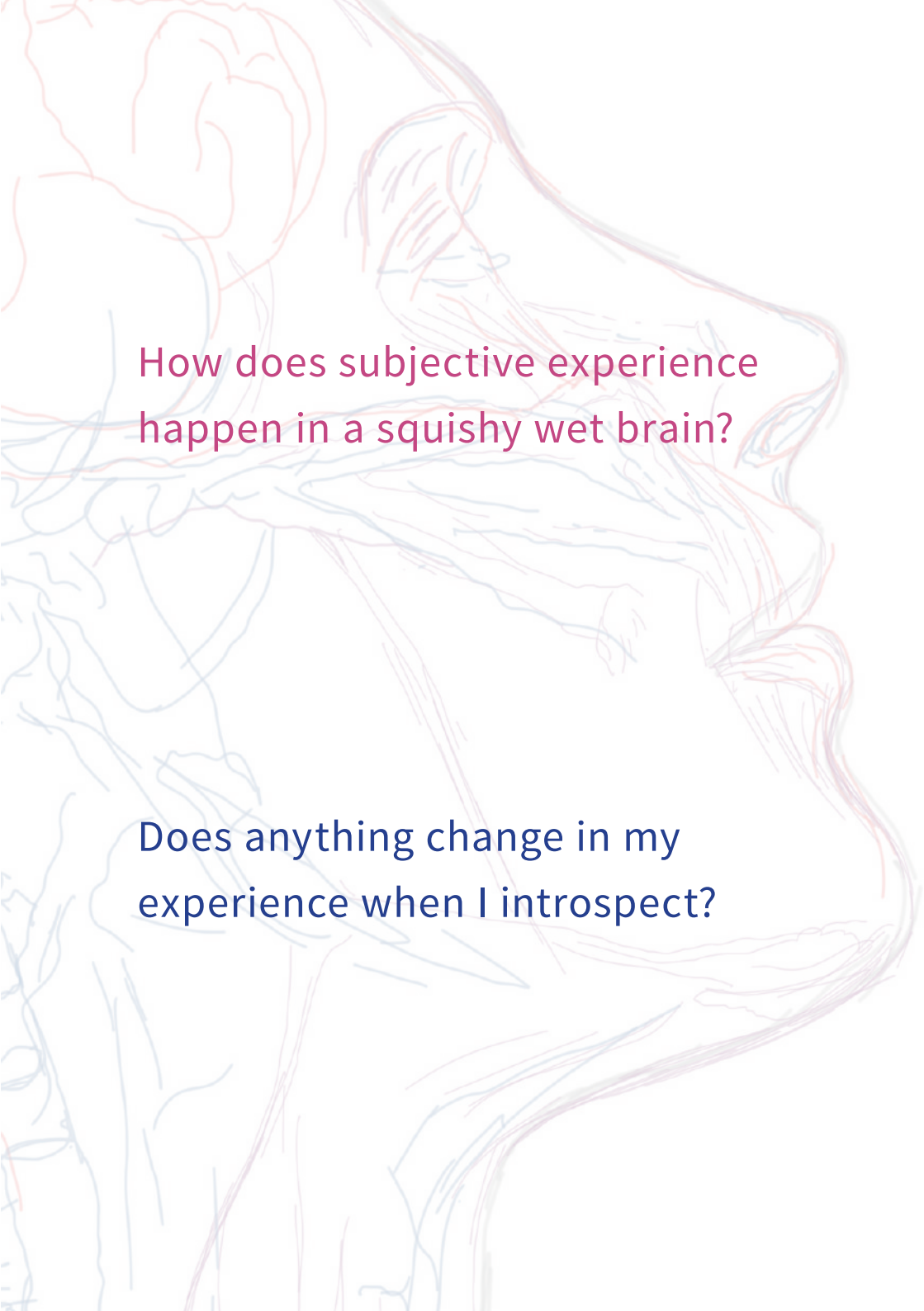
This handbook is a practical guide accompanying a series of live labs “Science on the Dance Floor” that we are conducting at various venues throughout 2026.

With this handbook, you can reproduce or repeat selected tasks, or follow the entire flow. Some exercises are thought to be done in pairs or small groups, but most of them can be done by a single person. In the studio setting, movement exploration tasks are facilitated by dancer and choreographer Irina Demina, participants of the workshop make their reports in a browser-based digital app. Discussions and feedback rounds are facilitated and led by members of the scientific team.

Just as in the lab, each exercise in the handbook is thought to invite you to actively engage with your experience and to reflect on it using scientific terms from cognitive science. We encourage you to follow the structure that we present here: We introduce each scientific term first through an experiential movement exploration task—not the other way around. You can read the instructions aloud or silently, then set a timer and carry out the movement exploration (or guide others through it). Afterwards, you are invited to report your experience either in the digital app (available on our website https://www.scienceonthedancefloor.com/downloads) or simply draw on the illustrations in this handbook.



METACOGNITION



How does subjective experience happen in a squishy wet brain?

Does anything change in my experience when I introspect?

Movement exploration

How to explore: with some gentle ambient soundtrack or in silence.
If you want to use a soundtrack, choose one that supports your introspection and movement, but make sure it is not distracting.
Recommended duration: 7-10 minutes.

Instructions

Walk through the space, gently turn your attention inward to observe your body sensations. Start by noticing the sensations in your feet.
How does it feel as they meet the floor?
What does it feel like when the floor receives your weight?

Observe how your weight shifts with each step.
Are there asymmetries in your movement?
Do some parts lead more than others?
Do you feel something in your knees?

Bring your attention to your pelvis.
What sensations are present there?

Continue upwards: your stomach, your chest, your shoulders, your arms…
Can you feel something in your fingertips?
In your nostrils?
What about your left eyebrow?
Your lower jaw?
Start to notice more nuanced sensations.
Which sensations are clear and vivid?
Which ones are more subtle or harder to notice?

Allow your attention to move through your body, curious, open.

You may choose to name these sensations quietly in your mind, point to them, or gently add small movements to those body parts.
What helps you deepen your connection to your body sensations?

If you want, explore changing levels while moving: try sitting or lying down on the floor. Notice how the sensations shift or stay the same. When ready, find your way back up and continue walking.
Feel free to repeat it as often as you like.

Report the sensations in your body

Draw a sensation on the body area where you are experiencing it.
Choose a colour for it.

Focus on the location, size and shape of each experience.
Use the intensity of each color to mark how vivid, or clear, the sensation is (light or faint marks for unclear sensations; stronger, more saturated marks for vivid ones).
Optionally, name the sensations.

You can draw as many sensations as you like.

SUBJECTIVE EXPERIENCE

("The What-it-is-like-ness")

and

METACOGNITION

How does subjective experience happen in a squishy wet brain?

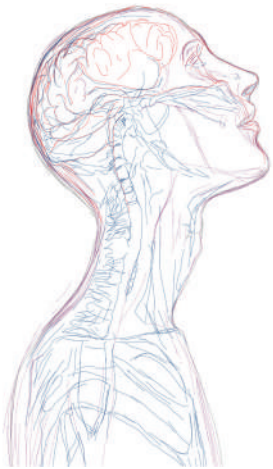
Does anything change in my experience when I introspect?

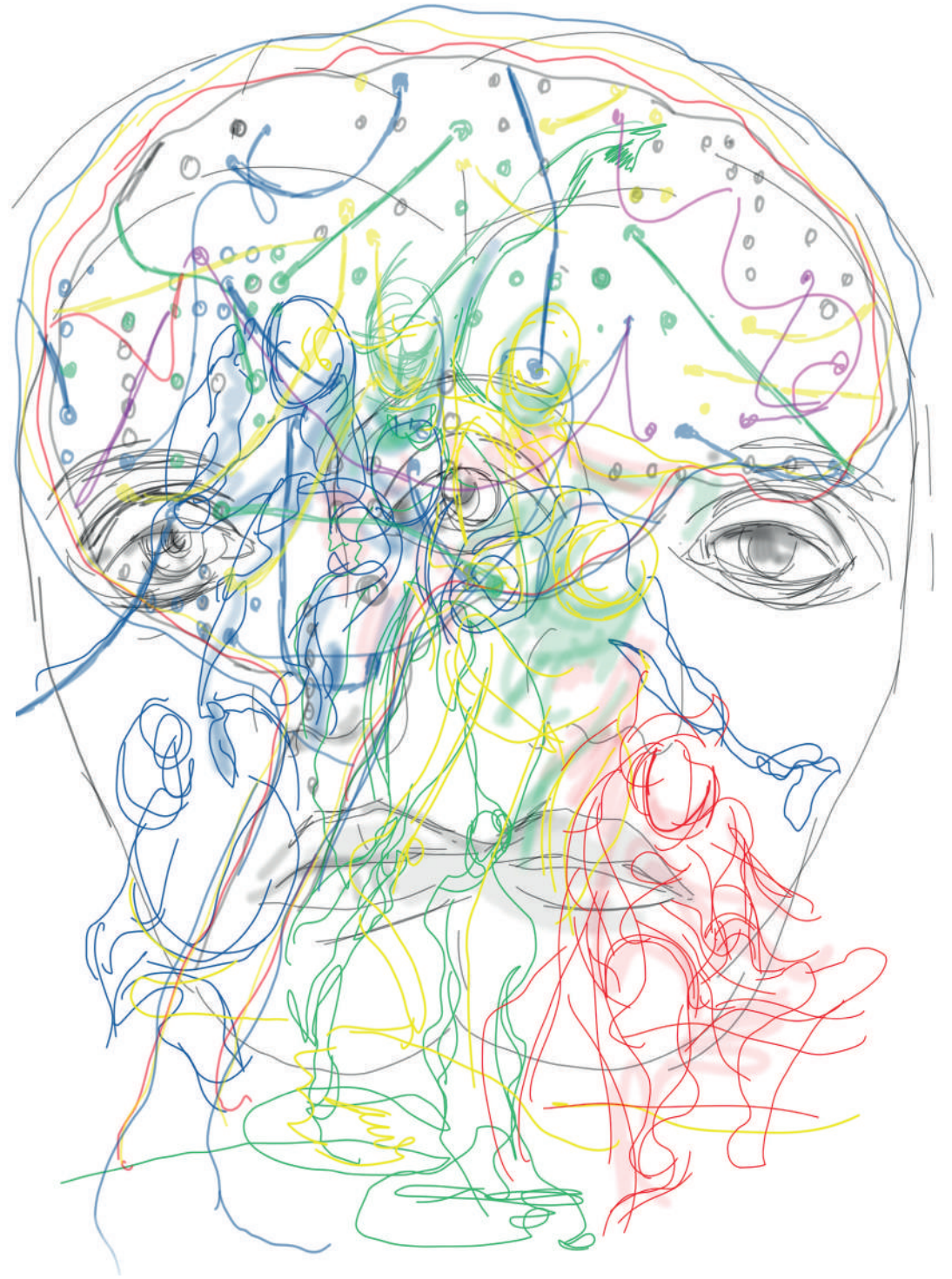
Not all systems have subjective experience. It does not feel like anything to be a lamp. And it does not feel like anything to be a digital camera. We (humans), on the other hand, consciously experience the world around us and our bodies within it — “It feels like something” to see, and it feels like something to dance.

But how do feelings and experiences happen in the brain?

The short answer is that we don’t know for sure. But to ask this question, one branch of research works on Metacognition: the brain’s ability to look at itself. Metacognition allows us to know, report, and potentially analyse what we see, feel, or think. Through metacognitive monitoring, the brain codes not only what it just saw but also, how much it should trust what it just saw. We know that because we can decode this information from human and animal brains.

Some philosophers suggest that this ability to reflect and report on our own mental states is what makes that mental state conscious. Others argue that there are conscious states that we cannot report. Neuroscientists have aimed at resolving this conflict by isolating brain activity related to perceiving, and brain activity related to reporting. These experiments revealed that the mere fact of reporting a mental state was responsible for a lot more of the brain activity than we previously thought. Still, and despite a lot of progress, fundamentally, we haven’t yet quite figured out how the brain knows itself.





MANIFOLD OF EXPERIENCES

What is the range of sensations that my body can experience?

Why does the same body feel so different at different times?

How to explore: in silence
Recommended duration: 4 minutes per task.

Movement exploration 1

Find a comfortable spot in space, stand still and close your eyes.
Recall how you woke up this morning.
How did your body feel? Were you tired, energized, heavy, tense, soft, restless, calm.. or something else?
Let this memory come back to you not through your mind, but through your body.

Notice how your body reacts as you remember.
Where in your body do you sense something shifting? Is there warmth, resistance, tightness, flow…?

Choose one sensation that stands out, and begin to amplify it gently with movement or shape. Kind of making it brighter, louder, more vivid.
Stay curious - how does this sensation make you move, how does it resonate in your body?

Allow it to unfold into some sort of a dance - not for the sake of performing a story, but exploring the physical memory.

Stay with your internal sensation. Let the dance evolve from within.

Report 1

Which salient sensation did you explore?
Name it, if you can, and draw it on the respective body part where you were mostly feeling it.
Try to pay attention to its **size, or its extent and its location.**
Here again, use color intensity to show how clearly you experienced it.

Movement exploration 2

Think about the last movie that truly touched you, left a trace, or stayed with you afterward. Let the memory return gently.

As you recall it, bring your attention to your body:
Which sensations arise? Is there perhaps warmth in your chest? Tightness in your throat? Maybe you feel it in your stomach? Contraction in your shoulders?

Stay with the sensation that feels most vivid.
Where does it live in your body? What texture does it have: is it dense, sharp, soft, spreading, pulsing?

Begin to amplify this sensation with movement or shape. Don't try to explain or imitate anything, let your body respond. Let this embodied memory guide your movement. Let it transform, shift, expand - and see what kind of dance emerges.

Stay close to your felt experience.
Let it remain subtle or grow bold, whatever your body asks for at this moment.

Report 2

Which salient sensation did you explore?

Name it, if you can, and draw it on the respective body part where you were mostly feeling it.
Try to pay attention to its **size, or its extent and its location.**
Here again, use color intensity to show how clearly you experienced it.

Movement exploration 3

Choose a personal memory you feel ready to connect with right now.
It could be an event, a situation, or a brief moment - something meaningful that you wish to carefully revisit. Be gentle with yourself.

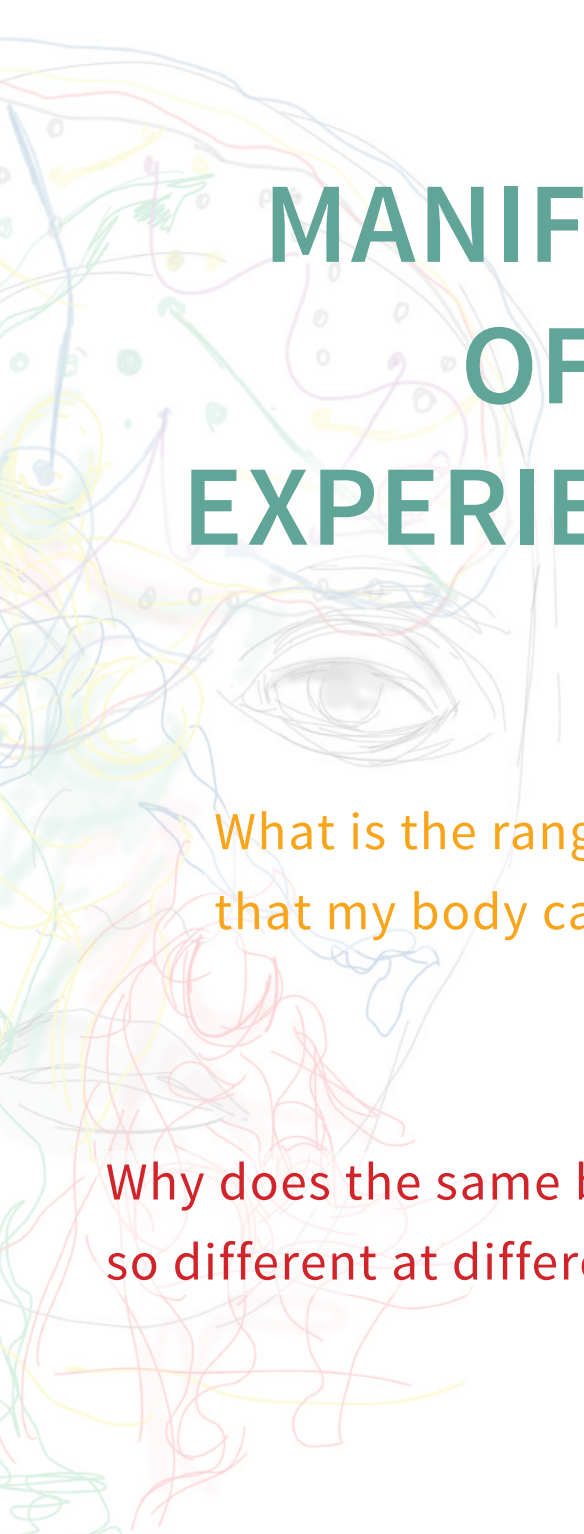
Before you begin, check in: are you feeling safe and grounded enough to revisit this memory right now?
If you're unsure or feel unsettled, rather choose a different memory - one that feels more appropriate in this moment.

Allow the memory to come to you gently.
As it settles, begin to notice how your body responds:
Where do you feel it? What are you feeling - opening, tingling, heaviness, tightness, warmth…?
Stay with what arises.
Where does it live in your body?
Let a movement or a shape emerge from this place in your body, however small or subtle. Let this embodied memory guide you into motion, however big or small it is. Maybe it is not even visible from the outside.

Allow the movement to evolve - not to reenact, but to physically explore how your body holds this experience.

Report 3

Which salient sensation did you explore?
Name it, if you can, and draw it on the respective body part where you were mostly feeling it.
Try to pay attention to its **size, or its extent and its location.**
Here again, use color intensity to show how clearly you experienced it.



MANIFOLD OF EXPERIENCES

What is the range of sensations that my body can experience?

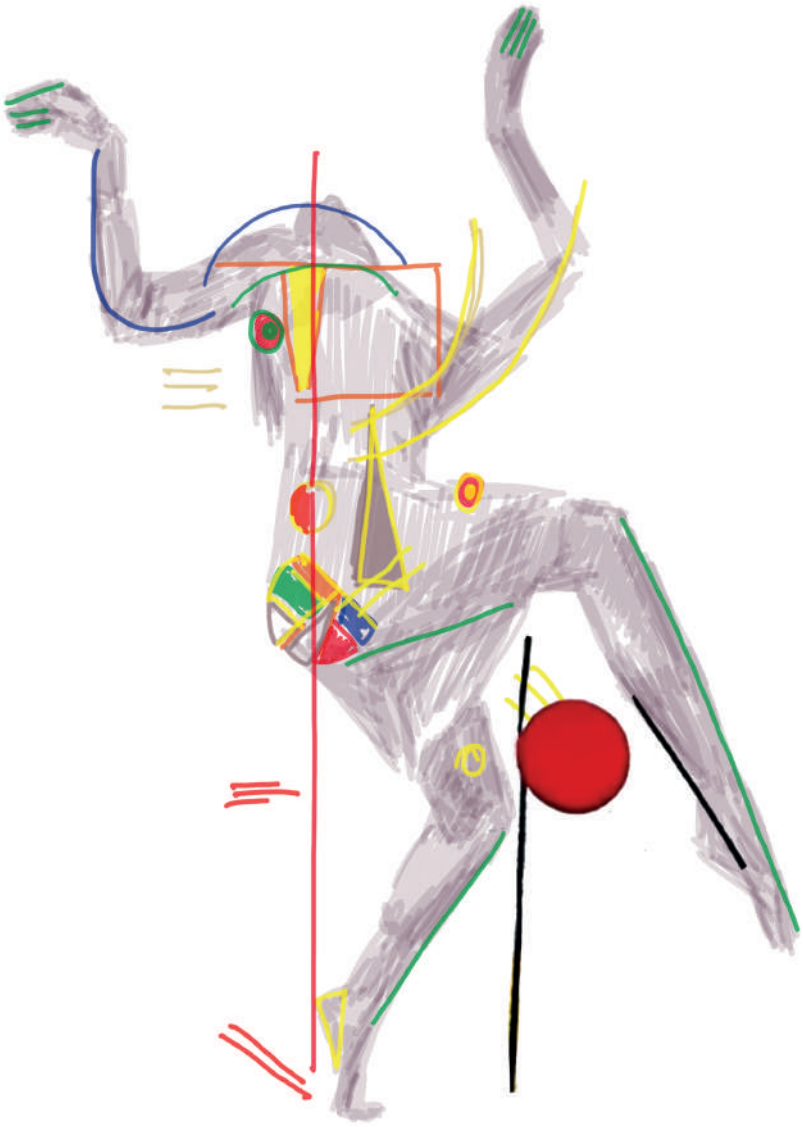
Why does the same body feel so different at different times?

Our conscious life is multifaceted and diverse. We experience seeing red, eating spicy pepper, feeling touched. These are very salient experiences that are commonly used in both science communication and scientific studies. It's common to build experiments studying, for example, visual perception. To understand what happens in the brain when we consciously perceive something, many scientists run experiments where they invite participants to the lab, and show them faint images, where conscious perception just about happens.

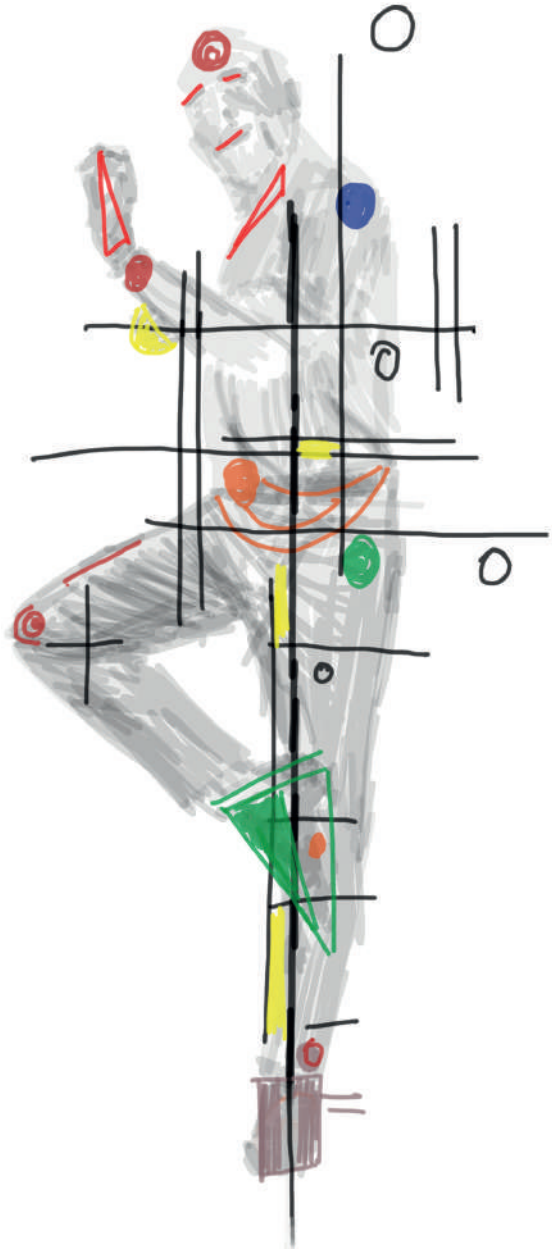
We don't only experience the world around us. It feels like something to inhabit our bodies (How would it feel to inhabit a different body?). An urge to move my feet feels like something, a need to stay still feels different. Sometimes, we don't seem to experience much about our bodies at all. This is why we argue that each of us already is a "natural experiment": We consciously experience some of the movements of our body, but have no conscious access to others.

Remember our point about reportability? One question many recent experiments have been asking is: Is there one single brain area, or mechanism, that allows us to assess and report our experiences? If I can reliably report what I see, will I also be able to reliably report how I moved? Initial studies had suggested that that was indeed the case. More recently, it looks like that's not true: I might be able to correctly report what I see, but have absolutely no idea about how I moved!

METACOGNITION OF MOVEMENTS



What do I know about my movement while I am moving?



What do I not know?

Movement exploration

How to explore: soft instrumental or ambient music without lyrics.
Estimated/recommended duration: 10 minutes in total, 3-4 minutes for each task.

For the moderator: After the music stops, give a 2–3 second silent pause before naming the body part, so that participants can stabilize their awareness of the moment before the body part comes in.

If you're doing this exercise alone, set a signal to interrupt you every 2 minutes, freeze for 2-3 seconds and then check the marked body part on the following images of body avatars.
Repeat the exercise 3 times, making three respective reports.

Instructions

Move freely through the space improvising to the music. Let your body guide you without planning or correcting. When the music stops (or the instructor gives another interruption cue), freeze in your current position, take a moment to introspect. Focus on your body exactly at that moment. Notice how each body part is present in your awareness.

You will hear the name of a specific body part (If you are doing the task alone, you will see a marker placed over specific body parts in the illustrations. Make sure you first freeze, and only then open the next illustration with the marked body part to report on it).
As you hear it/see it, recall how much detail of this body part was in your sensory awareness at the exact moment the music stopped.

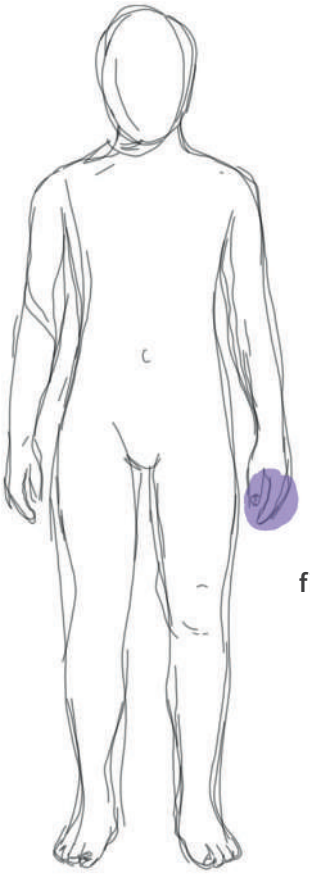
Report 1

How present was this body part in your awareness in that moment?
Scale: 0 (“Not at all”) to 100 (“That was the only thing I was thinking of”)
Place a mark on the line to indicate your answer.

right ankle

Report 2

How present was this body part in your awareness in that moment?
Scale: 0 (“Not at all”) to 100 (“That was the only thing I was thinking of”)
Place a mark on the line to indicate your answer.



fingers of the left hand

Report 3

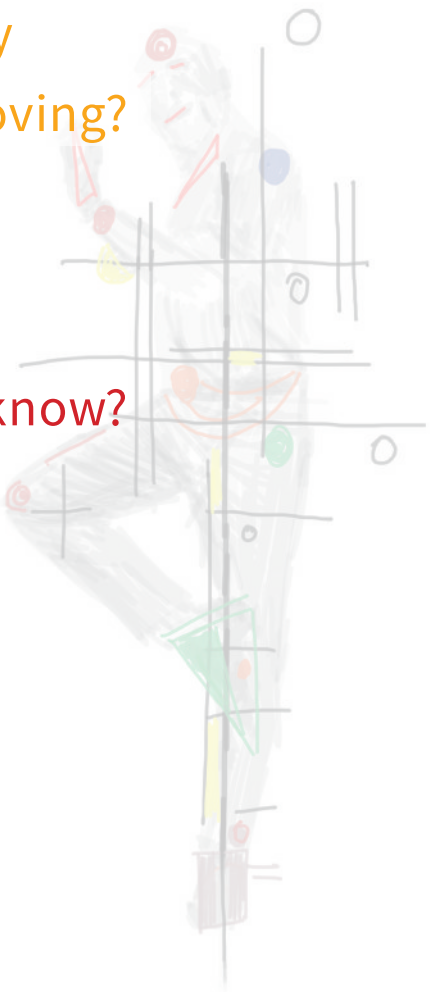
How present was this body part in your awareness in that moment?
Scale: 0 (“Not at all”) to 100 (“That was the only thing I was thinking of”)
Place a mark on the line to indicate your answer.

top of the head

METACOGNITION OF MOVEMENTS

What do I know about my movement while I am moving?

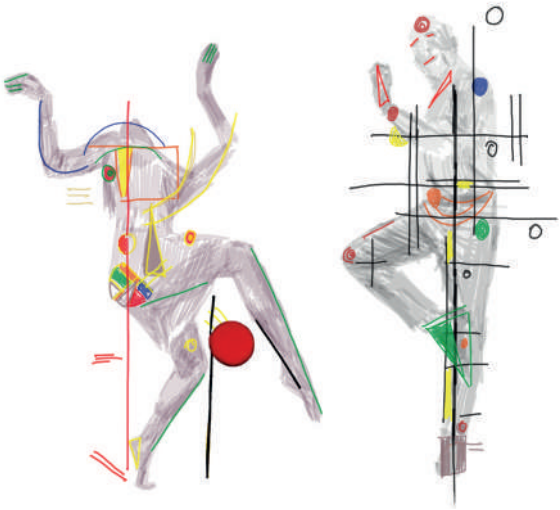
What do I not know?



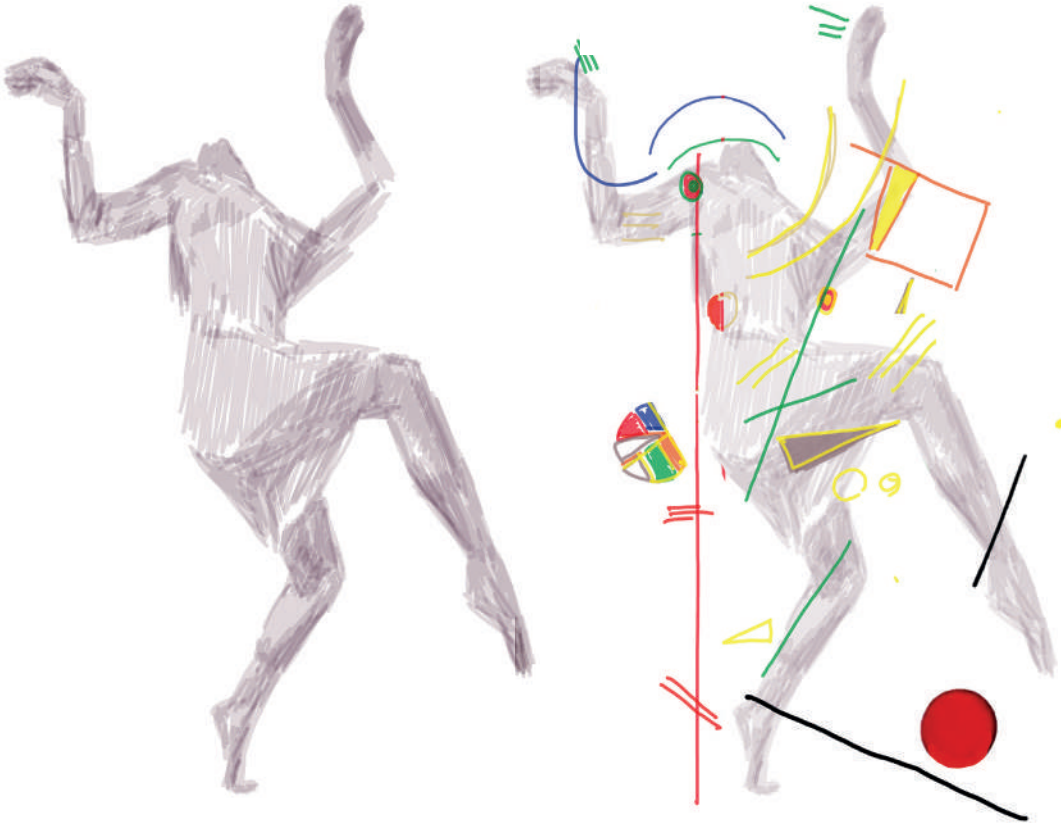
A lot of movement happens without metacognition.

A lot of the time we move (very precisely!) without thinking about it or even being able to report it. Classical experiments have shown that we make a lot of corrective movements without being able to report them. Interestingly, however, our body does know about these corrections: Our fingers slow down a bit on the movements just after we've made a typo — even if a computer corrected that typo and we did not see it, and cannot report it.

More deeply, we do not think about every muscle contraction we make; in fact we might not be able to think about them. We do not feel the electrical signals that travel through our nerves to make our muscles contract. In other words, we cannot metacognitively access our motor commands — the signals that the brain sends out to the muscles to drive our movements. This seems to be behind the boundary for metacognitive and conscious access. In our experimental work, we are trying to figure out if one can shift that boundary at all, and how.



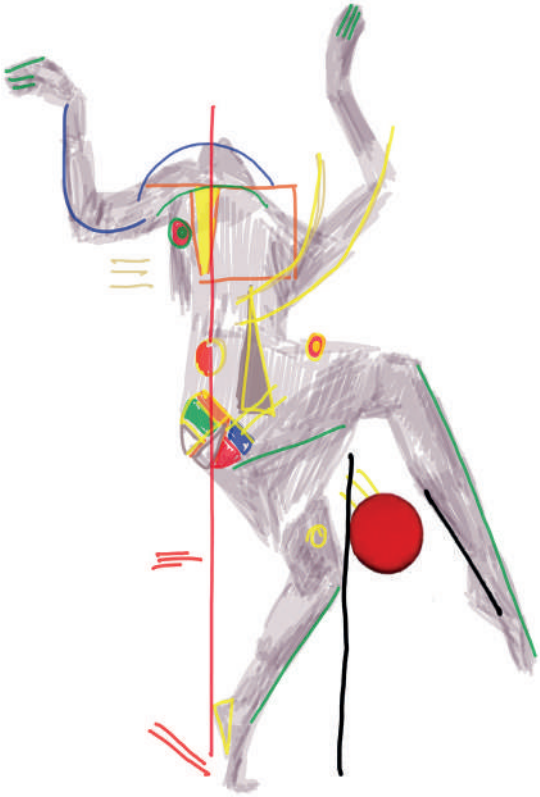
METACOGNITIVE



Do I really know?

Or do I think I know?

PRECISION



How
precise is my
knowledge
about my own
movements?

Movement exploration

How to explore: soft instrumental or ambient music without lyrics.
Estimated/recommended duration: 10 minutes in total.

For the moderator: Before starting this exercise, do a practice round counting "1,2,3" while moving to give people a sense for how long 3 seconds are and how many movements can happen in that time.

Instructions

Move freely to the music, letting your body follow its impulses.

When the music stops, freeze, then rewind: try to reproduce the last 3 seconds of your movements.
Reproduce the movements in the same order as originally.
If that helps you, you can try to reverse (from last to the first movement), and then repeat this loop (from last to the first movement and from first to the last one) several times.

How accurately **do *you* think** can you recall and reconstruct what happened in the last 3 seconds before the interruption?

Report

Let's think about the precision of your experience:

How confident are you that the reproduced movements match with the original ones? 0 - not confident at all, 100 - very confident.
Repeat the task three times.
After each repetition, place a marker on the line to indicate your confidence.

Round 1

Round 2

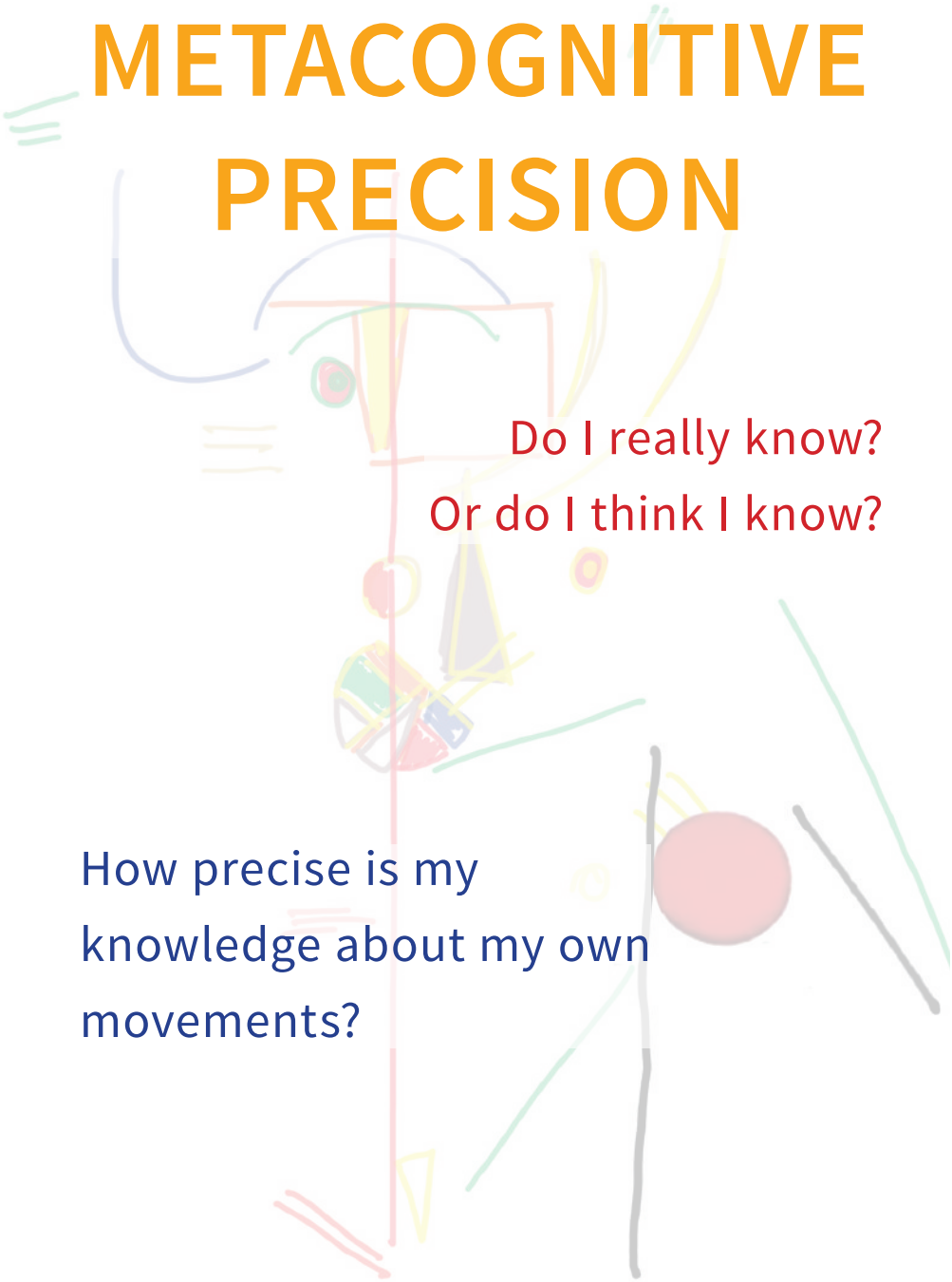
Round 3

METACOGNITIVE PRECISION

Do I really know?

Or do I think I know?

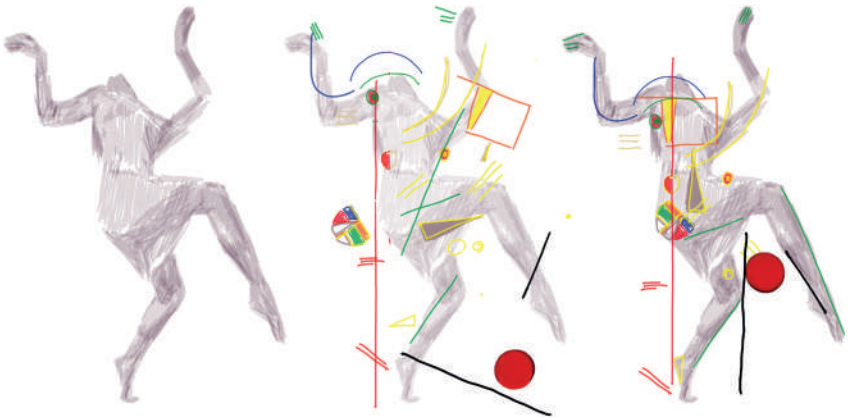
How precise is my knowledge about my own movements?



You may have agreed that there are aspects of our brain that we can introspect and consciously access (seeing red, hearing a tone, being touched, feeling hunger). There are other aspects that are obscure to our introspection, like the brain sending an electrical signal that will eventually reach our motor nerves to contract a muscle. But this needn't be an all-or-none dichotomy. Indeed, there are degrees of how clearly we can introspect a given brain process. We might have a very sharp and clear experience of pain in our arm, but much less sharp, or less salient, experiences of the intention to move our arm to ease the pain.

We care about this sharpness, or metacognitive precision. It is the precision with which the brain can access its own processes. If we think of our moving bodies, this corresponds to the precision with which we can report our own movements and our experience of moving.

Under one philosophical position, I will know best how I moved (or feel) because I have a privileged first-person perspective. Some recent experiments suggested that we think that we know better how we moved: We are more confident when describing how we moved our hands than when describing how our hands were moved by a robot. But we do not, in fact, know better: We are just as often correct, despite our higher confidence.



MEASURING

What can others see
that I cannot
feel?

METACOGNITIVE PRECISION

What do I feel,
that others cannot
see?

Movement exploration

How to explore: soft instrumental or ambient music without lyrics.
Estimated/recommended duration: 10 minutes per person.

Instructions

Find a partner.
Partner A is a “mover”, partner B is an “observer”.

MOVER begins moving freely while *OBSERVER* observes closely.
At any moment, the *OBSERVER* says “Stop!”
MOVER then reproduces the last 3 seconds of movement as precisely as possible.

Repeat the task up to three times. Both *MOVER* and *OBSERVER* report how well *MOVER* reproduced their own movements.

Then swap roles and do this exercise again.

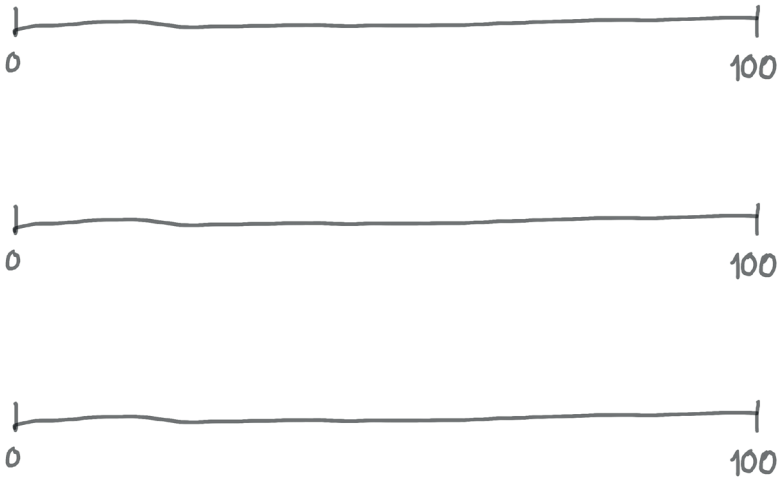
Report 1

How clearly did you experience your own movements?

Both the *moving* and *observing* partner report:
“MOVER”: How confident are you that the reproduced movements match the original ones?
“OBSERVER”: How well did the Mover reproduce the moves?
Draw a marker on the line to indicate your confidence.

Repeat the task up to three times, then swap roles.

Choose your role:
☐ Mover ☐ Observer



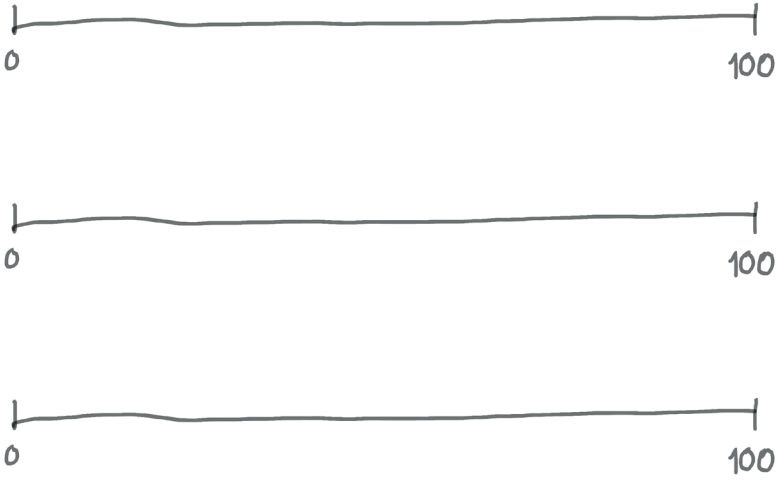
Report 2

How clearly did you experience your own movements?

Both the *moving* and *observing* partner report:
"*MOVER*": How confident are you that the reproduced movements match the original ones?
"*OBSERVER*": How well did the Mover reproduce the moves?
Draw a marker on the line to indicate your confidence.

Repeat the task up to three times, then swap roles.

Choose your role:
☐ Mover ☐ Observer



MEASURING METACOGNITIVE PRECISION

What can others see
that I cannot
feel?

What do I feel,
that others cannot
see?

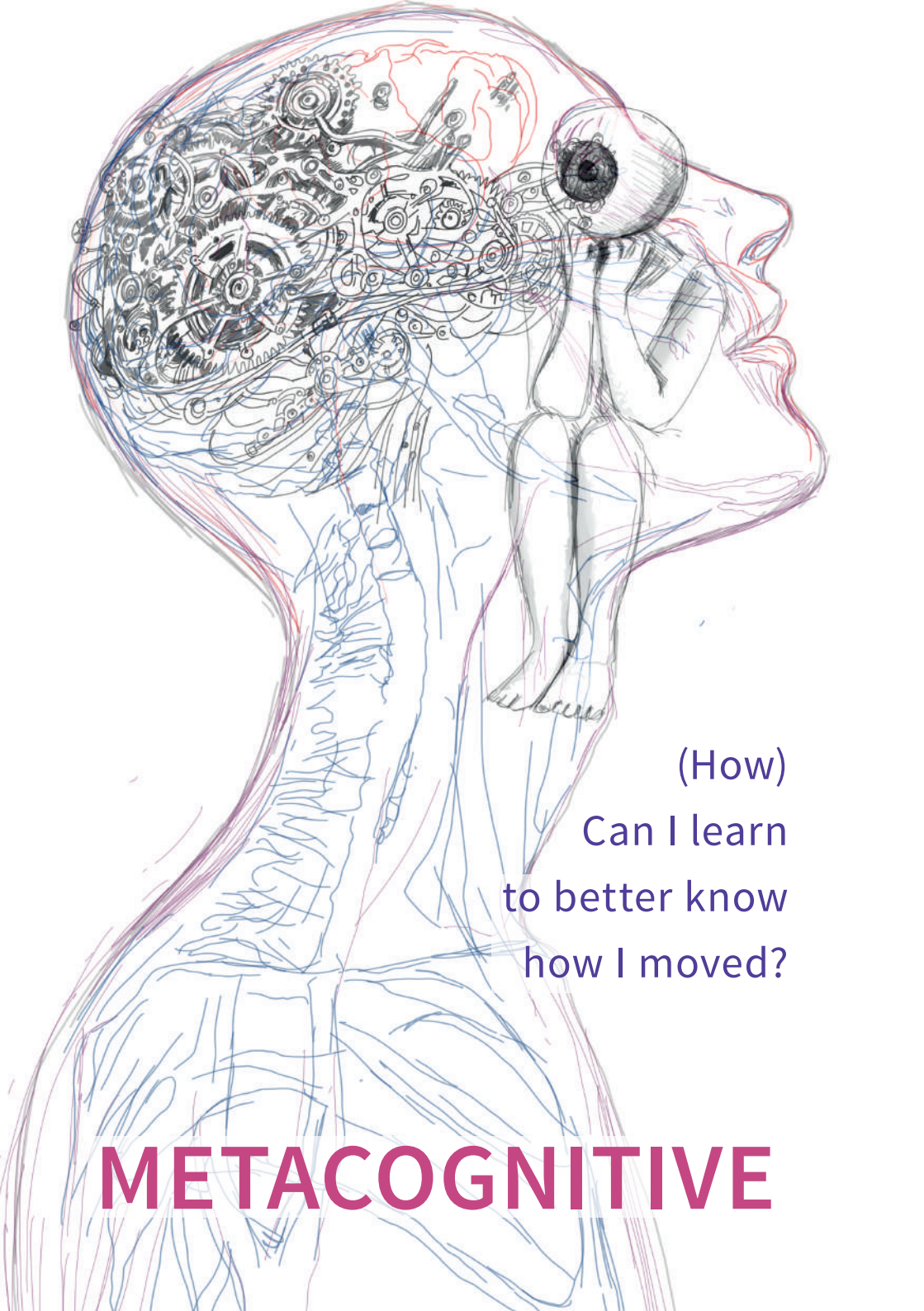
In some cases, an external observer (your partner) can judge whether your experience matched the way you moved. They might tell you that even though you were pretty sure about your right leg's movement, you missed one turn of your left elbow, or that you misperceived a movement to be wider than it really was. That is, they will judge your metacognitive precision to be somewhere less than the possible maximum.

Other experiences are more difficult to judge externally. Can your partner tell you that the tension you said you felt in your left arm was weaker than you think it was? Can they tell you that you are feeling more at ease than you think you are?

Experiments to measure a person's metacognitive precision in their visual perception abound, and usually involve showing two images that objectively differ (very slightly) in a single aspect, and asking participants to rate their confidence in that they have correctly found the difference between these two images. In these cases, there is a clear correct answer, and we can determine that sometimes participants are confident, but wrong. Conversely, it has been very difficult to find a way to measure metacognition of one's own emotions: It is difficult to claim that I, as an observer, or experimenter, objectively know how another person feels.

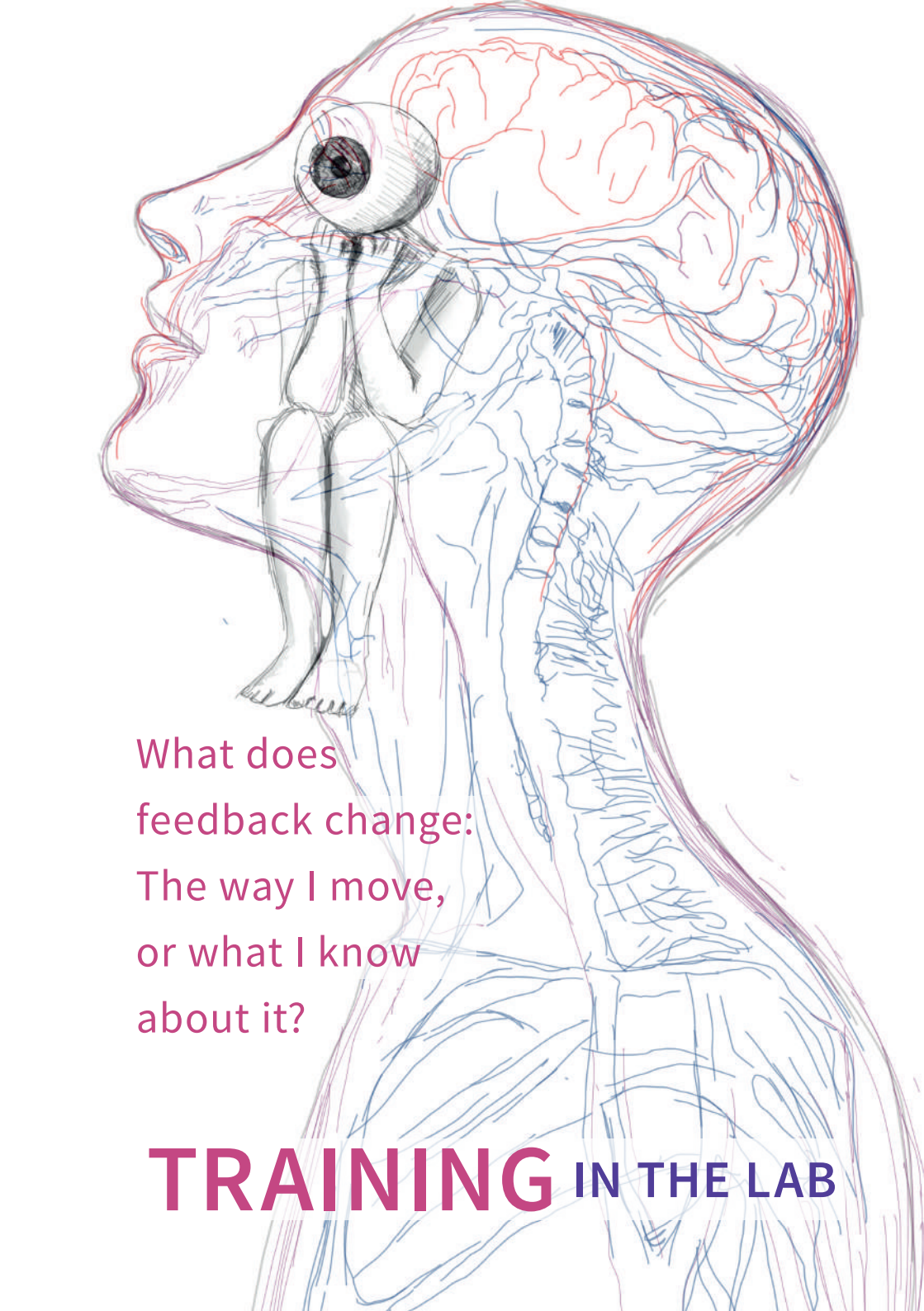
Reflection:

What changes in your awareness after you get feedback from an observer? Did you use any strategies to make your metacognitive information more precise?



(How)
Can I learn
to better know
how I moved?

METACOGNITIVE



What does
feedback change:
The way I move,
or what I know
about it?

TRAINING IN THE LAB

Movement exploration

How to explore: in silence.
Estimated/recommended duration: 5-7 minutes per person.

PARTNER MIRRORING
Form small groups of 3-4 people. Assign roles:
Partner A – the mover
Partner B – the mirror
Partners C & D – the observers

Mirroring

MOVER begins moving freely, without pre-planning. *MIRROR* mirrors *MOVER* in real-time, as precisely and completely as possible, like a human mirror.

Before you begin, check in with your "*Mirror*" partner: Are there any movements to avoid (e.g. due to injuries or physical limitations)?

Start slowly, with clear articulation, so the *MIRROR* can tune in.

Replay after an interruption

When you hear a beep sound (it can be from outside or cued by the *OBSERVER(S)*, like a clap or an instruction "Stop!"), both *MOVER* and *MIRROR* stop moving. Each partner tries to reproduce the previous 3 seconds of movement from memory, as in the previous task - individually and without syncing.

Both *MOVER* and *MIRROR* report in the app. *OBSERVERS(S)* watch closely and offer feedback afterwards:

Did the mover and mirror appear in sync?
How accurate was the replay after the interruption?
Did their reported confidence match their actual accuracy?

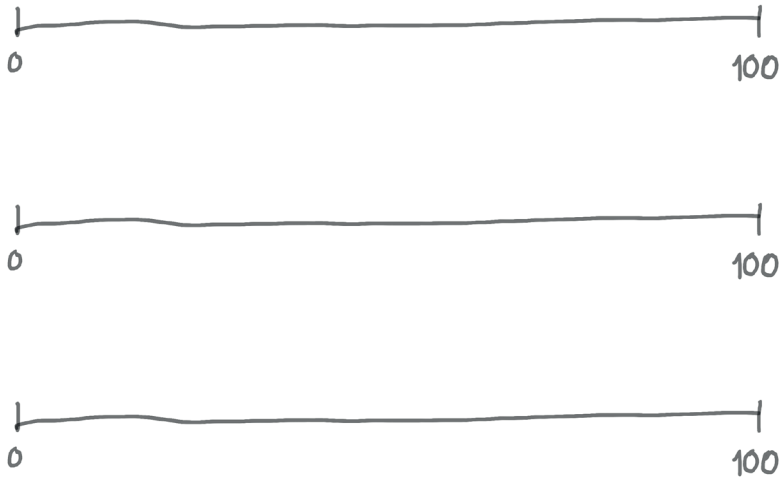
Swap roles and repeat!

Report 1

Both the *Mover* and *Mirror* partners report: How confident are you that the reproduced movements match the original ones?
Draw a marker on the line to indicate your confidence.

Observers give verbal feedback to both Mover and Mirror partners.
Repeat the task up to three times. Swap roles.

Choose your role:
☐ Mover ☐ Mirror ☐ Observer



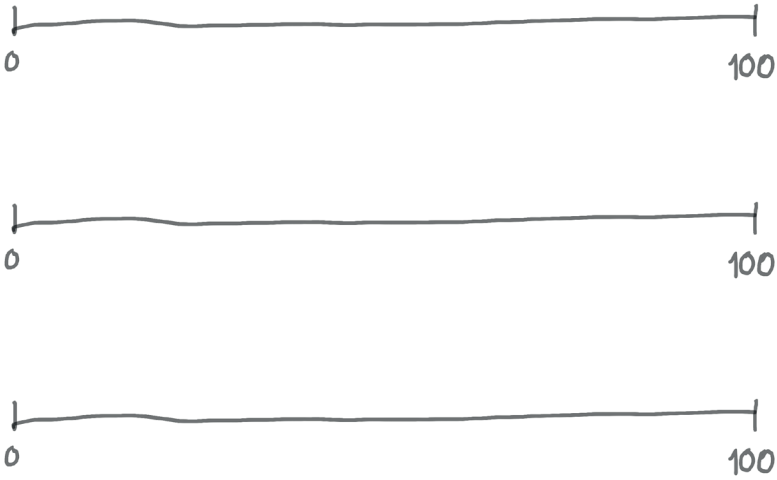
Report 2

Both the *Mover* and *Mirror* partners report: How confident are you that the reproduced movements match the original ones?
Draw a marker on the line to indicate your confidence.

Observers give verbal feedback to both your Mover and Mirror partners.
Repeat the task up to three times. Swap roles.

Choose your role:

☐ Mover ☐ Mirror ☐ Observer



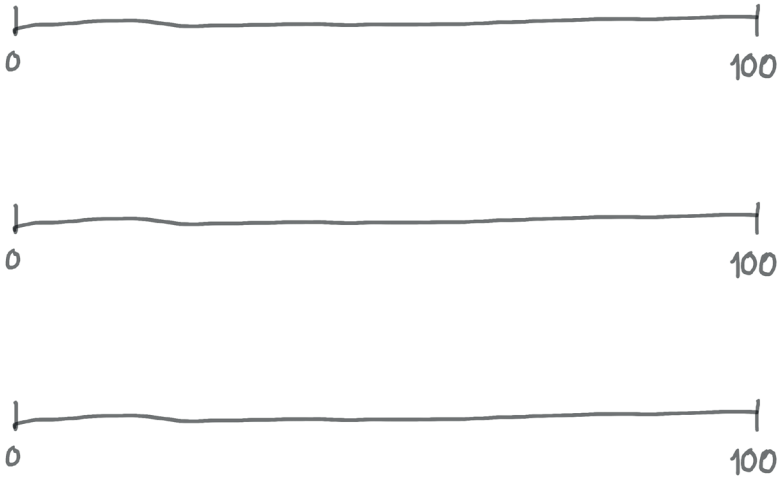
Report 3

Both the *Mover* and *Mirror* partners report: How confident are you that the reproduced movements match the original ones?
Draw a marker on the line to indicate your confidence.

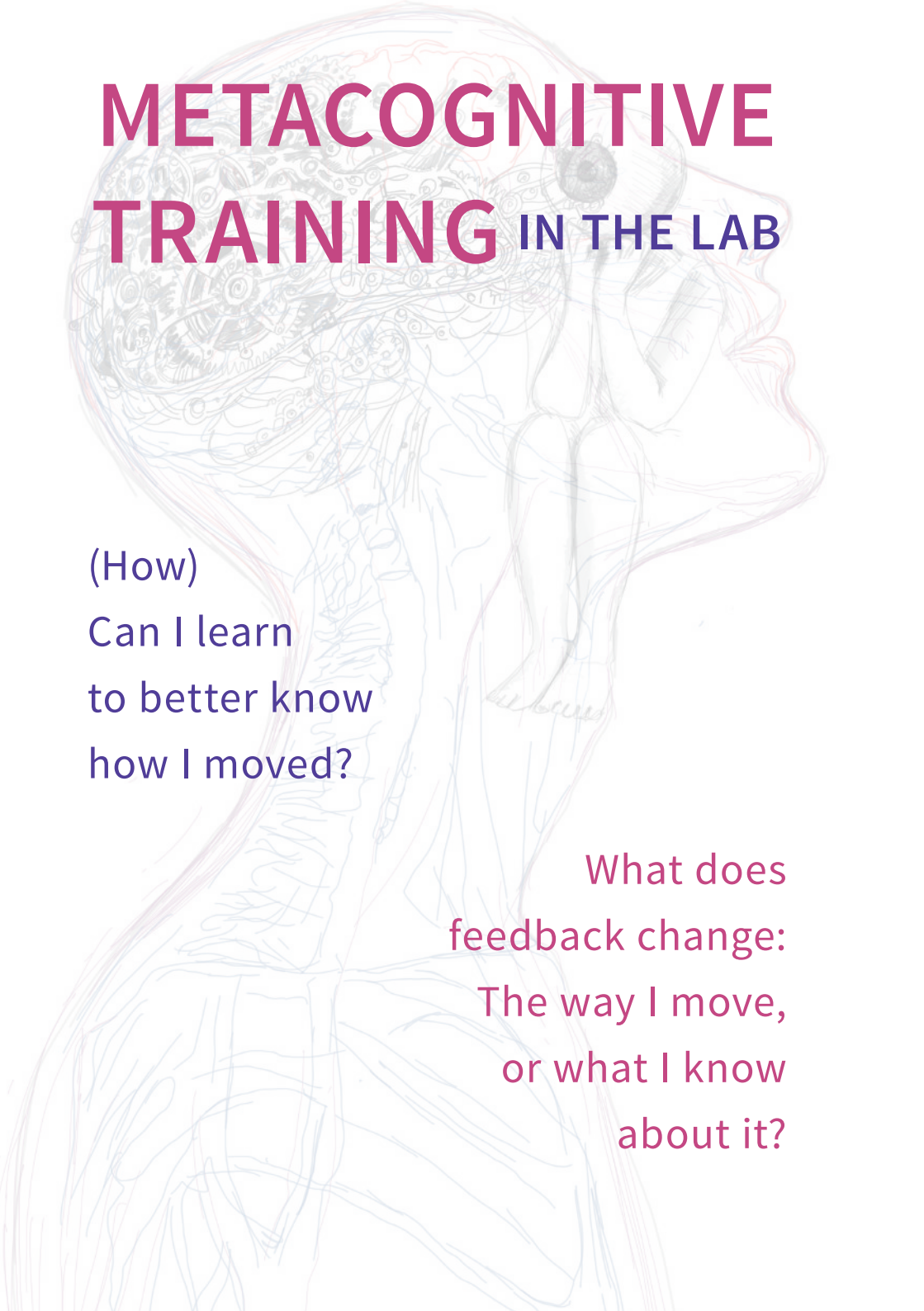
Observers give verbal feedback to both your Mover and Mirror partners.
Repeat the task up to three times. Swap roles.

Choose your role:

☐ Mover ☐ Mirror ☐ Observer



METACOGNITIVE TRAINING IN THE LAB



(How)
Can I learn
to better know
how I moved?

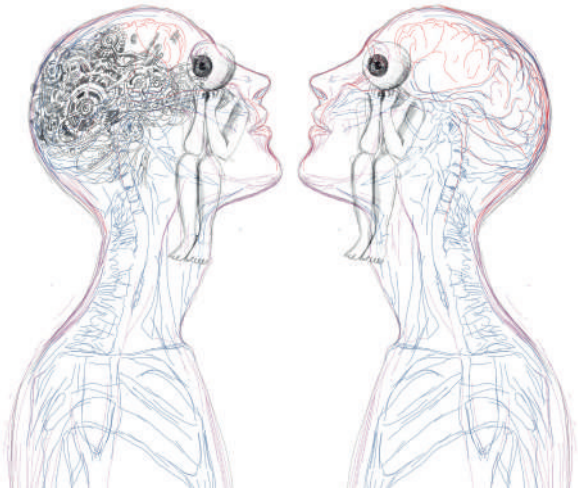
What does
feedback change:
The way I move,
or what I know
about it?

How can we reduce the differences between your partners' observations and your experience? In the different roles in this task you had access to different information about the same movement. Neither perspective guarantees accurate knowledge of what actually happened.

In our scientific work, we try to do this by giving feedback, just like your partner (the observer) did. Over many (many!) repetitions, we measure whether your brain incorporates feedback and progressively learns to report movement correctly, and more precisely. Does it work? Surprisingly, according to our studies it does not — or not as easily as we might expect!

Reflection:

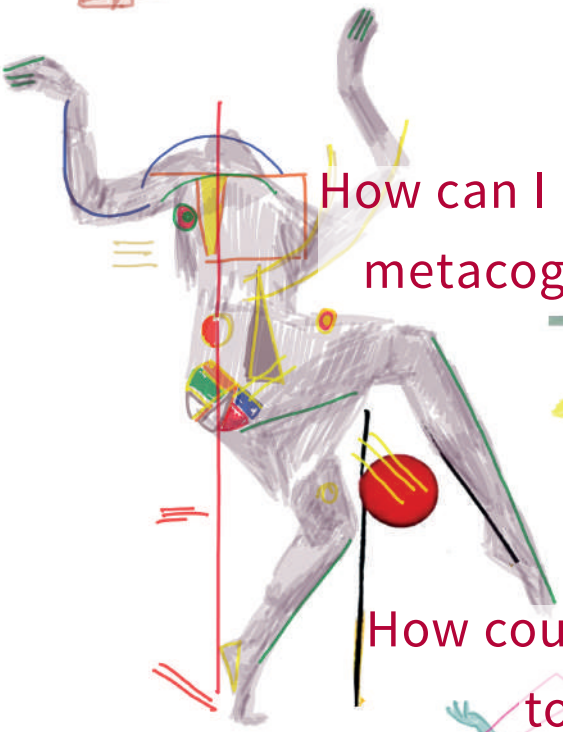
Would you say that your partner's feedback changed your metacognitive precision as you monitored the way you danced — your felt movement? Did it change the movement itself? In what ways? How did it not?



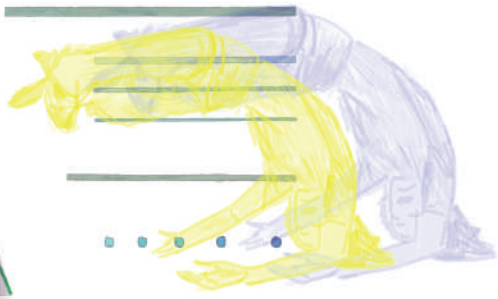
METACOGNITIVE TRAINING

OUTSIDE THE LAB



How can I improve my own metacognitive precision?



How could I teach others to improve theirs?



Movement exploration

Final improvisation session.

How to explore: with different music sound tracks.
Estimated/recommended duration: 10-20 minutes.
Optionally: introducing random interruption beeps.

You are now invited to improvise — individually and collectively — drawing from any of the exercises, sensations, or terms we explored today. Feel free to relate to each other in space. You can experiment with shifting your attention, interrupting yourself, resetting focus, triggering a new direction, responding in the moment, on the spot. You might choose to re-inhabit a sensation from earlier rounds, or simply notice what arises spontaneously in the moment. Stay responsive, stay curious. What moves you now and how does it make you move?

Training outside the lab

Reflection 1:

Would you say that the precision of your metacognitive knowledge about your own movements is better than those without your training?

If you do, do you think that your training is what directly helped you increase your motor metacognitive precision?

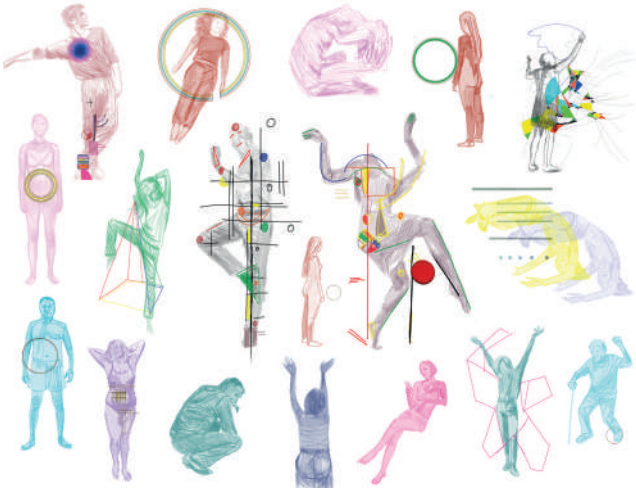
How would you teach others to increase their metacognitive precision when monitoring movements?

Reflection 2:

Now you've done these exercises: Does anything feel different about how you relate to your own movement?

Would you say that precise access to your own experience is beneficial for your artistic practice? Is it detrimental? How?

What questions do you wish scientists would do research on?



GLOSSARY

Subjective experience refers to our mental life — what it is like to perceive, feel, remember, or think.

Metacognition broadly refers to the capacity to reflect on, monitor, and regulate one's own cognitive processes. It enables individuals to evaluate the accuracy and limits of their thoughts, perceptions, and actions.

Motor awareness refers to the ability to perceive and evaluate one's own movements, including their initiation, execution, and outcomes. It allows individuals to assess whether actions unfold as intended.

Metacognitive precision refers to the degree of accuracy with which metacognitive judgments (such as confidence or error reports) track actual correct responses or mistakes. A person with high metacognitive precision might sometimes make mistakes, but will be able to correctly label them as being unsure about their answer. Conversely, a person with low metacognitive precision might be indiscriminately very confident of their own responses, regardless of whether they are correct. We develop and improve our metacognition as we grow: Children under the age of five are often confident regardless of whether they are correct or wrong!

Measuring metacognition involves quantifying how well individuals' self-evaluations of their cognitive processes correspond to their actual performance. This is commonly achieved using confidence ratings, error reports, or post-decision judgments, which are analyzed with behavioral and computational metrics to distinguish metacognitive ability from task performance itself.

Metacognitive training in the lab refers to experimental interventions designed to improve individuals' ability to monitor and evaluate their own cognitive processes. Training can involve feedback on confidence judgments, or guided reflection on performance, allowing researchers to assess whether metacognitive sensitivity or precision can be systematically enhanced through experience.

Metacognitive training outside the lab involves practices that cultivate awareness and regulation of one's own thinking and decision-making outside the lab. This includes strategies such as reflective self-questioning, evaluating confidence in judgments, learning from feedback, and monitoring errors, which can support improved learning, self-control, and adaptive behavior across real-world contexts.

Who are we?

We are a transdisciplinary team formed by cognitive neuroscientist Dr. Elisa Filevich (Hector Research Institute of Education Sciences and Psychology, Eberhard Karls Universität Tübingen), dance artist (Irina Demina), and both cognitive science researchers & dance practitioners (Deliah Seefluth and Gayatri Nerpagar).

Generously supported by the Volkswagen Stiftung, the European Union's Horizon Europe research and innovation programme, Fonds Darstellende Künste, the Hector Research Institute of Education Sciences and Psychology, and the Eberhard Karls Universität Tübingen, we have been engaged in an ongoing conversation exploring the intersection of neuroscience and dance practices. We focus on motor awareness: How we consciously experience and assess our own movements, and how well we can do so.

Our transdisciplinary research constellation turned out to be both stimulating and unusual, as the disciplines involved - dance and cognitive neuroscience - at first sight seem to share little in common, neither methodology nor vocabulary. Yet it soon became clear to us that there is much to exchange. Dance artists and performers study movement every day — in studios, on stage, and in everyday life. Meanwhile, cognitive neuroscientists are investigating in the labs how our brains perceive, control, and remember movement. Each field is generating insights, yet they rarely meet in dialogue. This project is an invitation to bring them together and foster conversation on questions of mutual interest.

Why are we together?

Over the course of several years, we have been conducting this dialogic science engagement project on motor and bodily awareness and metacognition, creating a platform of the upcoming workshop labs, where cognitive scientists and movement-practitioners will be meeting to discuss empirical findings and subjective experience, respectively, with the goal of developing a common language and thus allowing for each discipline to learn from the other.

Each of us comes to this project with different goals/interests. From the perspective of dance practitioners, we find this dialogue enriching because it can help us reflect on our artistic and choreographic practices and gain new insights into the processes in choreography, dance, and movement training. Beyond refining our own creative practices, it opens possibilities for more thoughtful and inclusive approaches to teaching dance and/or movement.

As cognitive (neuro)scientists, our work on awareness has become a bit of a "science of itself," focusing heavily –maybe too heavily– on polishing experimental methods. Of course, having good methods is essential if we want to properly study the topic. But this inward focus has sometimes distracted us from the bigger picture. A good example comes from research on the precision of motor awareness. The experiments in this area (including our own) tend to be long, repetitive, and pretty far removed from real-life situations. How different would our results be, if we included the perspective of dancers who routinely work with, and think about, their own motor awareness? Which new experimental methods could we develop? And perhaps more radically, which questions would we be asking? That's where this interactive project comes in: it will give us a space to observe these processes in action and, from there, design more grounded and potentially more effective ways to investigate and understand this fascinating topic.

How did it begin?

Irina Demina:

My interest, as a choreographer and dance practitioner, in engaging in a conversation with metacognitive research is probably rooted in my dance training and the lineage I belong to as an artist. At the Hochschulübergreifendes Zentrum Tanz Berlin, my studies were grounded in contemporary dance principles, emphasizing improvisation, somatic practices, and body-mind awareness. Unlike other dance training, in somatic improvisation mirrors or visual feedback are avoided, focusing instead on cultivating refined inner sensations and kinaesthetic imagery. There is no "right" movement that has to be trained, or "wrong" movements that have to be avoided; improvisation actually is about deviations from the norm and exploring the manifold possibilities. Dance, in this context, is rather a continuous practice of perception, training of experiencing, sensing, and crafting movement.

But how can one actually train it, and can one actually train it at all? What remains at the essence of dance if you strip away its spectacular physicality component? Why are some improvisation sessions feel "sharp" in sensations, and others are just "blurry"?

On another day, after a deeply satisfying improvisation session, I wrote in my diary "... today during this dance I felt especially deeply absorbed, as if I could e x p e r i e n c e, f e e l movement internally grow and resonate. A calm surrender and trust in not trying - just being without doing."

I find this state profoundly creative and generative from an artistic and choreographic perspective, so I started wondering, what are the "keys" to be able to access that state of deeply "felt" movements, because so far I couldn't find a reliable technique to bring myself there consistently. Sometimes it would happen effortlessly, other times not at all. How can one train it? How can one teach it to others?

I was keeping a journal, experimenting with applying different techniques, even recording my brainwave activity with a headband during improvisations - all in an attempt to discover patterns that could reliably lead me into this experience of 'deeply felt movement'. At some point, I found the website of Metamotor Lab and reached out to Elisa to ask: what does science know about this, how can one reliably train such "felt movements"?

That's when I learned that what I was (and am) searching for is called in science metacognitive precision. Science, it turns out, is also looking for ways to train this in lab conditions - yet struggles to do so. So we found ourselves reaching toward the same elusive goal, from different (opposite?) directions. Over the following years, this sparked a series of regular and compelling conversations and exchanges, later on Deliah Seefluth and Gayatri Nerpagar joined the project - which ultimately evolved into what we are now presenting in this booklet.

Elisa Filevich:

There is one extremely mysterious question: How does consciousness happen? How does our pink, squishy, mushy brain give rise to subjective experience?

The question is interesting, partly, I think, because we have very little idea of what an answer could be, or even how to ask the question. For the past few years, in my research group we have been trying to figure out how to ask one part of the question: How, and how much conscious access do we have to the way we move? And how is motor awareness different from, say, visual awareness?

A few years ago Irina contacted me asking similar questions but coming from a very different perspective. I had no real answers, but we started to organize our thoughts, finding points of contact as well as interesting differences in our approaches (mine experimental, hers experiential). Noticing, dissecting, exploring, and refining these differences required

that we find a common language to communicate and has been a very enriching and enjoyable part of my work.

Science on the Dance Floor is our attempt to share this enriching process with a wider audience and an invitation to join this interdisciplinary conversation—perhaps even to start your own.

Deliah Seefluth:

In one way or another, I have worked on improving my movement awareness all my life. First through gymnastics, then dance, and later Yoga. When I first started full-time training as a dancer and dance pedagogue, I trained for long hours every day and focused on improving my technique and physical abilities. My dance training then often emphasised repetition and correct form. I noticed that I would practice, but not always give time to reflect on it. I started training less, but more deliberately, and searched for ways to move with more authenticity. It led me to use tools to become more present and mindful when I danced and choreographed and—with time—my movement practice emphasised listening inward in addition to external feedback. Rather than prioritising how the movement looked, I went back to how I used to train when I started—giving time to explore how a movement felt with different textures and intentions—and it showed in the quality with which I moved.

This experience directly influenced the way I approached our conversations with *Science on the Dance Floor*. In practice, I feel that different tools have helped me to increase my awareness of how I move. However, the more I now work on experiments in the lab, I understand that it is very hard to scientifically measure whether and how we actually increase the precision of our movement awareness. Questions that seem to have intuitive answers for me from a dancer's perspective are not as clear when it comes to actually measuring them in the lab.

Science on the Dance Floor wonderfully connects scientific research on motor metacognition with an openness to understand movement from a dance practitioner's perspective. Our multidisciplinary team brings

together a wealth of experiences and backgrounds and our work from the past years inspired me to rethink what I thought I knew about movement awareness. I am excited to bring our workshops to the public and see where this dialogue and exchange of perspectives can lead us.

Gayatri Nerpagar:

One of my professors once said, paraphrasing Daniel Wolpert, a neuroscientist at Columbia University, “Your brain is for movement, moving your body”. This phrase stuck with me and made me wonder about the brain-body connection. Movement comes so naturally to us that we rarely notice its complexity: how we can effortlessly reach for a cup of hot coffee without spilling it, or how dancers can time each gesture to music with precision and grace.

As a dancer, I think about these scientific questions from the perspective of a practitioner. I have trained in Bharatnatyam since the age of ten. What I recall from my training is being told to practice extensively to achieve the perfect posture and movement. Practice and repetition were the keys to achieving precision. Over time, however, I became increasingly aware of how I moved, where my weight was placed, how my limbs aligned, and how each gesture occupied space. This growing awareness transformed my dancing. With experience came freedom. I began experimenting with choreography and improvisation, letting the music guide my choices. Out of countless possible movements, some felt right — not only technically correct but deeply satisfying, as if they belonged to the music. That “felt right” moment is difficult to explain, but I believe it emerges from years of embodied practice, where technical mastery and sensory intuition meet.

When I look back at my dance training as a cognitive neuroscientist, I wonder how our brain can monitor movement precisely and how it is trained to do so. Lab studies say that we cannot necessarily train precision, which is contradictory to my experience as a dancer. But all these studies are done in a lab, which is rather tedious and far from real-life movement.

Science on the Dance Floor is the exact place where I can bring my two worlds together and look at the movement from a dancer's and scientist's perspective.

Julia B. Nowikowa:

I came to *Science on the Dance Floor* from an artistic and design perspective, with the question of how to make visible something that cannot be shown directly: the inner perception of movement, the difference between what a body does and what we know, remember, or feel about it. From the beginning, I was interested in finding a visual form for these in-between spaces — not as an explanation, but as an approach.

Throughout the process, I listened closely not only to the texts and conversations within the project, but also looked to art for ways of thinking about body, movement, and rhythm. Henri Matisse became an important point of reference: the freedom of his figures, the reduction to a few lines, the ease with which a posture or movement becomes visible through simple means. This had a strong influence on me. Some of the small figures that first appear in the main image and re-emerge throughout the booklet grew out of this engagement. They carry something mobile, open, and playful through the publication.

Kandinsky entered my process later, but became a crucial reference. Precisely for that reason, he was so important. His direct engagement with dance, and with the translation of movement into line, form, and colour, was a key moment for me. Not because I found a ready-made solution there, but because I recognized in his work something I had been searching for myself. In that sense, encountering Kandinsky was also affirming: it strengthened something I had already been following intuitively, but had not yet fully articulated.

My exchange with Irina Demina and Elisa Filevich was especially valuable in this process. Our conversations were never only about

whether a design “worked,” but about what a concept meant, how much openness an image should retain, and how far a visual work can carry meaning without becoming didactic. That was one of the most rewarding aspects for me: that we were working together toward a form that would be neither mere illustration nor pure assertion. This process was particularly intense around the concept of metacognition. That we eventually arrived at an image that felt right to all of us was one of the strongest moments of this collaboration for me.

For this reason, I do not see the images in this booklet as explanations of scientific concepts. They are closer to attempts to open a space for thought and perception. They are not meant to define, but to accompany; not to narrow, but to inspire. In the context of a workshop, this feels especially important to me: that the visual layer offers something without fixing everything in advance. Perhaps this is precisely what I find most compelling about the project — the attempt to bring art and science together in a way that allows both to remain open, and to set each other in motion.

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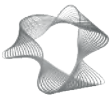

SCARBOD LAB
SCIENCE ART BODY

SCIENCE ON THE DANCE FLOOR
Understanding the Science of Motor Metacognition Through Dance.

Project initiated by
Elisa Filevich and Irina Demina

Concept development & text:
Elisa Filevich, Irina Demina,
Deliah Seefluth, Gayatri Nerpagar.

Illustrations, design and layout: Julia B. Nowikowa

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The authors assume no responsibility for injuries or misuse.
Participants should consult professionals when needed.