State of the mind: Emotions, body feelings, and thoughts share distributed neural networks.

Suzanne Oosterwijk, Kristen A. Lindquist, Eric Anderson, Rebecca Dautoff, Yoshiya Moriguchi, & Lisa Feldman Barrett

Supplementary Materials

Descriptions of types of experiences

Body Feeling:

"The first type of experience I'm going to ask you to create today are body feelings. A bodily sensation consists of internal, visceral sensations that you feel inside your body. Internal sensations are feelings like pain, hunger, or thirst. Sometimes you have very specific feelings in your organs such as a sense of your stomach muscles constricting when you're nervous or excited, the feeling of tightening you get in your lungs when you need more air, the feeling of your heart fluttering in your chest, and so on. Sometimes you have more vague feelings, where your body just feels pleasant, or excited, or calm. Sometimes you might feel discomfort or tired or kind of wound up. You're always having bodily feelings, even if you don't pay attention to them at every second of the day. In fact, you typically don't attend to them unless your attention is drawn to them by a big change—like the feeling of a sudden pain for instance—but you can choose to pay attention to them at any time. For instance, if I were going to describe my bodily sensation to you right now, I'd say I can feel my stomach grumbling, I can feel my heart beating a little faster than usual and I can feel my lungs expanding as I take a deep breath. What are your bodily sensations like right now?" **[prompt the participant to answer. Ask questions to make sure the person gives internal somatovisceral sensations. Make sure to correct his/her description if not correct. If he/she has trouble, prompt with the following questions: 1) "Try to focus on the pit of your stomach. Can you feel it? What does it feel like? Are your stomach muscles constricting? Are they digesting something? Are they calm?" 2) "Try to focus on your heart beating. Can you feel it? What does it feel like? Is it beating fast or slow?"]**

Emotion:

"The second type of experience I'm going to ask you to create today is an emotion. Emotions are mental states like fear, sadness, anger, happiness, and so on. For example, anger is an unpleasant, energized emotion that occurs when you experience an obstacle has been placed in your way, when your beliefs or values have been violated, or when your goals are interfered with. Fear is an unpleasant, energized emotion that occurs when

you experience uncertainty or threat or you worry about being harmed. Both anger and fear are more energetic than sadness, which is an unpleasant, low-energy state that occurs when you have lost something or someone important to you. Happiness is a pleasant, slightly energized state that occurs when you experience something or someone to be pleasing. These are just a few examples of emotions but there are many more. As with body sensations, you can ignore your emotions or you can pay attention to them. For instance, if I were to describe the emotions I am feeling right now, I would say that I'm feeling pretty happy. I feel happy because I'm feeling pleasant but only medium energy. I find this task to be pretty pleasing because I really like my job. What emotions are you having right now? Can you describe the last time you felt angry? Afraid?" **[prompt the participant to answer. Make sure to correct his/her description if not correct]**

Thought:

"The third type of experience I'm going to ask you to create is a thought. Just as with body sensations and emotions, you have a stream of thoughts throughout each day. A thought is a state that involves creating an idea or a representation of something that is happening in the world around you right now. It involves objectively reviewing something in your mind's eye. As with the other experiences, we're not always aware we're having thoughts but we can pay attention to the thoughts we're having. For instance, if I were to describe the thoughts I am having right now, I would say that I'm thinking of how to best describe these different experiences to you. I am thinking that I must remember to ask you to remove all the metal objects that you might have as I prepare you to go into the scanner. I'm thinking about the objects on that desk. The key about thoughts is that you can have them without feeling much of anything—this may seem difficult, but it's doable. For instance, I can think about a time when I was almost in a car accident. It's possible to just think objectively about what happened while not cultivating any feelings or emotions. You can think of this as reviewing something in your mind in a "cool" way instead of a "hot" way. In this case, I would review in my mind the other car veering towards me, me turning the wheel, seeing the sidewalk get closer and closer to my vehicle, and me finally straightening out the wheel. What thoughts are you having right now? What thoughts would you have when going to the grocery store? When skiing down a slope? "**[prompt the participant to answer. Make sure to correct his/her description if not correct]**

Perception:

"Finally, the forth type of experience you will create today is called a perception. In this type of experience, you take note only of the objects in a scene and their relationship in space, but you would not have any reaction to them, or try to analyze them or think about them in any way. Perceptions involve creating a representation of something that is happening in the world around you without having ideas or emotions about those things.

It just involves objectively listing things around you. As with the other experiences, we're mostly unaware we're perceiving objects throughout the day but we can pay attention to the objects around us if we choose to. For instance, if I were to describe the objects I am perceiving right now, I would note the table, chairs, walls, pen and so on. I can also see a person – you – as you sit the chair. The table and chairs are on the floor, and floor is covered by carpet. Further, I can see my pen is blue and silver. I'm holding the pen. What objects are you perceiving around you right now? What objects would you perceive when going to the grocery store? When skiing down a slope?" **[prompt the participant to answer. Make sure to correct his/her description if not correct]**

Instructions for completing the construction task:

"Now, let me briefly tell you about what the scanner task will be like. On a given trial, you'll first see a cue that will tell you whether we want you to create a body feeling, emotion, thought or perception. It will say "body", "emotion", "thought", or "perception." Then you will hear the short version of one of the scenarios you just heard. Next, there will be a construction phase where we want you to create the experience in reaction to the scenario. Once you feel you've created the experience, you'll push a button and then elaborate on that experience in your head for the rest of the trial. The way you elaborate on it is to keep having that same experience without changing it or thinking about or experiencing anything else. Does this make sense? Let's go through each type of experience to further clarify."

e.g., Bodily Sensation:
"Let's say you see the cue "body" on a given trial when in the scanner. Next, you'll hear a short version of a scenario like this:"

> *You and a co-worker are walking into a dark meeting room in your office building. Everything in the vicinity is strangely quiet.*

"Your goal will be to create a body sensation in reaction to the scenario. While you listen to the cue, try to recall the full version of the scenario as best you can. In this case, we'd like you to remember something like this."

> *You and a co-worker are walking into a dark meeting room in your office building. Everything in the vicinity is strangely quiet. Your co-worker pushes the door open wide. The lights flash on and everyone in the room is screaming "Happy Birthday" to you. You look around at everyone and start laughing. Your face feels hot and flushed.*

"Once you hear the scenario, you will have 20s to create the experience and elaborate on it. You should plan to spend the first 5-10s creating the body sensations, and then about 10 sections to let the sensations carry forward, during which time you'll experience them as intensely as possible. The body sensations I might experience would include the quickening of my heart, faster breathing, and my face feeling hot and flushed. Once you

have these bodily sensations in mind, press the button and then elaborate on them by continuing to feel them for the rest of the trial. Basically, you are experiencing the scene from the point of view of your body. What bodily states would you experience during this scenario?" **[prompt the participant to answer. Ask questions to make sure the person gives both internal sensory as well as muscular sensations. Make sure to correct his/her description if not correct]**

Exploration of Correlations between Self-report Ratings and Brain Activity

We explored whether our major findings (i.e., differential engagement of the salience network and default network across mental states) could be further defined by a relationship between self-report ratings of success and vividness on the construction task and engagement of the salience or default network. There were no systematic correlations between self-reported success and vividness and activity in the salience or default network. See Table 1. The only significant correlation we observed was between self-reported success at constructing emotions and activity in the right default network during the experience phase of the experiment. This finding, although not predicted a priori, is consistent with our hypothesis that emotions engage the process of conceptualization.

Exploration of Sex Differences

We also explored whether our findings could be further defined by an interaction with sex. We analyzed percent signal change within the salience network and the default network for the three mental state conditions adding sex as a between subjects factor. These analyses did not demonstrate any significant main effects or interactions (all p's > .10). Means and standard deviations for males and females in each mental state condition and test statistics for the interaction between mental state and sex are presented in Table 2. These results indicate that there were no sex differences in the neural dynamics of construction in our study.

Table 1. Correlations between self-report ratings and network activity

Rating		lh D experience	lh D immersion	rh D experience	rh D immersion	lh S experience	lh S immersion	rh S experience	rh S immersion
		Percent signal change within network							
vividness bodily feelings	Pearson Correlation	.027	-.243	.112	-.114	.049	-.046	.155	-.070
	Sig. (2-tailed)	.911	.303	.637	.631	.839	.848	.513	.770
vividness emotions	Pearson Correlation	.182	-.345	.328	-.246	.204	-.163	.327	-.080
	Sig. (2-tailed)	.443	.136	.158	.297	.389	.491	.159	.738
vividness thoughts	Pearson Correlation	-.001	-.185	.143	.057	-.259	.123	-.080	.118
	Sig. (2-tailed)	.996	.435	.548	.813	.270	.606	.737	.620
success bodily feelings	Pearson Correlation	-.001	-.228	.093	-.087	-.008	.013	.074	-.024
	Sig. (2-tailed)	.996	.334	.696	.717	.972	.957	.757	.922
success emotions	Pearson Correlation	.298	-.288	.484	-.149	.136	-.076	.287	-.008
	Sig. (2-tailed)	.202	.218	.031*	.531	.566	.752	.221	.974
success thoughts	Pearson Correlation	.026	-.253	.141	.014	-.272	.104	-.103	.101
	Sig. (2-tailed)	.912	.282	.554	.953	.247	.663	.665	.671

Table 2. Sex Differences in Salience and Default Network

		M_{males} (SD)			$M_{females}$ (SD)				
		Body	Emotion	Thought	Body	Emotion	Thought	F	p-value
Immersion phase	lh salience	.25(.15)	.26(.10)	.19(.12)	.26(.18)	.21(.13)	.09(.13)	1.11	.34
	rh salience	.14(.20)	.17(.10)	.12(.13)	.16(.20)	.10(.15)	-.02(.15)	1.94	.16
	lh default	.10(.18)	.15(.12)	.12(.14)	.23(.19)	.17(.18)	.10(.12)	2.56	.11
	rh default	-.03(.25)	-.01(.12)	-.00(.13)	.07(.24)	.03(.19)	-.04(.16)	1.98	.17
Experience phase	lh salience	.30(.13)	.27(.14)	.24(.12)	.21(.23)	.18(.18)	.23 (.16)	1.78	.19
	rh salience	.18(.11)	.15(.14).	.13(.13)	.12(.21)	.11(.17)	.15(.17)	1.61	.22
	lh default	.04(.25)	.07(.30)	.11(.24)	.08(.15)	.06(.15)	.16(.20)	.77	.47
	rh default	-.10(.25)	-.07(.30)	-.04(.27)	-.08(.18)	-.09(.20)	.03(.25)	1.47	.24

Additional results cited in the main text

Table 3. Significant clusters in conjunction analysis for the *scenario immersion phase*.

Region	Network parcellation	Tal X	Tal Y	Tal Z	k	max
lh temporal lobe	SM/D	-56.6	-7.8	0.1	12682	10.76
rh temporal lobe	SM/D	48.3	-30.3	3.2	7114	8.42
lh vlPFC/dlPFC	FP/D	-51.8	20.7	15.8	5867	7.29
lh superiorfrontal	S/FP	-10.4	13.8	42.2	2868	6.72
lh precentral	SM	-37.7	-14.2	53.6	3773	6.62
lh fusiform	LI	-42.1	-18.4	-19.2	304	5.39
lh frontoinsula	S/FP	-28	25.6	5.9	532	5.31
lh inferior parietal	FP	-35.8	-53.8	36.8	713	5.30
rh superiorfrontal	S	10.3	21.1	36.2	431	5.06
rh superiorfrontal	S	6.9	8.4	56.6	380	4.99
rh postcentral	SM	54.9	-10	12.7	323	4.14
lh medial prefrontal*	D	-8.4	40.9	-2.6	1373	-5.68
lh occipital lobe*	V	-23.7	-94.9	5.2	463	-3.95
rh medial prefrontal*	D	12.4	38.3	-2.2	1545	-7.42
rh occipital lobe*	V	24.8	-92.6	5.9	130	-3.10

Note: clusters are significant at $p < .001$ and $k \geq 100$ (uncorrected). Network parcellation: SM: somatomotor; D: default; FP: frontoparietal; S: salience; DA: dorsal attention; LI: limbic; V: visual. * *indicates a deactivation compared to fixation*

Table 4. Clusters of activation within subcortical regions in the conjunction analysis (p < .0001; k > 20) for the *scenario immersion phase*.

	Region	Tal X	Tal Y	Tal Z	k	max
Conjunction scenario immersion	lh pallidum/putamen/caudate	-19.8	1.3	6.4	155	6.37
	lh thalamus	-9.9	-14.2	7.2	86	5.94
	rh cerebellum	29.7	-59.3	-39.9	297	5.36
	rh cerebellum	15.8	-74.4	-30.8	347	5.33
	lh cerebellum	-23.8	-54.4	-20	44	5.16
	lh cerebellum	-23.8	-63.1	-38.1	43	4.72
	rh cerebellum	31.2	-52.7	-23.4	27	4.42

Table 5. Overview of mean percent signal change within the seven intrinsic network ROIs for body feeling, emotion and thought.

Network		Listening				Experience			
		Body	emotion	thought	F	body	emotion	thought	F
lh	Default	.17 (.04)	.16 (.03)	.11 (.03)	1.56	.06 (.05)	.07 (.05)	.14 (.05)	5.34 **
	Salience	.26 (.04)	.23 (.03)	.14 (.03)	5.33 **	.26 (.04)	.23 (.04)	.23 (.03)	.75
	Dorsal attention	.21 (.05)	.18 (.04)	.11 (.04)	3.34 *	.25 (.05)	.21 (.04)	.25 (.04)	1.27
	Frontoparietal	.30 (.04)	.24 (.04)	.19 (.04)	4.63 *	.24 (.06)	.19 (.05)	.22 (.04)	1.79
	Limbic	.07 (.05)	.10 (.05)	.03 (.05)	.79	.02 (.07)	.01 (.07)	.10 (.08)	2.83
	Somatomotor	.35 (.05)	.37 (.04)	.30 (.04)	2.31	.14 (.04)	.13 (.03)	.17 (.04)	.77
	Visual	-.15 (.10)	-.15 (.10)	-.20 (.11)	1.08	-.15 (.09)	-.11 (.10)	-.09 (.10)	2.98
rh	Default	.02 (.05)	.01 (.04)	-.02 (.03)	.69	-.09 (.05)	-.08 (.06)	-.01 (.06)	4.39 *
	Salience	.15 (.04)	.13 (.03)	.05 (.03)	3.36 *	.14 (.04)	.13 (.03)	.14 (.03)	.24
	Dorsal attention	.03 (.05)	.01 (.04)	-.06 (.04)	3.62 *	.08 (.05)	.05 (.04)	.09 (.04)	.79
	Frontoparietal	.10 (.05)	.05 (.04)	.01 (.04)	2.72	-.00 (.05)	-.04 (.05)	-.00 (.05)	.90
	Limbic	-.02 (.07)	-.00 (.07)	-.05 (.05)	.25	-.05 (.10)	-.08 (.11)	.02 (.10)	2.13
	Somatomotor	.23 (.05)	.27 (.04)	.21 (.04)	.99	.04 (.04)	.03 (.04)	.08 (.04)	1.29
	Visual	-.14 (.09)	-.13 (.09)	-.20 (.10)	1.48	-.13 (.09)	-.08 (.10)	-.07 (.09)	1.93

Note: F-statistic is reported for the main effect. * $p =< .05$; ** $p < .01$. *Standard errors in parentheses.*