Social Processes: Workshop Proceedings

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Background

The Research Domain Criteria (RDoC) project is designed to implement Strategy 1.4 of the NIMH Strategic Plan: *Develop, for research purposes, new ways of classifying mental disorders based on dimensions of observable behavior and neurobiological measures.* NIMH intends RDoC to serve as a research framework encouraging new approaches to research on mental disorders, in which fundamental dimensions that cut across traditional disorder categories are used as the basis for grouping patients in clinical studies. RDoC represents an inherently translational approach, considering psychopathology in terms of dysregulation and dysfunction in fundamental aspects of behavior as established through basic neuroscience and behavioral science research. The major RDoC framework consists of a matrix where the rows represent specified functional *Constructs*, summarizing data about a specified functional dimension of behavior, characterized in aggregate by the genes, molecules, circuits, etc., responsible for it. Constructs are in turn grouped into higher-level *Domains of functioning*, reflecting contemporary knowledge about major systems of cognition, motivation, and social behavior. In its present form, there are five Domains in the RDoC matrix: Negative Valence Systems, Positive Valence Systems, Cognitive Systems, Systems for Social Processes, and Arousal/Regulatory Systems. The matrix columns specify *Units of Analysis* used to study the Constructs, and include genes, molecules, cells, circuits, physiology (e.g., heart-rate or event-related potentials), behavior, and self-reports. The matrix also has a separate column to specify well-validated paradigms used in studying each Construct.

The RDoC matrix is being developed to serve as a heuristic and it is subject to change with scientific advances from the field. To "build the matrix," NIMH has been bringing together leading experts to coalesce and articulate the state of knowledge for each of the five domains. Six meetings are planned: this workshop, focused on the Social Processes (SP) domain, was fifth in the series.

For detailed information about RDoC, proceedings from prior workshops, and the updated matrix, please see the RDoC web page.

Workshop Proceedings

The NIMH RDoC Working Group initially proposed four draft Constructs within the SP domain: 1) Social Dominance, 2) Affiliation/Separation, 3) Facial Expression Identification, and 4) Self and Other. Based on each individual's scientific expertise, the workshop participants were assigned to one of three "construct groups" (Social Dominance and Affiliation/Separation were considered by a single construct group). Each group was tasked with 1) deciding whether and how their group's Construct(s) should be revised from the original conceptualization, 2) generating a definition for each Construct, 3) filling in the elements of the matrix for each Unit of Analysis for the Construct(s) and 4) generating a list of promising and reliable research

paradigms that can be used to study the Constructs. Each construct group was split into two parallel breakout groups, each with their own moderator, to facilitate discussion and encourage exploration of divergent opinions. Following breakout group meetings, the construct groups reassembled for further discussion and refinement of the products, which was followed by an iterative process of reporting-out and discussion with the entire workshop and reconvening in construct groups.

The SP workshop participants discussed the RDoC team's proposed Constructs, suggesting some re-organization and re-naming. The participants reached consensus on the definitions of four Constructs; the definitions of these four are provided below, followed by a summary of the group discussions. The group noted outstanding issues for one additional Construct, and information regarding the issues under consideration is also included below.

Construct Definitions

1. **Affiliation and Attachment:** Affiliation is engagement in positive social interactions with other individuals. Attachment is selective affiliation as a consequence of the development of a social bond. Affiliation and Attachment are moderated by social information processing (processing of social cues) and social motivation. Affiliation is a behavioral consequence of social motivation and can manifest itself in social approach behaviors. Affiliation and Attachment require detection of and attention to social cues, as well as social learning and memory associated with the formation of relationships. Affiliation and Attachment include both the positive physiological consequences of social interactions and the behavioral and physiological consequences of disruptions to social relationships. Clinical manifestations of disruptions in Affiliation and Attachment include social withdrawal, social indifference and anhedonia, and over-attachment.

2. **Social Communication:** A dynamic process that includes both receptive and productive aspects used for exchange of socially relevant information. Social communication is essential for the integration and maintenance of the individual in the social environment. This Construct is reciprocal and interactive, and social communication abilities may appear very early in life. Social communication is distinguishable from other cognitive systems (e.g., perception, cognitive control, memory, attention) in that it particularly involves interactions with conspecifics. The underlying neural substrates of social communication evolved to support both automatic/reflexive and volitional control, including the motivation and ability to engage in social communication. Receptive aspects may be implicit or explicit; examples include affect recognition, facial recognition and characterization. Productive aspects include eye contact, expressive reciprocation, and gaze following. Although facial communication was set aside as a separate sub-construct for the purposes of identifying matrix elements, social communication typically utilizes information from several modalities, including facial, vocal, gestural, postural, and olfactory processing. Social Communication was organized into the following sub-constructs:
    a) Reception of Facial Communication: The capacity to perceive someone's emotional state non-verbally based on facial expressions.

b) Production of Facial Communication: The capacity to convey one's emotional state non-verbally via facial expression.
c) Reception of Non-Facial Communication: The capacity to perceive social and emotional information based on modalities other than facial expression, including non-verbal gestures, affective prosody, distress calling, cooing, etc.
d) Production of Non-Facial Communication: The capacity to express social and emotional information based on modalities other than facial expression, including non-verbal gestures, affective prosody, distress calling, cooing, etc.

3. **Perception and Understanding of Self:** The processes and/or representations involved in being aware of, accessing knowledge about, and/or making judgments about the self. These processes/representations can include current cognitive or emotional internal states, traits, and/or abilities, either in isolation or in relationship to others, as well as the mechanisms that support self-awareness, self-monitoring, and self-knowledge. Perception and Understanding of Self was organized into the following sub-constructs:
   a) Agency: The ability to recognize one's self as the agent of one's actions and thoughts, including the recognition of one's own body/body parts.
   b) Self-Knowledge: The ability to make judgments about one's current cognitive or emotional internal states, traits, and/or abilities.

4. **Perception and Understanding of Others:** The processes and/or representations involved in being aware of, accessing knowledge about, reasoning about, and/or making judgments about other animate entities, including information about cognitive or emotional states, traits or abilities. Perception and Understanding of Others was organized into the following sub-constructs:
   a) Animacy Perception: The ability to appropriately perceive that another entity is an agent (i.e., has a face, interacts contingently, and exhibits biological motion).
   b) Action Perception: The ability to perceive the purpose of an action being performed by an animate entity.
   c) Understanding Mental States: The ability to make judgments and/or attributions about the mental state of other animate entities that allows one to predict or interpret their behaviors. Mental state refers to intentions, beliefs, desires, and emotions.

Summary of Construct Group Deliberations

The material in the following sections is intended to provide background and context for the final Construct definitions provided above. Workshop participants discussed a variety of considerations and perspectives, and the resulting set of Constructs and definitions emerged.

Affiliation/Separation and Social Dominance Group

Definition Development

A single group was charged with considering the Affiliation/Separation and Social Dominance constructs. They began by generating an expansive list of relevant behaviors and processes for

the respective constructs. The list included: social reward/motivation (e.g., saliency of social cues, social approach behavior), social learning (e.g., social recognition, saliency of social cues), social attachment and bonding (processes for forming attachments to be distinguished from those that maintain attachments), the homeostasis of attachment, social anxiety and withdrawal, grieving and separation, anxiety and/or stress as a consequence of separation, social buffering, and nurturing behavior.

There was debate about whether to re-organize Affiliation/Separation into two constructs. Separation, as in the case of separation anxiety, was seen as a component of attachment. Therefore, to more broadly encompass separation and integrate it with affiliation, the Construct was renamed "Affiliation and Attachment." In these terms, separation was seen as a response to the loss of attachment (i.e., you cannot have a significant separation without first having an attachment). The Affiliation and Attachment construct captures the social information processing necessary for bonding as well as the disruptions inherent in separation.

The group preferred the term "Social Hierarchies" rather than "Social Dominance" because it captured more completely social interactions related to status and power. Inherent in some of these behaviors and processes was the role of social dominance or hierarchies and the expression and role of aggression.

One of the themes that ran through much of the discussion included how behaviors of a single individual might manifest under some circumstances but not others. The group also worked hard to clarify which sets of behaviors belong on a single dimension, albeit at opposite ends of the spectrum, and which are actually dimensionally distinct. The group considered whether there are different psychological or neural processes corresponding to such behaviors. For instance, the processes subserving affiliation and avoidance may be distinct, and both types of behavior may appear in different combinations in the same person depending on the situation.

Another theme in the group deliberations concerned the optimal level at which to specify the many relevant processes (e.g., domain, construct, etc.). There was some discussion about the nature of a construct and how best to hierarchically classify the phenomena and processes being proposed as constructs (or sub-constructs). The term "exemplars" was useful to move the process forward, but recurring discussions on these issues underscored the challenge of defining these constructs. That is, there are a series of interacting, hierarchical processes involved in affiliation, social hierarchies, and aggression. After much consideration of the optimal number of constructs and construct groupings, and in light of the many relevant behaviors and processes generated at the outset of the group deliberations, an initial effort was directed toward focusing on two Constructs: (1) Affiliation and Attachment and (2) Social Hierarchies (the latter replacing social dominance). Although both of these Constructs were discussed further, only the discussion of Affiliation and Attachment led to definitions and matrix elements which were sufficiently distinct and specific to be appropriate for further investigation using the RDoC approach at this time. Work on the Social Hierarchies Construct is ongoing.

Other Considerations

The group thought it important to address developmental and cultural aspects of social processes. Participants recognized that these issues are both complex and pervasive across all Constructs under consideration. Developmental processes may in some sense be considered as an additional dimension to the matrix and, although there is no way to formally represent developmental processes in the matrix, the importance and expectation of incorporating developmental processes into studies across all Domains and Constructs was clearly acknowledged.

Specifically, it was noted that neurodevelopmental processes are very important to consider in studies of most social processes. In typical development, there are variations across development in genetic and neurobiological mechanisms, circuits, and behavioral manifestations of social processes. In disorders of behavior, variations in developmental timing across the lifespan of genetic, epigenetic, or neural pathogenic mechanisms can lead to different types or severity of effects on social processes. Moreover, the developmental timing of alterations in social processes can have differing "downstream" consequences on other aspects of mental health and function. For example, low levels of social motivation and attention to social cues starting in very early childhood may have more severe consequences on social cognition and social skill development than an adult-onset reduction in social motivation and attention. Also, high levels of social stress may have different effects on social processes and underlying neural mechanisms at different developmental stages.

Similarly, cultural and historical differences are also important to consider when studying social processes. There are important cultural and historical differences in patterns of, and expectations regarding social behaviors, including affiliation, aggression, and gender roles. Definitions of what is considered normative vs. pathological social processes vary by cultural norms. For example, there are differences in patterns of parenting behaviors and attachment, romantic attachment behaviors, social status and hierarchy structures, and patterns of aggressive behaviors.

Facial Expression/Social Communication Group

Modality Specificity

This group was initially charged with considering the proposed construct of Facial Expression Identification. The group first discussed whether this construct was too narrow. On one hand, facial expressions are critical to the social experiences of humans and non-human primates, the subject has been very well-studied, much is known about the neural circuits involved in the various aspects of facial expression identification, and impairments in facial processing have been identified in various mental disorders. This degree of specificity might be appropriate for an RDoC construct, because it allows detailed elements to be included for nearly all of the matrix units of analysis. Such a construct might provide optimal traction for the implementation of future studies that examine facial expression processing in mental disorders, and that are consistent with the RDoC approach.

On the other hand, there are many other critically important forms of emotional and social expression and communication that are not likely to be included in the other constructs. Many members of the group thought that it would be important to be more inclusive, in order to

stimulate research in areas of social and emotional expression that have not been as well-researched as facial expression. Olfaction was noted as an example of a sensory modality that is increasingly studied as a means of social communication in non-human and human research, and holds promise for translational investigation.

The group discussed the importance of identifying construct(s) that are well-defined, defensible, and forward-looking without being overly-inclusive or broad. Research on social communication has focused, perhaps disproportionately, on the use of prototypical, unimodal facial stimuli rather than more subtle, naturalistic, dynamic, cross-modal behaviors and communicative signals. Participants acknowledged that these more sophisticated methods will likely yield useful new information; however, for the purposes of large-scale research and standardized probes, it is often necessary to simplify methods. To some degree, scientific progress in this area has been guided, and at times constrained, by the availability of experimental paradigms and stimuli. New technologies have emerged to study expression and communication via other modalities using interactive and dynamic tasks that allow the study of more naturalistic behaviors.

The group discussed the extent to which the processing of emotional information that is conveyed via different modalities (e.g., facial, verbal, gestural) is mediated by distinct versus overlapping neural circuits. For example, some aspects of emotional information processing (e.g., learning) may be impaired due to damage to a specific brain area, regardless of the modality of the emotional information. Other aspects (e.g., those related more closely to perception) are implemented by modality-specific circuits. There is evidence that facial affect processing is not simply processed by a single circuit; instead, it is processed in different brain areas depending on the emotional content of the face, suggesting some shared activation in response to faces, but also partial dissociation. In some disorders, impairment of emotional information processing co-occurs across modalities but in others, the impairment is for a specific type of emotional information (e.g., detection of prosody may be intact but facial emotion identification is impaired; detection of some facial emotions, but not others, may be impaired).

In addition, the group discussed the extent to which the processing of different emotions may have partially distinct neural circuitry, although it is likely that some common substrates are involved in processing disparate emotions. For example, while fear may involve robust amygdala processing, positive emotions may implicate striatal reward systems.

There was some consensus that since this Construct group is part of the Social Processes Domain, it would be reasonable to focus on the uniquely social aspects of the constructs rather than the more purely perceptual aspects (which could be considered under the Perception construct in the Cognitive Processes Domain).

Reception versus Production

Another important question addressed by the group was whether the constructs should focus on the receptive aspects of social communication (e.g., affect identification), or should also include the production of social signals/behaviors (e.g., the generation of facial expressions, prosodic changes or communicative gestures). There was some consensus that focusing on receptive processes was too limiting and excludes the interactive nature of social processes. In addition,

individual differences in the production and timing of speech are important for understanding social behavior and its disruption. The group also agreed that the neural circuits involved in reception and production generation of social communications were sufficiently dissociable. It was further noted that one can have a dissociation between the ability to perceive another's emotion and the experience of affective resonance (i.e.., some individuals may be capable of identifying emotion in others, but not experience a visceral or empathic response). Even within the realm of production/generation, there are important differences between the muscle activation patterns involved in spontaneous and induced expressions; these can be dissociated in some stroke patients who cannot generate a facial expression deliberately, but can do so spontaneously.

After discussing these issues and considering various alternative constructs, including "non-verbal emotional communication," "social affective expression," "social affective communication" and "social interaction," the group decided to define a single overarching Construct, "Social Communication," and four sub-constructs: Reception of Facial Communication, Production of Facial Communication, Reception of Non-Facial Communication, Production of Non-Facial Communication. Because responses to faces are perhaps the best-studied examples of social communication, Reception of Facial Communication was selected for elaboration in the matrix. This capacity involves both the motivation and ability to process faces, and is manifested early in development.

Although less research has focused on non-facial (compared to facial) social communication and production (versus reception) of social communication, it was felt that the non-facial constructs nonetheless met the criteria for Constructs (i.e., that the construct could be associated with a neural circuit or circuits and that they are related to psychopathology). Because social communication is evolutionarily recent and highly complex, it can be thought of as a unitary construct; organizing or dividing it by modality may distort its distinctive inherent complexity. The group discussed the extent to which it might be reasonable to combine communication across different modalities into one construct because once the neural signals pass through primary sensory cortex, the processing is largely integrative and multi-modal. Ultimately, it was decided that there was sufficient specificity to justify different constructs for facial and non-facial communication, while acknowledging the utility and promise of research that examines social communication by incorporating measures of multiple modalities. It was noted that although some networks may be best understood in relation to face processing, their roles may not be restricted to face processing, and future work may show their importance in other modalities. For example, fusiform gyrus is widely considered to be a face processing area, but more recent research suggests that it may be an "expertise area" with individual differences in the types of stimuli that activate the fusiform gyrus (i.e., a symphony conductor's fusiform gyrus will respond to music more than faces). The group also chose to focus on the broader idea of "communication" rather than affect or emotion because not all social communication is emotional and not all expressions of emotion are social. For example, vocal and facial communication also includes information about sickness and health status.

Overlap with Other RDoC Constructs

The group discussed the relationships between social communication and other RDoC constructs that could be considered to be the inherent result of the densely interconnected nature of the brain as it has evolved. Although the loss of a loved one or relationship is a social perturbation, it does not necessarily involve communication, and so it is included in the Loss Construct in the Negative Valence Systems Domain, and is not considered under the social communication construct. Motivation is an important determinant of the quality and quantity of social communication, but was not identified as a construct because it was thought that the Approach Motivation construct in the Positive Valence Systems domain would reasonably include motivation for social behavior. Similarly, attention is an important element in social communication, but it was thought that the various characteristics and functions of attention that are involved in social communication had been considered under the Attention Construct in the Cognition Domain. Visual and auditory perception are essential to social communication, but although facial and vocal perception were not elaborated in the matrix for the Perception Construct in the Cognition domain, "face identification" and "emotion expression identification" were included as paradigms under the Visual Perception sub-construct.

The construct group attempted to focus their discussion and generation of matrix elements on the specifically *social* aspects of these constructs. Similarly, the group discussed the boundary between the Language Construct in the Cognition Domain and Social Communication. Irony and sarcasm, despite being features of speech, were considered to be social communication because the meaning of the language was enhanced by this social information. The group made a distinction between perceiving another person's emotions and making an interpretation about their feelings or actions. For example, recognizing a smile was considered to be part of social communication but the ability to know that a person is smiling because they are trying to achieve an interpersonal goal was considered to be relevant to the Self and Other Domain, although the border between social communication and the cognitive processes involved in Self and Other processes is somewhat difficult to define.

Human versus Non-human

Social communication was discussed as a set of evolutionarily important processes that subserve the inherently dynamic integration and maintenance of individuals in their social network. Although these evolutionary forces would apply similarly to humans and non-humans, social processes differ in important ways between humans and non-humans (perhaps more so than for other constructs). The group recognized the important contributions of research using non-human animals, and considered that different species may use different modalities to communicate similar social information (e.g., humans might convey distress primarily via facial expression whereas other animals might use vocalizations). Only elements that were considered to be applicable to studies of humans were included in the matrix for the Social Communication Constructs.

Intentional/Conscious versus Automatic/Unconscious Communication

Social communication occurs not only via intentional, conscious means, but also unintentionally and unconsciously. Importantly, social communication can include the detection of a mismatch or discrepancy between an individual's intentional and unintentional communication or between

verbal communication and action. Different modalities of social communication are subject to different degrees of control. For example, some individuals can control their facial expression but not vocal expression, and communication that is intentional or conscious might be controlled by different circuits than that which is automatic or unconscious.

Self and Other Group

Construct and Definition Development

Members of the Self and Other Construct group expressed some early uneasiness with the vagueness and potential for multiple interpretations of the terms "Self and Other." In early discussions, the group considered various components of these concepts and possible terms that could be used to better specify the Construct. Ideas related to "self" included self-knowledge, self-reflection, self-awareness, self-recognition, self-representation, and self-understanding. It was noted that any of these constructs might include various sub-components, such as knowledge of one's traits, disposition, beliefs, affective states, etc. Ideas related to "other" included person perception, animacy, and mental state attribution.

One theoretical framework considered was a model (Baumeister, 1998) that considers three aspects of self: cognitive (what do you know about yourself), affective (how do you feel about yourself), and executive (what do you do with yourself). Another conceptual approach discussed was more action- and intention-based (Spunt & Lieberman, 2012), focusing on those systems which process information about what is done (action perception/imitation/mirroring), why something is done (mentalizing/mental state attribution/theory of mind), and who does it (self-reflection/self-knowledge). The groups decided to utilize the construct titles of "Perception and Understanding of Self" and "Perception and Understanding of Others," and generated the working definitions of each with the goals of capturing their multi-faceted components.

The group then tried to identify core sub-components of each of these constructs. For the "Perception and Understanding of Self" Construct, two sub-constructs were initially proposed: "Agency" and Understanding mental states." For "Perception and Understanding of Others," three sub-constructs were initially proposed: "Animacy," "Action perception," and "Understanding mental states." Because of the parallels between these sets of sub-constructs, considerable time was spent discussing whether action perception should be included within the Self Construct as well. In the end, the group decided not to include action perception (or action production) as a sub-construct of "Perception and Understanding of Self," because they could not identify social process-specific neural circuitry of interest (other than motor systems or those covered in the Social Communication Construct).

The group also considered whether the organization of constructs should be arranged orthogonally to the original conceptualization. That is, they discussed making the major constructs "animacy," "action perception," and" understanding mental states" and having "self" and "other" as sub-constructs under each of these. Some members of the group felt that doing so would have the benefits of increasing clarity/specificity, reducing "baggage" associated with the ideas of "self" and "other," and potentially allowing the RDoC matrix to be divided more cleanly along neural circuit divisions. In the end, the matrix components fell more easily into place by

leaving “Perception and Understanding of Self” and “Perception and Understanding of Others” as the Constructs.

During the discussions, multiple additional issues related to terminology, the conceptualization of self and other, and the goals of the RDoC initiative were discussed. The group discussed the question of whether the concept of “self” can really be separated from that of “other.” The group noted overlaps and subtle differences between the meanings of some commonly used terms, such as “theory of mind” versus “mentalizing,” “animacy” versus “agency,” “detection of a social agent” versus “understanding other.” They noted that knowledge about self/other might include both external physical attributes (“low level”) and internal mental attributes (“high level”). There are a number of social processes and behaviors that may wholly or partially emerge from the interactions between Self and Other circuitry. These include phenomena such as imitation, mimicry, empathy, cooperation/competition, play, social acceptance, social exclusion, and communication. Some of these are considered under other constructs within the Social Processes Domain, but some are not.

In choosing terms and concepts to focus on, the group sought to maintain relevancy to the clinical arena and psychopathology, without focusing on specific diagnostic categories. Priority was given to sub-constructs with dimensionality. They also considered the importance of developmental trajectories and of including tasks/paradigms that could be used with a broad age range of subjects.

Additional Constructs Considered

Over the course of the workshop, the “Self and Other” group considered multiple additional constructs:

Self-regulation

Self-regulation was discussed extensively. Some self-regulatory processes may engage general purpose cognitive control mechanisms, but there may also be processes specific to modulating self-related behaviors. Key aspects of self-regulation may occur through the interaction of constructs and mechanisms specified in Social Processes, and those specified in Cognitive Systems (e.g., executive control, inhibition), Positive Valence Systems (e.g., reward and motivation), Negative Valence Systems (e.g., fear and anxiety), and/or Arousal/Regulatory Systems.

The group did not reach a complete consensus as to whether self-regulation could be captured as a simple interaction of two or more of these constructs. There was some agreement that self-regulation has not been considered to be its own construct because there is not enough current data to distinguish it from other constructs at this time. In addition, the group felt it would be difficult to include all self-regulation abilities in the “Self and Other” construct and would make it too inclusive.

The group agreed that the topic of self-regulation is extremely important and only minimally addressed in the Cognitive Systems and Negative Valence Systems workshops. As such, the

group felt that it is critical to encourage research that examines the interactions among these systems, both at the behavioral and neural levels. Particular emphasis was placed on processes related to emotion/affect regulation, willpower and self-control. These domains may be explicitly addressed in the Arousal and Regulatory Systems construct workshop. However, if not, the group thought that the operation of such regulatory and control systems, and the mechanisms by which different systems interact, require consideration as an independent construct (or even domain) and may necessitate a separate RDoC meeting focused on these critical and highly psychopathology-relevant regulatory systems.

Empathy

The group noted that different disciplines study empathy in different ways and may use the word "empathy" to describe many different processes (e.g., a set of affective reactions, a focus on others, or pro-social behavior) and behaviors (e.g., facial imitation vs. an internal process of consideration of differences between self and other). The group agreed that empathy included multiple important emotional and cognitive pieces and suggested there may be a difference between affective and cognitive empathy (e.g., understanding what another is feeling or thinking). The group discussed several different neural circuits that might be involved in empathy, such as the mirror system or the septum. They noted that the fMRI findings observed depend on how stimuli were presented (e.g., whether a subject sees or reads about another). Given the plethora of potential psychological definitions and the lack of clarity regarding underlying circuitry, empathy was not considered appropriate as an RDoC Construct at this time.

Physiological and/or Physical States

Members of the group noted that judgments about current physiological and/or physical states may not engage the same systems(s) as those involved in mental states. The distinction may be in the degree to which the judgment requires drawing an inference about oneself versus a direct report of a current physical or physiological state of the system. The interoceptive and proprioceptive systems were discussed briefly. The group noted that interoception may be relevant to multiple psychopathologies (including eating disorders and anxiety disorders). The insula is critically involved in interoception; the degree to which it demonstrates changes in the blood oxygen level-dependent (BOLD) response in functional magnetic resonance imaging (fMRI) studies may depend on the degree to which the paradigm used requires drawing inferences about someone versus reporting directly on one's current physical or physiological state. The group recommended including interoception within the Arousal and Regulatory Systems Workshop. The group noted that proprioception involves the motor system, somatosensory system, cerebellum, and supplementary motor area. It was not considered necessary to include this as an RDoC Construct.

Learning/Memory

The group noted that learning and memory are involved in all processes, and are especially important across development. As a Construct, learning/memory includes autobiographical memories and is, therefore, relevant to "Perception and Understanding of Self." The group felt

that the circuitry involved in social versus non-social learning/memory remains an open question at this time.

Interactions between Self and Other

Although noted as important areas of future study, the following topics were not considered ready to be RDoC Constructs at this time: Imitation (mirror neurons), cooperation/competition, exclusion, social comparison, and regulation of social interactions.

Other topics that were discussed briefly included insight, social motivation, self-esteem, pro-social motivation/altruism, social reward, and resting state activity (resting state activity will be covered as part of the Arousal and Regulatory Systems Workshop).

Additional Discussion Topics

Specificity of Circuits

When populating the RDoC matrix, the group discussed several limitations related to the specificity of the proposed circuits. The group agreed that there are two well-defined neural networks: one often called the "default," "social," or "self" network, and the other more consistently related to action perception. However, the degree to which each of these networks is specific and separable is somewhat unclear as yet. Moreover, it may not be possible to separate self versus other sub-components at all developmental time points.

The group noted that some sub-constructs may be more clearly separable at a cognitive/behavioral level than at the neural level. There was some consideration of the issues of reverse inference arising in fMRI studies. In addition, many tasks/behavioral paradigms currently in use may involve more than one sub-construct. The group suggested that additional work needs to be done in the arena of paradigm development and validation. For the RDoC matrix, the group focused on tasks that can reliably discriminate between these two networks. However, the group also noted that this is not the only way of studying these questions/constructs. There may be tasks that jointly recruit multiple circuits, and these may be more interesting and/or ethologically valid.

Areas of Potential Overlap with Other Domains and Constructs

The group identified several areas of overlap with other Domains and Constructs. Specific areas included Face Expression Identification (person recognition/animacy, social communication, and social threat), Negative Valence (social threat), Cognitive Control, and Language.

Additional Questions Identified at the Workshop:

- Various agents have been shown to modulate default system activity (e.g., alpha 7, ketamine, etc.). However, it is not known whether this also changes self-knowledge or ability to understand the mental state of others.

- There is evidence that serotonergic agents change behavior in the performance of emotion-perception or economic games. However, it is not yet clear how directly it might influence these social processes constructs.
- Various substances (alcohol, MDMA, etc) can influence the way people think about self and other, but this may not be specific to understanding of self or other.

NIMH encourages comments on any aspect of the workshop and proceedings outlined here. Please send comments to: rdoc@mail.nih.gov.

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Social Processes Matrix Specifications

1. Affiliation and attachment: Attachment formation and maintenance

Units of Analysis							
Genes	**Molecules**	**Cells**	**Circuits**	**Physiology**	**Behavior**	**Self-reports**	**Paradigms**
OXTR, AVPR1A, MOR *OXT, Tyrosine Hydroxylase, DRD2, MOR, *CRF, KOR, CRFR2, DRD1	Oxytocin, vasopressin, oxytocin receptor, vasopressin 1a receptor, dopamine Mu opioid receptor *CRF, KOR, CRFR2, D1	*Magnocellular OT	VTA- NAcc-VP-amygdala, PVN, OFC, FF gyrus, VMPFC *Amygdala, BNST, PVN, NAcc	Sex steroid changes; HPA down-regulation; Vagal tone; Immune markers HPA axis activation; immune responses ("sickness"); activation of sympathetic activity; vagal withdrawal	Attachment Formation–maintaining proximity; preference for individual Attachment maintenance -- Distress upon separation	Inventory of Parent and Peer Attachment Scale; Attachment Questionnaire for Children Scale; Adult Attachment Interview; Bartholomew and Shaver Examples (no comment on validity): Social Anhedonia scale; Experience in Close Relationships Scale, Parental Bonding Instrument, Attachment Style interview; QSORT Parent Attachment interview Bereavement scales; social subscales of depression	Social Buffering of Stress Strange Situation Separation

* Candidate molecules and circuits based on animal studies.

2. A. Social Communication: Reception of Facial Communication

Units of Analysis							
Genes	**Molecules**	**Cells**	**Circuits**	**Physiology**	**Behavior**	**Self-reports**	**Paradigms**
OXTR CNTNAP2 5HTT COMT FMR1 BDFN Other autism risk genes	Oxytocin Vasopressin Serotonin GABA FMRP Testosterone Dopamine	Face selective neurons-FFA, STS, amygdala Neurons with mirror properties	V1-FFA-STS-amygdala V1-FFA-STS-VS IFG-INS-amygdala/VS OFC-ACC-amygdala-striatum amygdala-brainstem Resting state networks	SCR HR/BP/respiration Pupil dilation Startle reflex Facial EMG ERP N170, N250; ECoG Frontal brain asymmetry (decreased alpha to faces) Local cerebral blood flow changes Network dynamics, including within and between network structure (e.g., coherence, functional connectivity)	Identification of emotion Eye gaze detection Scanning patterns Behavioral observation/coding systems Implicit mimicry	Face dimensional rating scales Arousal ratings	Emotional face expression tests Face feature manipulation (e.g. morphing) Still Face paradigm Distress paradigms Social Reward paradigms Emotional Stroop/emotional go/no-go Social Flanker, other attention paradigms Dynamic Social stimulus tasks Conditioning paradigms Joint attention tasks Face priming tasks Chimeric tasks Masking paradigms Implicit social perception tasks

2. B. Social Communication: Production of Facial Communication

Units of Analysis							
Genes	**Molecules**	**Cells**	**Circuits**	**Physiology**	**Behavior**	**Self-reports**	**Paradigms**
CNTNAP2 FOXP2 SHANK3 NRX1 OXTR Other autism risk genes	Contactin AP		Eye movements: PPC-SC-SNc-SEF-FEF-CB Facial Expression: Regions including PAG, AC	Facial EMG SC, HR variability, pupil dilation Photoplethysmo-graphy (skin color measure of capillary dilation; temperature) NIRS Tear production	Eye gaze aversion/contact Head turning Reciprocal eye contact Reciprocal emotional expression Facial affect production Joint attention Behavioral observation/coding systems Imitation of facial gestures	Berkeley Expressivity Questionnaire	Imitation of affect Directed facial action tasks expression: FACS and FACES coding system; other automated facial analysis “Thin slices” of non-verbal behavior test Relived Memories paradigm Human-Computer interaction Social games e.g. cyberball Provocative tasks/settings to elicit expressions Still Face paradigm Distress paradigms

2. C. Social Communication: Reception of Non-Facial Communication

Units of Analysis							
Genes	**Molecules**	**Cells**	**Circuits**	**Physiology**	**Behavior**	**Self-reports**	**Paradigms**
FOXP2 CNTNAP2 OXTR ? NGF	Oxytocin		A1-RSTG, STS, VLPFC, MPFC	EEG features, e.g., evoked gamma Local cerebral blood flow changes Network dynamics, including within and between network structure (e.g., coherence, functional connectivity)	Comprehension of emotional prosody Irony/sarcasm comprehension? Metaphor comprehension? Comprehension of non-verbal gestures Humor comprehension	Social Responsiveness Scale	Sentence Prosody tests CELF Prosody Language vs. non-language discrimination Biological Motion discrimination (with and without emotion) Olfactory hedonics measures Profile of non-verbal sensitivity “Thin slices” of non-verbal behavior test Still Face paradigm

2. D. Social Communication: Production of Non-Facial Communication

Units of Analysis							
Genes	**Molecules**	**Cells**	**Circuits**	**Physiology**	**Behavior**	**Self-reports**	**Paradigms**
FOXP2 OXTR ? NGF			R-IFG-RSTG (Songbird circuits?)		Response to distress/separation distress Crying/laughing Vocalizations Speech (affective) prosody Gestural/postural expressions Interactive play		Computer interface tasks Vocal production coding systems e.g., spectral analysis, computational linguistics Still Face paradigm

3. A. Perception and Understanding of Self: Agency

Units of Analysis							
Genes	**Molecules**	**Cells**	**Circuits**	**Physiology**	**Behavior**	**Self-Reports**	**Paradigms**
			Right parietal; right insula, right inferior frontal; SMA, somatosensory, premotor	Scalp Motor Potentials	Evidence that one understands ownership of one's own body parts or action (thoughts/behaviors); Hallucinations; Delusions of Control	Perceptual Aberration Scale	Identification of one's own biological motion; Joy Stick manipulation (decoupling motor and sensory feedback); illusions of will; Ford Corollary Discharge Paradigm; Reality Monitoring

3. B. Perception and Understanding of Self: Self-Knowledge

Units of Analysis							
Genes	**Molecules**	**Cells**	**Circuits**	**Physiology**	**Behavior**	**Self-Reports**	**Paradigms**
		Von Economo neurons??	MPFC, posterior cingulate/precuneus, left inferior frontal cortex, ventral anterior cingulate (valence specific)	P300s to self-relevant stimuli	Developmentally appropriate perception of one's competences, skills, abilities beliefs, intentions, desires, and/or emotional states	Levels of Emotional Awareness; Toronto Alexithymia scale; Private Self-Consciousness; Self Components of Attributional Styles Questionnaire; Self-monitoring	Self Judgments; Self reference effect; Meta-cognition Tasks; Discrepancies in self and peer ratings [i.e., peer nomination]

						scale	

4. A. Perception and Understanding of Others: Animacy Perception

Units of Analysis							
Genes	**Molecules**	**Cells**	**Circuits**	**Physiology**	**Behavior**	**Self-Reports**	**Paradigms**
			STS, extrastriate body area, occipital face area, fusiform face area	MU Suppression	The ability to appropriately attribute animacy to other agents		Point-light displays; Attributions of contingent behavior

4 B. Perception and Understanding of Others: Action Perception

Units of Analysis							
Genes	**Molecules**	**Cells**	**Circuits**	**Physiology**	**Behavior**	**Self-Reports**	**Paradigms**

		Mirror Neurons	Ventral/dorsal premotor, inferior parietal, STS	MU suppression, cortico-spinal facilitation (TMS)	Imitation; mimicry; Gaze following; Ability to identify what actions an agent is executing	Balanced Emotional Empathy Scale; Perspective Taking and Empathic Concern subscales of the Interpersonal Reactivity Index; Empathy Quotient	Action observation, Imitation, Self-Other Morphs; Non verbal decoding tasks; How component of Why/How Task; Profile of Non-Verbal Sensitivity; Empathic Accuracy Tasks

4. C. Perception and Understanding of Others: Understanding Mental States:

Units of Analysis							
Genes	**Molecules**	**Cells**	**Circuits**	**Physiology**	**Behavior**	**Self-Reports**	**Paradigms**
Genes that influence Vasopressin or oxytocin	Vasopressin; Oxytocin		MPFC, TPJ, temporal pole, precuneus; STS		Developmentally appropriate interpretations of other intentions, goals and beliefs	Other components of Attributional Styles Questionnaires; Balanced Emotional Empathy Scale; Perspective taking and empathic concern subscales of interpersonal reactivity index; Empathy Quotient	Other Trait or State Judgments; Strange Stores; Directors Task, Faux Pas; Reading the Mind in the Eye's; Why component of Why/How Task; Theory of Mind Tasks in children; Dunbar's Intentionality Questionnaire; Irony comprehension; Empathic Accuracy Tasks