**Detecting the Contents of Consciousness in Infants**

**Program Members:** Dr. Janet Werker (CBD Senior Fellow, BMC Advisor) and Dr. Alona Fyshe (BMC Azrieli Global Scholar)

**Research Project**

Recent research shows that by as early as 6 months, infants are beginning to recognize words and to be able to map them to objects [1]. Still unknown is how those lexical concepts are represented, to what degree they resemble the complex feature structure of adult lexical representations, and how they move towards this complex representation during language acquisition. In this application we propose to develop and apply machine learning methodologies using EEG recordings to detect the contents of these representations in infants and adults. We are particularly interested in elucidating the extent to which the neural representations include complex properties such as animacy and agency, which are indicative of higher order reasoning, and perhaps consciousness.

Much of the work probing infants’ semantic representations has used ERP responses as an indicator of comprehension by measuring the centro-partietal N400 that is uniquely evoked when there is a mismatch the expected meaning. This measure can indicate whether infants detect stimuli that are semantically incongruous. Although this method, as well as others [1] have been used to show that young infants know words [2,3], work to date has not addressed the complexity of these representations and how they develop to become more like those of adults. Here, we propose to probe infants’ semantic representations using methodologies developed for adults. This will entail first applying a training algorithm on a large text corpora to represent adult semantic representational structure, and second applying Representational Similarity Analysis to the EEG signal recorded from infant brains in response to auditory/visual (word plus picture) stimuli, to reconstruct the feature matrix of words in the infant brain, and compare it to the same words in the adult brain, as well as representations build from a corpora. This will enable us to determine the kinds of features represented in the very earliest lexical entries, and how these change across development.

Scientific Questions

1. Can gross category distinctions (e.g. animate/inanimate) be decoded using EEG recorded from infants at 7 months of age? 12 months of age?
2. Can fine grained semantic distinctions (e.g. cup vs car) be decoded using EEG recorded from infants at 7 months of age? 12 months of age?

Methodology

**Phase 1: Data collection**

Data collection will take place at the Infant Studies Center at UBC, where Werker has a well-established lab. We will collect EEG data using her existing 64 channel EGI system. The infants will come in to the lab and view a set of paired audio and visual stimuli. The audio stimuli will precede the visual stimuli, and be predictive of the visual stimuli in the control condition (e.g. the word dog followed by a picture of a dog). In the unexpected condition, the visual stimuli will not be the predicted stimuli for the given word (e.g. the word “mommy” followed by a picture of a dog). The stimuli will come from two broad categories: animate and inanimate objects. Within each of these classes, we will present different exemplars of several more fine-grained semantic classes.

**Phase 2: Sanity check**

The paradigm described in Phase 1 uses predictable visual stimuli for each word. As in previous work [2, 3, 4], we expect to see a larger magnitude response in centro-parietal sensors around 400ms after the onset of the unexpected visual stimuli (N400 response) as compared to expected visual stimuli. We will use cluster permutation tests to determine if the infants can differentiate between the expected vs unexpected visual stimuli and successfully associate the auditory and visual stimuli.

**Phase 3: Gross category distinctions (Animate vs. inanimate)**

Here, we will train a machine learning classifier to differentiate animate vs. inanimate auditory stimuli using the EEG data as input. Multiple algorithms could be used, a support vector machine being one promising option. If we can successfully predict the animacy of a stimulus from the EEG, that will indicate that there exists a detectable difference the infant’s neural response to animate and inanimate stimuli, as has been shown in adults [5], and reveal that abstract features characterize the early lexicon.

**Phase 4: Finer category distinction (Ball vs. cup)**

Phase 4a: word vectors. Using the EEG data collected during the auditory stimuli presentations, we will train multiple regression models that have been shown to differentiate between pairs of concepts in adults, (see 6; 7). In this phase we will represent each concept with a word vector, trained on a large text corpus. Though the word vectors represent adult-level world knowledge, much of that knowledge could be obtained by 7 months of age (e.g. the size of a cup). Our work will test if the similar fine-grained concept distinctions can be detected in infants using corpus-based models.

Phase 4b: RSA analysis. For this phase, we will collect a similar dataset to that described in Phase 1, using adult subjects. We will use Representational Similarity Analysis [8] to more explicitly test if the intra-subject EEG similarity of adults is comparable to the intra-subject EEG similarity in infants. RSA will allow us to more directly test how neural representations vary across ages without relying on word vectors.

In summary, we propose a set of experiments to shed light on the contents of consciousness in young infants. By investigating the predictive strength of object-word associative knowledge, as well as the ontological categories of early words, we will be better positioned to explore the maturation of the human semantic system, and contribute to a deeper understanding of the earliest steps in abstract cognitions.

**Budget and Timeline**

* 40% Post-doc for 2 years = 2 x $20,000/year = $40,000

Budget Justification

The bulk of the work described here is data collection and analysis. For this we will need a Post Doc who can collect quality EEG data (supervised by Dr. Werker) and assist in performing the intricate analyses (supervised by Dr. Fyshe). We anticipate we will need to collect around 20 adult and 40 infant participants.

Timeline

Post Doc September 2019 - August 2021. We anticipate Data collection will be done by May 2020, and model fitting can begin soon after.

Beyond the Catalyst Grant

This grant will put in place a pilot dataset and act as proof of concept that we can detect the contents of consciousness in infants. This work will also create a framework for data analysis that can lead to other possible research directions. This will position Drs Werker and Fyshe to apply for additional funding from outside sources, as well as solidify collaborative ties between their respective labs.

**References**

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