Title of the study (one request per article):
The early development of self-regulation

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Wave (more options are possible):

- ☐ Rondom zw – 20 weeks
- ☐ Rondom zw – 30 weeks
- ☒ Rondom 0 – 5 mo
- ☒ Rondom 0 – 10 mo
- ☒ Rondom 3 (not available yet)
- ☐ Rondom 6 (not available yet)
- ☐ Rondom 9
- ☐ Rondom 12 (not available yet)
- ☐ Rondom 15 (not available yet)

We ask you to provide us with a clear background, methods section and data-analysis plan. These parts of the proposal will be publicly displayed for reference.

Background of the project (max. 500 words): Please provide a short background including the rational of your study as you would do in an introduction of the paper
Self-regulation, which is defined as the ability to automatically or purposely control thoughts, feelings and behavior, is predictive for development in many domains in life (Raver et al., 2012). For instance, competent self-regulation is associated with higher

academic competence and lower vulnerability to externalizing and internalizing problems (e.g., Eisenberg et al., 2000; Murray & Kochanska, 2002; Rodriquez et al., 2005). Therefore, Posner and Rothbart (2000) assume that understanding the development and outcomes of self-regulation is the single most crucial goal for advancing an understanding of psychopathology and development in general.

Self-regulation involves different constructs, such as emotion, behavior and cognition, which are related to different areas in the brain (Checa, Rodríguez-Bailón, & Rueda, 2008; Posner & Rothbart, 2000). Consequently, self-regulation is accompanied by neuronal activity in different brain areas that need to exchange information through neuronal pathways, resulting in efficient brain networks (Heatherton, 2011; Posner, Rothbart, Sheese, & Voelker, 2014; Rothbart & Rueda, 2005). The temporal correlations between spatially remote neuronal activity in different brain areas are defined as functional brain connectivity (Friston et al., 1993).

Functional brain connectivity develops throughout the life span, with large increases from childhood to adolescence (Smit et al., 2012). Particularly during childhood, early environmental experiences are presumed to determine to a large degree which neuronal connections persist and which are selectively eliminated due to lack of use (Fox, Levitt, & Nelson, 2010; Knudsen, 2001). Therefore, early environmental experiences can have a direct impact on functional brain connectivity (De Bellis, 2001; Glaser, 2000; Nelson, 2000).

Parents play a major role in children’s early environmental experience. For example, differences in functional brain connectivity have been associated with adverse parenting behaviors like childhood maltreatment (Birn, Patriat, Phillips, Germain, & Herringa, 2014) and early severe socio-emotional deprivation (Eluvathingal et al., 2006). Regarding favorable parenting behaviors, results of a previous study showed that infants exposed to higher quality interactions with their mothers had more pronounced increases in frontal power than their peers (Bernier, Calkins, & Bell, 2016). However, research that directly examines how favorable and general parenting behaviors affect the functional brain connectivity of children is lacking.

On the contrary to functional brain connectivity, there are multiple studies showing that parenting behaviors might influence the early development of self-regulation (Bernier, Carlson, & Whipple 2010; Eisenberg, Smith, Sadovsky, & Spinrad, 2004; Grolnick & Farkas, 2002; Karreman, van Tuijl, van Aken, & Deković, 2006). However, due to the dynamic interplay between early environmental experiences, brain development and behavioural outcomes (Coll, Bearer, & Lerner, 2014), a mediation process transiting through functional brain connectivity is proposed. Therefore, the aim of this study is (1) to examine the effect of functional brain connectivity and early environmental experiences on the early development of self-regulation and (2) examine whether the effect of early environmental experiences is mediated by functional brain connectivity.

In sum, the current study adds to the literature due to the longitudinal design of self-regulation with a multi-method approach including both behavioural and neuroimaging measures. In addition, studies of functional brain connectivity almost exclusively focus on adverse and pervasive environmental experiences. The current study extends previous studies by including parenting behaviors in a community sample and examine mediation through functional brain connectivity.

Research question

1. What is the relation between early environmental experiences and the early development of self-regulation?

2. What is the relation between functional brain connectivity and the early development of self-regulation?
3. Is the relation between early environmental experiences and the early development of self-regulation mediated by functional brain connectivity?

Methods Describe the methods as in the paper in which the data will be presented, according to the categories below, with a total **maximum** of 1500 words. For a description of task, methods etc. refer to the website, if possible.

Design of the study (for instance cross-sectional, longitudinal etc.; substantiate your choices)

To examine the early development of self-regulation and to test mediation, a three wave longitudinal study will be conducted. Early environmental experiences, functional brain connectivity and their relation to the early development of self-regulation will be examined at the age of 5 months (wave 1), the age of 10 months (wave 2) and around the age of 3 years (wave 3).

Study population and sample-size (entire population or a subset; substantiate your choices e.g. Provide a rationale for the requested sample-size, for instance using a power calculation)

Data for analyses will be derived from YOUth, an ongoing longitudinal cohort study in the Netherlands. No useful power calculation for the current study can be calculated, since the effect sizes of early environmental experiences, the early development of self-regulation and a mediation through functional brain connectivity are currently unknown. In general, individual differences in network characteristics are relatively small. Looking at previous studies examining functional brain connectivity and the early development of self-regulation solely, sample sizes range from the smallest sample size of 25 infants resulting in no effect

(Mundy, Fox, & Card, 2003) to the largest sample size of 365 infants with a medium effect size, $d = 0.56$ (Cuevas, Swingler, Bell, Marcovitch, & Calkins, 2012). Based on these findings, the current study strives for using as many infants as possible (all infants analysed by Bauke van der Velde and Chantal Kemner).

Data processing and preparation (including necessary recoding of data etc.)

The early development of self-regulation will be measured using two constructs of self-regulation: effortful control and compliance.

Effortful control. To determine parent reported child effortful control at wave 1 (around 5-months) and wave 2 (around 10-months), a short form of the Infant Behavior Questionnaire Revised (IBQ-R-SF; Gartstein & Rothbart, 2003) will be used. The IBQ-R-SF consists of three factors measuring general patterns of infant behaviour. In the current study, only the Effortful control factor will be used. Effortful Control includes the subscales of Duration of Orienting, Low Intensity Pleasure, Cuddliness, and Soothability, which reflects the degree to which children focus attention, avoid distractions, and employ planning. To determine parent reported child effortful control at wave 3 (around 3-years), a short form of the Early Childhood Behavior Questionnaire (ECBQ; Putnam,Gartstein, & Rothbart, 2006) will be used. The ECBQ is the parallel measure of the IBQ-R-SF to cover the next age range. In the current study, the subscales Inhibitory Control , Attention Shifting, Low-Intensity Pleasure, Cuddliness and Attention Focusing will be used as an indicator for effortful control. All items will be scored on a 7-point Likert scale ranging from never to always.

Compliance. The Parent-Child Interaction (PCI) video tasks will be used to assess observed child compliance at all three waves. Observed compliance will be coded during a

3-min cleanup, which will follow after a 12-min play situation with one parent (see e.g., Kochanska, 2002; Kemp, Lunkenheimer, Albrecht, & Chen, 2016). Parents will be cued to instruct their children to clean up toys in a transparent box. Child compliance will be coded using the revision of the Erickson scale (Egeland, Erickson, Clemenhagen- Moon, Hiester, & Korfmacher, 1990; Erickson, Sroufe, & Egeland, 1985). Two trained and reliable coders will code the child's compliance on a seven-point Likert scale.

The early environmental experiences will be measured using four groups of family factors that are ordered according to the level of the proximity to the child's everyday experience: proximal factors, distal factors, contextual factors and global factors (Deković, Janssens, & van As, 2003).

Proximal factor = parental behavior in interaction with the child. The Comprehensive Early Childhood Parenting Questionnaire (CECPAQ; Verhoeven, Deković, Bodden, & van Baar, 2017) will be used for reported parenting behavior at the first two waves. The CECPAQ consists of five domains of parenting relevant to the development of toddlers and pre-schoolers: support, stimulation, structure, positive discipline and harsh discipline. Observed parenting behaviors will be determined using the PCI video tasks. Parenting behaviors will be observed during structured tasks and unstructured free play (e.g., Kemp, et al., 2016; Eisenberg et al., 2010; Calkins & Johnson, 1998). Qualitative aspects of the observed parenting behaviors will be coded by two trained and reliable coders. The revision of the Erickson scale (Egeland, Erickson, Clemenhagen- Moon, Hiester, & Korfmacher, 1990; Erickson, Sroufe, & Egeland, 1985) will be used to assess five dimensions of parenting (supportive presence, respecting child's autonomy, structure and limit setting, quality of instruction and hostility). Each dimension is divided into seven subscales and will be coded on a seven-point Likert scale.

Distal factor = characteristics of the parents. To assess the amount of parental stress at wave 1 (around 5-months) and wave 2 (around 10-months), a Dutch translation of the Parenting Stress Index (PSI; Abidin, 1990) will be used for parents self-reported stress called the Nijmeegse Ouderlijke Stress Index (NOSI; De Brock, Vermulst, Gerris, & Abidin, 2001). The NOSI consists of three subscales, focusing on three major domains of stress: child characteristics, parent characteristics, and situational/demographic life stress. All items will be scored on a 5-point Likert scale.

Contextual factor = family relationship. The questionnaire about demographics will be used to assess parents reported household and family relations at wave 1 and wave 2. The items about the relationship between the parents of the child and with the child and the amount of people and the type of people in the household will be used to assess the family relationships of the child.

Global factor = demographics. The questionnaire about demographics will be used to assess parents reported education and economic situation at wave 1 and wave 2. In the current study, the highest level of education for which the parent obtained a diploma and the amount of income of the household will be of interest.

Functional brain connectivity

To examine the degree of functional connectivity between the brain areas at wave 1 and wave 2, the EEG-coherence task will be used. EEG coherence is the normalized cross-correlation of the EEG signal at two different electrodes. Continuous EEG will be recorded using a 32-channel ActiveTwo BioSemi system, configured to the standard International 10-20 System (channels: 28 lateral channels FP1/2; F7/8; F3/4; AF3/4; FC1/2, FC5/6, C3/4, T7/8, CP1/2, CP5/6, P3/4, P7/8, O1/2, PO3/4, plus 4 midline channels Fz, Cz, Pz, Oz), at a sampling rate of 2048 Hz. The EEG data will be recorded relative to common mode sense and driven right leg (CMS/DRL) electrodes placed near Cz to provide an active ground.

Handling missing data (describe how you will detect and handle missingness in the data)

Infants will be included in the data analysis only if the EEG data is clean and present and if the PCI videos are present for wave 1 and wave 2. Missing data concerning the questionnaires will be handled using maximum likelihood estimation.

Data analysis methods (including statistical design and statistical analysis plan. If it is not possible to provide a detailed statistical plan, as this does not fit in with the research questions formulated above, please explain.)

To test main effects and mediation with the longitudinal data, a three wave cross-lagged panel model (CLPM) will be used (Figure 1). The effects will be calculated using MPlus software.

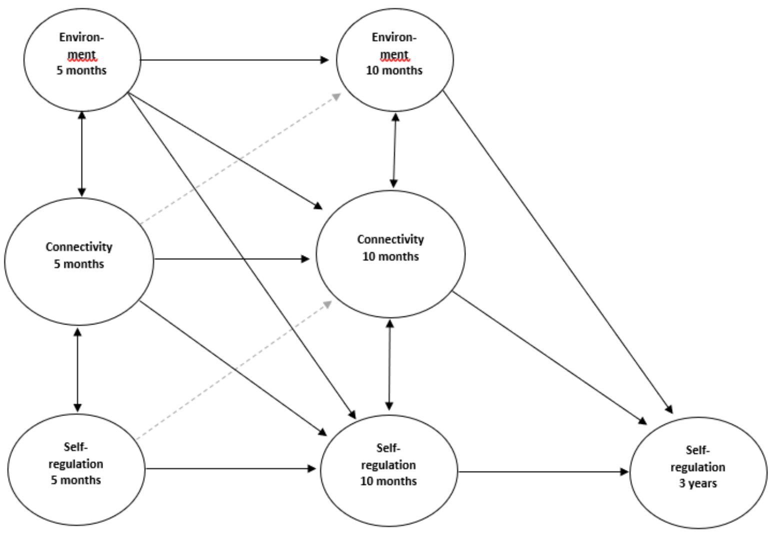

Figure 1. A cross-lagged panel model on the associations between early environmental experiences, functional brain connectivity and the early development of self-regulation

The EEG data is already analyzed by Bauke van der Velde and Chantal Kemner using Matlab, by means of the FieldTrip toolbox (van der Velde, Haartsen, & Kemner, 2019). The original 2048 Hz data has been down sampled to 512 Hz, using chip interpolation and band-pass filtered at 0.1-70 Hz with a two-way Butterworth filter. Artifacts were removed from the continuous EEG. The cleaned data for each subject is bandpass filtered into 6 bands: delta (0.1-3 Hz), theta (3-6 Hz), alpha1 (6 – 9 Hz), alpha2 (9 – 12 Hz), beta (12 – 25 Hz), and gamma (25 – 45 Hz). The resulting data has been cut into 5s. epochs. 20 random epochs are picked per subject per session. For each epoch, connectivity between pairs of electrodes (32*31/2 = 496) are calculated with the phase lag index (PLI) and the debiased weighted PLI, both relying on the same principle of phase locking or phase synchrony (Tass et al., 1998). The resulting PLI can range from 0 to 1. Connectivity matrices are created, with each cell corresponding to the PLI between two electrodes.

Several graph measures are calculated using the acquired individual connectivity matrices. To eliminate the need for arbitrary thresholds, proportional thresholding is performed at 10 different points ranging from 10 percent included until 100 percent included. The following graph measures are calculated for each threshold using the brain connectivity toolbox (Sporns & Rubinov, 2010): global connectivity, average clustering coefficient (Cw), characteristic (average shortest) path length (Lw); and small-worldness index (SWI, calculated as the ratio between normalized Cw and normalized Lw). Both the normalized clustering coefficient and normalized path length are used in this study to overcome the problematic influence of total connectivity on graph characteristics (van den Heuvel et al., 2017). An area under the curve (AUC) is calculated for each characteristic in order to simplify this curve to one value.

A high correlation between the graph characteristics was expected. Therefore, a factor analysis is performed to simplify the neural correlates into one factor explaining most of the variance. This factor will be used in the cross-lagged panel model.
Planned subgroup analyses (if applicable. Substantiate your choices)
Not applicable
Planned sensitivity analyses (if applicable. Substantiate your choices) Sensitivity analyses are analyses that you plan beforehand to test whether certain factors have a major influence on your results.
To examine whether other demographic factors have an influence on the results, sensitivity analyses for age and gender will be conducted.

2. Timeline and milestones (including dates of when to analyze/write up):

Since coding the PCI videos will take a lot of time, we strive for analyzing the data at the beginning of 2020. Subsequently, writing can start at the beginning of 2020 and halfway through 2020. We strive for finishing the paper before November 2020.

3. Output (e.g. article, report, etc.):
Research article

4. Proposed authors + affiliations (please note that the YOUth data access committee can request certain authors to be included):

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