What Are You Looking At?
Using Eye Tracking Glasses to Monitor Toddler Attention in Natural Learning Situations

Nicole Altvater-Mackensen

1. Introduction

Investigating eye gaze offers a window into the learning mind as eye movements are linked to attention and cognitive processing (Yarbus, 1967; Hyönä et al., 2003). Because eye tracking is non-invasive and does not require and overt behavioral response, it is a suitable tool to use with infants and toddlers (for a review on the use of eye tracking in infancy research see Gredebäck et al., 2010). Researchers developed widely applied paradigms in which infants' looking is used to infer the discrimination, categorization or recognition of different stimuli (Michnick Golinkoff et al., 2013; Oakes, 2010). A prominent example in research on language development is the looking while listening procedure (Fernald et al., 2008), in which a child is presented with two images side-by-side of which one is labelled. Measuring how long it takes the child to orient towards the labelled object is taken as a measure of word recognition. Within the different paradigms employed, researchers assume that gaze direction coincides with attention and that it informs us about what children are interested in, what information they pick up, which predictions they make and which expectations they have (for a critical review on the conceptual foundations of preferential looking paradigms see Tafreshi et al., 2014).

Most eye tracking studies to date use remote, stationary eye trackers, providing objective measures of eye gaze in a pre-defined, calibrated space. They mostly present stimulus material such as pictures and videos on screen and monitor infants' eye movements and/or pupil dilation to assess their perception and understanding of these stimuli. This research allows for tight experimental control and provides important insights into the specifics of cognitive processing. However, the controlled set-up comes at a cost: it allows to automatically assess how infants explore a predefined visual space, but gaze mapping is limited to this

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visual space and the child is required to keep a certain distance and angle to the eye tracker to allow automatic detection of the pupil. Also, when the child grabs an object or points at something, gaze might be lost due to the arm occluding the eye tracker. Such constraints restrict the use of remote eye tracking in behavioral research. In addition, studies usually use very controlled – and compared to the real world – reduced stimuli. This might limit the ecological validity of the results obtained (for a detailed discussion see Ladouce et al., 2017). Recent approaches further highlight the embodiment of cognition in development (Laakso, 2011) and the role of social interaction for cognitive processing and learning (Csibra & Gergely, 2009). Against this background, it seems necessary to investigate infants' processing in more naturalistic and complex settings to fully describe and understand the mechanisms and processes of cognitive development.

Yet, recording eye gaze from children in natural situations is a difficult endeavor. While recent developments include eye tracking glasses which allow adult participants to freely move around and interact, the commercially available systems do not fit on an infant or toddler head. Some researchers have turned to small head-mounted cameras (e.g., Smith et al., 2011) to study infant cognition in interaction with objects and people. In this approach, the child's field of view is recorded and from what is visible in the scene, it is inferred what the child is looking at. This research has, for instance, illustrated that children are most likely to learn a novel label when it is uttered at a time when its referent is dominant in the child's view (Yu & Smith, 2012). However, head-mounted cameras do not track the child's gaze. Image processing algorithms allow to automatically detect, e.g., objects of interest and faces in the scene and to calculate their relative (visual) salience. But if several objects (or faces or both) are visible in close proximity, it remains unclear what exactly the child is fixating at a specific point in time. Neither can it be determined at which part of an object or face the child is looking, for instance whether the child is attending to the eyes or the mouth (as, e.g., investigated using stationary eye tracking in Lewkowicz & Hansen-Tift, 2012).

Other researchers have therefore developed mobile eye tracking systems employing similar components as adult eye tracking glasses but attaching them to a light-weight headgear (Franchak et al., 2011). One major challenge, however, remains in these systems: How can we determine that a look falls within a specific area of interest? In screen-based systems, areas of interest can be defined in terms of fixed coordinates because the eye tracker and the screen on which stimuli are presented are stationary. In contrast, the field of view constantly changes in mobile systems due to movement of the participant (or movement of objects/people in the scene). So far, this mapping problem has been solved through manual coding of scene data – an approach similar to the coding of looking data from video cameras that is time- and resource-intensive.

1.1. The current study

In this paper, we present a prototype of mobile eye tracking glasses suitable for toddlers and describe its use in a set-up that allows for automatic coding of gaze data. The eye tracker consists of three cameras: a world view camera, which is fixated centrally and records the toddler's view; and two cameras which each record one of the toddler's eyes. All components are taken from the Pupil Labs Core system (www.pupil-labs.com) and were built into the frame of toddler sunglasses. To solve the mapping problem, we employed apriltags, small black and white codes similar to QR-codes, that were fixated on or near relevant objects in the world. The tags are automatically detected by image processing software and serve as reference points for data analysis. In the following paragraphs, we will present the components and set-up of the eye tracking glasses, as well as basic principles and routines of data acquisition and analysis. Data from an example experiment with 2- to 5-year-olds illustrate data quality and potential pitfalls in data collection.

The first part of the study involved the recording of a shared reading interaction between a narrator and the child. The narrator read out a picture book describing the travel of a microbe through the body, visiting organs such as the lungs and the stomach. The microbe appeared on each page (next to other unfamiliar bacteria) and was labelled with a novel name several times throughout the story. The second part of the study involved a preferential looking task. We presented children with trials in which familiar objects were labelled (such as apple), trials in which unfamiliar bacteria from the book were presented and trials in which the travelling microbe was labelled – either with its correctly or mispronounced name following previous mispronunciation detection tasks (Swingley & Aslin, 2000).

The main aim of the study was to investigate how attention modulates word learning, in particular whether attention during reading predicts how well toddlers remember and recognize the microbe and its name. We are currently finishing data analysis and will report the study and its results in detail elsewhere. Here, we will focus on the eye tracking method. Thus, we do not go into detail on the specifics of the task but describe the experimental set-up and data processing in general using the study to illustrate how we implemented eye tracking glasses for the use with very young children.

2. Method and Materials

2.1. Participants

75 German-learning toddlers (age 27-59 months, M = 45, SD = 8; 41 female) were recruited to take part in a five-minute one-to-one reading session and a subsequent preferential looking task. Children were recruited in four day care centers of a middle-sized city in Western Germany with mid to high socio-economic status. 26 children were reported to be bilingual. Home languages included English, French, Italian, Spanish, Portuguese, Croatian, Russian, Korean and Arabic. German language skills were assessed through short version of standardized language inventories (depending on age: SETK2, Grimm, 2016; and SSV, Grimm, 2017). All children showed age-appropriate receptive German language development with respect to the monolingual norms.

Eye gaze was constantly recorded for 45 children in the reading interaction (age 27-59 months, M = 46, SD = 8; 22 female; 16 bilingual) and for 43 children in the preferential looking task (age 27-57 months, M = 46, SD = 9; 22 female; 13 bilingual). Reasons why children dropped out or provided insufficient eye tracking data are reported in detail in the result section.

2.2. Hardware

We used a mobile set-up and tested children in their day cares. The set-up included the eye tracking glasses, a laptop to run the software that controlled the eye tracker and stimulus presentation in the preferential looking task, a 120 cm by 90 cm canvas screen, a small beamer on a tripod to present stimuli in the preferential looking task, and a (optional) video camera to record the testing (see Figure 1 for a schematic of the set-up). All equipment fits into two small bags and is set-up in a few minutes so that it can easily be carried around and installed where needed.

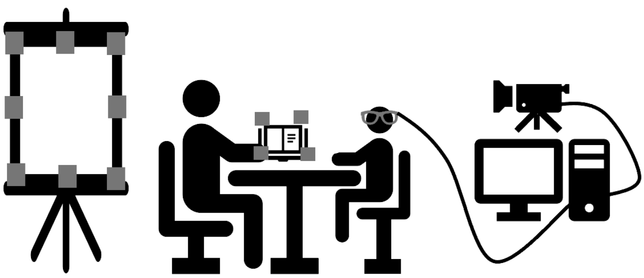

Figure 1: Set-up. Narrator and toddler sitting opposite to each other during reading. The canvas screen is placed behind the narrator, laptop and beamer are placed behind the child. Apriltags (marked in grey) allow to define areas of interest, such as the speaker's face and the book.

Eye tracking glasses are based on the components of the binocular Pupil Labs Core system (Kassner, Patera, & Bulling, 2014). The Core system includes one small HD scene camera with a sampling rate of 30 Hz that captures the field of view, and two small eye cameras with a sampling rate of 200 Hz that record the pupil. The toddler-sized prototype is based on a sunglasses frame. We added a small bar over the bridge to which we attached the scene camera, allowing us to slightly tilt the camera to accurately capture the child's view. Small sliders attached to the sidebars hold the eye cameras. The sliders allow to adjust the distance between eyes and cameras, flexible joints further allow to adjust the camera angle. This helps to position the cameras so that they robustly capture the children's eyes. To reduce bending, cables were taped to rim and sidepieces of the frame. This resulted in lightweight, fun-looking spectacles that fitted most of the toddlers we tested (see Figure 2 for a 3-year-old participant wearing the glasses). The frame was not usable with children that already wore glasses, though. For few of the very young participants (under 3 years), the frame was a bit too large and tended to slide on the nose, resulting in difficulties to robustly track the eyes. We therefore started to prepare frames of different size to be able to flexibly choose the best fitting frame for each child.

Figure 2: Toddler wearing prototype of eye tracking glasses. The front camera captures the toddler's view, the cameras at the sides record the eyes.

Figure 3: Screen shot of the scene camera in the reading interaction. Apriltags used to define areas of interest are visible on the screen and the book. The dashed line marks the book surface. The toddler's current gaze focus is indicated by the black dot.

To allow automatic mapping of gaze coordinates to objects of interest in the real world, we used apriltags, i.e., small black and white codes that can be automatically detected in the scene video (see analysis section for more detail on the mapping procedure). Tags were attached to each corner of the book to define the book surface. Further tags were attached to the canvas screen to define images in the preferential looking task. The tags on the canvas screen were also used to define the narrator's face: Child and narrator were sitting opposite to each other with the screen positioned behind the narrator so that the tags surrounded her head. We used four 9 cm by 9 cm tags on the screen corners and four 6 cm by 6 cm tags on the screen sides. Four smaller 3 cm by 3 cm tags were placed on the book corners (see Figure 3 for an exemplary screen shot of the scene camera in the reading interaction).

2.3. Software

The eye tracker was used with the software PupilCapture. It reads the video streams from the scene camera and the eye cameras to detect the pupils, to track the gaze and to plot gaze points onto the scene view in real-time. Calibration was also performed through PupilCapture. The gaze data was later annotated and exported with the software PupilPlayer. Both PupilCapture and PupilPlayer are open-source software provided by Pupil Labs (for more information see https://docs.pupil-labs.com/core/).

To control stimulus presentation in the preferential looking task we used the experiment builder OpenSesame (Mathôt, Schreij, & Theeuwes, 2012). To process and analyze the eye tracking data we customized scripts in R (R Core Team, 2019).

2.4. Stimuli

In the reading interaction, the narrator read a commercially available 6-page picture book to the children. The book introduces children to the body by means of a microbe that travels to different organs, such as lungs, heart and gut. The book is very colorful, with lots of small details and flaps that can be opened. Next to the microbe, which appears on each double-page, there are lots of other bacteria and body cells presented and children are introduced how they benefit or harm the body.

In the preferential looking task, children were presented with colored drawings of objects on a light-grey background that measured 30 cm by 40 cm on the screen. Objects included six familiar objects, such as apple, as well as four bacteria and the microbe that had appeared in the book. Audio stimuli were recorded by the narrator and included recordings of familiar object labels as well as novel labels for the objects that appeared in the book. Labels were embedded in six different carrier sentences, such as "Siehst Du den Apfel? [Do you see the apple?]" and included correctly pronounced as well as mispronounced labels.

2.5. Procedure

The narrator spent some days in the day care to familiarize with the children before testing. Testing took place throughout the day. Each child was tested individually in a quiet, separate room in the day care. Next to the narrator, an experimenter was present who controlled the experimental set-up. Narrator and child sat opposite of each other with a distance of approximately 50 cm. The narrator first administered the standardized language test. Then she offered to read the book to the child. If the child agreed, the narrator explained that the child would need special spectacles for her travel through the body and put on the eye tracking glasses. The experimenter adjusted scene and eye cameras when necessary and clipped the cable to the child's shirt to prevent cable bending and movement. Then a nine-point real-world calibration was performed using a black-and-white calibration marker printed on cardboard. The narrator held the marker in front of her and in front of all eight apriltags attached to the canvas screen and asked the child to look at the marker. Calibration for each point was repeated until sufficient data was collected for all nine points. Then eye tracking recording was initiated and the narrator read the book to the child. To standardize the reading across children, one narrator read to all children and strictly followed a script. She reacted to children with smiles, nods and short answers to questions, but did not further elaborate on the story. After the reading, the narrator asked if the child wanted to watch a short video. If the child agreed, the narrator sat next to the child and the experimenter started the preferential looking task. In total, 34 trials were presented. Each trial lasted 5000 ms and presented a target and a distractor object side-by-side. The target was labelled half-way through the trial with target label onset starting at 2500 ms. Trials were blocked and pseudorandomized to counterbalance target side as well as familiarity of target and distractor. Each trial was started by the experimenter through button press to ensure that the child attended to the screen at trial onset. After the preferential looking task (or when the child did not want to further participate), the eye tracking recording was stopped, and the narrator took of the spectacles. She thanked the child for participating and escorted him/her back to the group.

2.6. Analysis

Eye gaze data was analyzed with reference to areas of interest in time and space. Using the surface tracker plug-in in PupilPlayer, we defined areas of interest in space based on the apriltags in the scene. The first area of interest defined the book based on the four apriltags attached to its corners. The second area of interest defined the narrator's face based on the apriltags attached to the screen behind the narrator. The third and fourth areas of interest defined left and right image on screen in the preferential looking task. Using the annotation player plug-in, we further inserted key events to mark trial onsets in the preferential looking task. For the reading interaction, we exported information on how many gaze points fell within the book surface, the face surface or somewhere else over the course of the interaction (in number of frames). For the preferential looking task, we exported information on whether a gaze point fell on the right or left image or somewhere else for every time frame over the course of the experiment as well as time stamps of key events marking trial onsets.

For the reading interaction, we calculated the proportion of time that a child spent looking at the narrator, the book or elsewhere to estimate children's attention. We defined overall attention to the reading as the proportion of time that children spend looking either at the book or the narrator (number of time frames with gaze points on book or narrator divided by total number of time frames with gaze points in the reading interaction). For the preferential looking task, we aligned gaze information with trial information and calculated for every trial how much time children spend looking at either the target image, the distractor image or somewhere else throughout the trial. We defined overall attention to the preferential looking task as the proportion of time that children spend looking at an image (number of time frames with gaze points on left or right image divided by total number of time frames with gaze points in a trial). We further calculated the increase in proportion of target looking (number of time frames with gaze points on target image divided by number of time frames with gaze points on either image) after target labelling as a measure of word recognition.

3. Results and Discussion

3.1. Dropout

From 75 children that were originally recruited, 45 children provided data for the reading interaction and 43 children provided data for the preferential looking task. This results in a relatively high drop-out rate of approximately 40% of children. Note, however, that the current study was conducted to test and pilot the set-up. Indeed, dropout rates decreased from 66% in the first 15 children to 26% in the last 15 children tested (see Figure 4).

Dropouts can be attributed to child-related criteria or technical criteria. 12 children provided insufficient data because of bad calibration (3), failure to track apriltags in the scene video (4), or other technical errors, such as failure to record (3), no sound (1) or the laptop crashing (1). Fifteen children could not be included because they refused to participate (5) or were not willing to wear the glasses (10). Two additional children only provided data for the reading interaction but were unwilling to participate in the preferential looking task. Three children were excluded from the study because they knew the book. Taken together, there is a relatively high number of 10 children who refused to wear the eye tracking glasses (or could not wear the spectacles because they already wore glasses), a dropout that is rather specific to our set-up. Otherwise, however, exclusion seems comparable to preferential looking studies with toddlers of similar age that used screen-based systems. In a recent meta-analysis Von Holzen and Bergmann (2019) report dropout rates ranging from 0% (Bailey & Plunkett, 2002) to 69% (Swingley, 2016) in mispronunciation detection studies with one- to four-year-olds using the preferential looking paradigm.

To estimate data loss for the children included in the analysis, we binned the raw gaze data and down-sampled tracking rate to 30 Hz, matching the sampling rate of the scene camera. This resulted in a data set with hardly any data loss (i.e., the number of time frames with recorded gaze points matched the number of time frames per child and task), most probably because the eye cameras had a more than six times higher tracking rate.

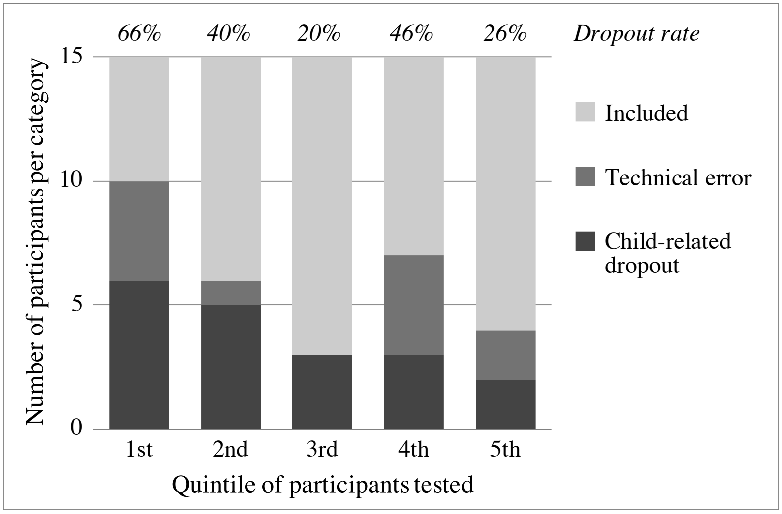

Figure 4: Overview of dropout rate and children included, children excluded due to child-related criteria and children excluded due to technical criteria split by participant quintile.

3.2. Reading interaction

Eye gaze was analyzed for 45 children in the reading interaction. The length of individual reading interactions ranged from 173 to 356 seconds (M = 201, SD = 31). In general children were quite attentive: they fixated on average two-third of the time either the book or the narrator (M = 63%, SD = 25; range 9 – 99; see Figure 5). This suggests to us that the experimental set-up with the spectacles did not distract children from the shared book reading and that the set-up is in principle suitable to capture natural interactions.

3.3. Preferential Looking Task

Eye gaze was analyzed for 43 children in the preferential looking task. Again, children were generally very attentive: in 3 out of 4 trials gaze data was registered on either target or distractor image for more than 90% of time frames (M = 82%, SD = 15; range 3 – 96; Figure 6). The data further shows a robust increase in proportion of target looking after labelling for familiar objects ($t(42) = 4.9499$, $p < .01$). This suggests that the set-up is suitable to assess word recognition using the preferential looking paradigm.

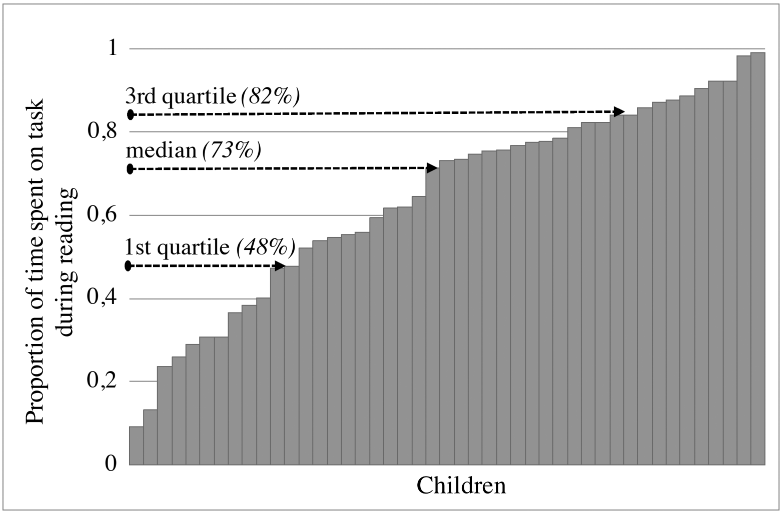

Figure 5: Distribution of attention in the reading interaction across the 45 children included in the analysis.

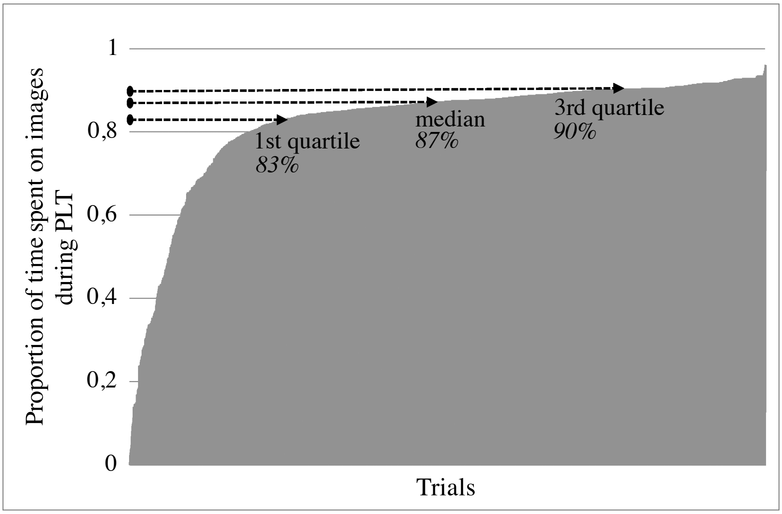

Figure 6: Distribution of attention in the preferential looking task (PLT) across all 1445 trials contributed by the 43 children included in the analysis.

3.4. Potential pitfalls

As stated above, we found the set-up suitable to record toddler eye gaze in the natural reading interaction as well as in the more standardized screen-based preferential looking task. Nevertheless, we identified a number of potential pitfalls during testing. First, a relatively high number of toddlers refused to participate or to wear the glasses. Higher dropout rates at the beginning of studies might (at least in part) be due to experimenters needing to gain routine (cf. Hessels & Hoogte, 2019; van der Velde & Junge, 2020). Thus, initial training of experimenters and thinking of an appropriate cover story to make the spectacles attractive to wear for children might help to reduce dropout considerably.

Second, some children did not provide sufficient data because apriltags could not be detected in the scene video. In general, it seems advisable to use several tags per area of interest to increase the chance that at least one tag remains clearly visible and can be used as anchor point for surface definition. Also, tags should not be too small and lightning conditions should be controlled to facilitate detection. Further, warped tags are not recognized so it helps to fixate tags on flat, stable surfaces that the scene camera captures from a frontal angle.

Third, when the frame was not fitting optimally, children tended to peek above the rim. This made it difficult to track children's eye gaze as the scene camera was not capturing the child's field of view. Data quality also suffered because children were more likely to touch the glasses when they felt them sliding on their nose. Thus, it seems worth the effort to prepare frames of different sizes to which the components of the eye tracker can be attached to be able to flexibly chose a well-fitting frame based on the child's head size.

3.5. Conclusion

We built a prototype of eye tracking glasses suitable to test toddlers and very young children. The glasses are lightweight and easy to use so that they provide a useful mean to study children out of the laboratory, e.g., in day care settings. Data quality appears to be comparable to screen-based systems. In our experience, calibration and tracking of eye gaze tended to be more robust with the glasses than with screen-based system: movement affects gaze tracking less than with stationary systems because children do not have to keep a stable position. This seems useful not only for testing in natural situations, but potentially also for experimental settings in which toddlers might have difficulties to sit still.

Data analysis, however, is less straight-forward than in screen-based systems. While the mapping problem can be solved through the use of tags that are automatically detected in the scene video, it requires some preparation (and piloting) in terms of tag placement. Also, experience with and scripts for analyzing raw eye tracking data are essential to extract and process the relevant information from the data stream. However, analysis based on tags seems an efficient way to assess real-world looking behavior in developmental studies. It neither requires training of algorithms to detect objects of interest in the scene (as reported by, e.g., Smith et al., 2011) nor does it involve time-consuming hand-annotation of the video stream (as described in, e.g., Franchak et al., 2011). This might make it easier to implement for researchers with restricted resources and limited computational expertise who are willing to accept a potential trade-off in accuracy.

To conclude, we presented a flexible approach to assess very young children's looking behavior. We hope that others will find it useful and that it will encourage developmental researchers to think about ways to move their experimental set-ups out of the laboratory.

References

Bailey, Todd M., & Plunkett, Kim (2002). Phonological specificity in early words. *Cognitive Development*, 17, 1265-1282. doi: org/10.1016/S0885-2014(02)00116-8

Fernald, Anne, Zangl, Renate, Luz Portillo, Ana, & Marchman, Virgina A. (2008). Looking while listening: using eye movements to monitor spoken language comprehension by infants and young children. In: Sekerina, I.A., Fernandez, E.M., & Clahsen, H., *Developmental Psycholinguistics: On-line methods in children's language processing*, pp. 97-135. Amsterdam: John Benjamins.

Franchak, John M., Kretch, Kari S., Soska, Kasey C., & Adolph, Karen, E. (2011). Head-mounted eye tracking: a new method to describe infant looking. *Child Development, 82,* 1738-1750. doi: 10.1111/j.1467-8624.2011.01670.x

Csibra, Gergely, & Gergely, György (2009). Natural pedagogy. *Trends in Cognitive Sciences, 13,* 148-153. doi: 10.1016/j.tics.2009.01.005

Gredebäck, Gustaf, Johnson, Scott, & Von Hofsten, Claas (2010). Eye tracking in infancy research. *Developmental Neuropsychology, 35,* 1-19. doi: 10.1080/87565640903325758

Grimm, Hannelore (2016). *SETK-2: Sprachentwicklungstest für zweijährige Kinder [Language assessment for 2-year-olds].* Göttingen: Hogrefe.

Grimm, Hannelore (2017). *SSV: Sprachscreening für das Vorschulalter [Language screening for preschoolers].* Göttingen: Hogrefe.

Hessels, Roy S., & Hooge, Ignace T.C. (2019). Eye tracking in developmental cognitive neuroscience–The good, the bad and the ugly. *Developmental Cognitive Neuroscience*, *40*, 100710. doi: 10.1016/j.dcn.2019.100710

Hyönä, J., Radach, R., & Deubel, H. (2003). *The mind's eye: cognitive and applied aspects of eye movement research*. Amsterdam: Elsevier. doi: 10.1016/B978-0-444-51020-4.X5000-2

Kassner, Moritz, Patera, William, & Bulling, Andreas (2014). Pupil: an open source platform for pervasive eye tracking and mobile gaze-based interaction. *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication,* pp. 1151-1160. New York, NY, USA: ACM. doi: 10.1145/2638728.2641695

Laakso, Aarre (2011). Embodiment and development in cognitive science. *Cognition, Brain, Behavior, 15,* 409-425.

Lewkowicz, David J. & Hansen-Tift, Amy M. (2012). Infants deploy selective attention to the mouth of a talking face when learning speech. *Proceedings of the National Academy of Sciences, 109,* 1431-1436. doi: 10.1073/pnas.1114783109

Mathôt, Sebastiaan, Schreij, Daniel, & Theeuwes, Jan (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. *Behavior Research Methods* 44, 314-324. doi:10.3758/s13428-011-0168-7

Michnick Golinkoff, Roberta, Ma, Weiyi, Song, Lulu, & Hirsh-Pasek, Kathy (2013). Twenty-five years using the intermodal preferential looking paradigm to study language acquisition: What have we learned? *Perspectives on Psychological Science, 8,* 316-339.

Oakes, Lisa, M. (2010). Using habituation of looking time to assess mental processes in infancy. *Journal of Cognition and Development, 11,* 255-268.

R Core Team (2019). R: A language and environment for statistical computing. Vienna, Austria: R Foudation for Statistical Computing. https://www.R-project.org/

Smith, Linda B., Yu, Chen, & Pereira, Alfredo F. (2011). Not your mother's view: the dynamics of toddler visual experience. *Developmental Science, 14,* 9-17. doi: 10.1111/j.1467-7687.2009.00947.x

Swingley, Daniel (2016). Two-year-olds interpret novel phonological neighbors as familiar words. *Developmental Psychology*, 52, 1011-1023. doi: 10.1037/dev0000114

Swingley, Daniel, & Aslin, Richard N. (2000). Spoken word recognition and lexical representation in very young children. *Cognition, 76,* 147-166. doi: 10.1016/S0010-0277(00)00081-0

Tafreshi, Donna, Thompson, Joseph, J., & Racine, Timothy P. (2014). An analysis of the conceptual foundations of the infant preferential looking paradigm. *Human Development, 57,* 222-240.

Van der Velde, Bauke, & Junge, Caroline (2020). Limiting data loss in infant EEG: putting hunches to the test. *Developmental Cognitive Neuroscience*, *45*, 100809. doi: 10.1016/j.dcn.2020.100809

Von Holzen, Katie, & Bergmann, Christina (2019). The development of infants‘ responses to mispronunciations: A meta-analysis. Preprint doi: 10.31234/osf.io/dze29

Yarbus, Alfred L. (1967). Eye Movements During Perception of Complex Objects. In: Eye Movements and Vision, pp. 171-211. Boston, MA: Springer. doi: 10.1007/978-1-4899-5379-7_8

Yu, Chen & Smith, Linda B. (2012). Embodied attention and word learning by toddlers. *Cognition, 125,* 244-262. doi: 10.1016/j.cognition.2012.06.016

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