Using Pupil Labs' Neon eye-tracking module for infants aged 3 to 24 months

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Video demonstrations:
https://youtu.be/ldanZW603Fs - https://youtu.be/vj5wvd1JuIk - https://youtu.be/4lynIBO4ydA

***Abstract*—While most studies analyzing infant visual attention use methods varying from annotations of videos from head-mounted cameras [1], [2], [4], [5] to fixed screen-based eye-tracking setups [6], [7], [8], [9], [10], increasing interest has been shown towards solutions that would pair the precision of eye-tracking with the free mobility offered by video annotation. This would allow infant research to gather high-quality visual attention data in naturalistic situations, which might yield results more representative of real-world infant environments [11]. For this purpose, various forms of portable eye-tracking devices have been developed and used to study infant cognition [3], [12], [13], [14], along with frequently time-consuming infant-adapted calibration procedures. Recently, the advent of calibration-free lightweight wearable eye-tracking systems developed by Pupil Labs© is offering new and simpler ways to study infant visual attention with the advantages of deep-learning calibration and miniaturization. However, despite a wide variety of wearing accessories being offered by the company, no suitable option currently exists for infants younger than 2 years old. In this paper, instructions will be provided to build a new wearing accessory for Pupil Labs' Neon eye-tracking module adapted to 3 to 24 months-old infants, along with usage instructions.**

Keywords*—*infant research, eye-tracking, Pupil Labs, Neon, calibration-free eye-tracking

I. Introduction

This document provides a series of instructions on how to make and use an accessory meant to facilitate the usage of Pupil Labs' Neon eye-tracking module with infants aged 3 to 24 months. This eye-tracking module is particularly useful in the context of infant development research, as it is lightweight and miniaturised, and uses a deep-learning powered calibration which automatically adapts to its user — avoiding time-consuming calibration processes which might be difficult for infants to complete. In the initial phases of our experimentation with this tool, we tested various ways of using Pupil Labs' official child-adapted frames designed for children aged 2 and older. However, due to their size and shape, we were not successful in adapting these to infant users. This led to the development of a new wearing accessory aimed towards infant wearers, which we have successfully been using to gather eye-tracking data from infants aged 3 to 24 months. We currently have an acceptance rate of #% using this tool in laboratory conditions, and #% in nurseries. Among the acceptance group #% have been excluded from our study due to infants removing the accessory or due to badly a positioned module preventing an accurate calibration. In our entire sample of infants tested, we currently have a #% inclusion rate.

II. Making the Accessory

A. Materials

- A wide flat elastic band.
  Here we used a 40mm-wide elastic band for sewing, generally used for tightening waistbands.
- Adhesive hook and loop (Velcro) strip tape.
  35mm-wide.
- A plastic adjustment buckle.
- A 3D printed receptacle for the Neon eye-tracking module[1], adapted from Pupil Labs' open source "Just act natural" frame geometry[2].
- A piece of thick and soft fabric to smooth out the plastic edges.
- Pupil Labs' Bare metal bundle: Neon eye-tracking module + Nest PCB + Android device[3].

B. Assembly

Cut a 60cm-long piece of the elastic band and sew 3 pieces of the rough (hook) side of the hook and loop strip tape (see fig.1).

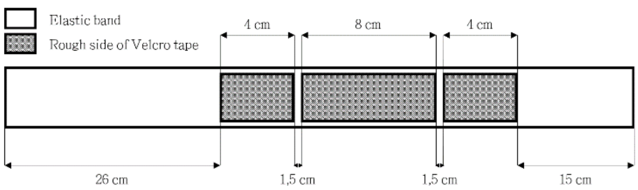


Figure 1: Headband illustration with elastic band and hook and loop strip tape dimensions.

Insert both edges of the elastic band in the adjustment buckle and sew one of the edges in a closed loop.

Cut a thin strip of the adhesive hook and loop tape, stick both sides together and form a loop around the side of the buckle. This will be used to assure the Neon eye-tracking module's wire remains towards the back of the infant's head so as not to distract them.

1 - https://github.com/JerJoss/InfantEyeTrackingHeadband/blob/main/Custom_Neon_Module_receptacle.STL
2 - https://github.com/pupil-labs/neon-geometry
3 - https://pupil-labs.com/products/neon/shop#bare-metal

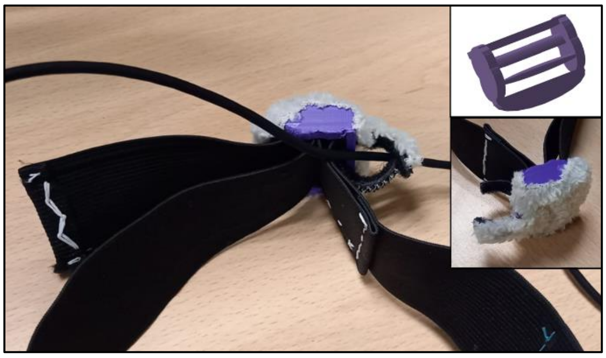


Figure 5: Picture of the buckle at the back of the headband.

Glue a piece of the thick soft fabric over the buckle and the wire loop. This will make these surfaces softer in case of contact with the infant's skin, and will decrease other problems such as the plastic or loop getting caught in the fabric of the parents' clothing when the infant sit on the parent's lap (see fig.2).

Glue a piece of the thick soft fabric on the upper front section of the 3D printed module receptacle, along with some optional decorations. And glue a piece of the soft (loop) side of the hook and loop strip tape on the upper back section of the receptacle.

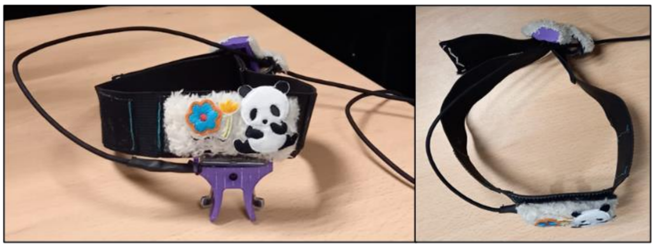
Screw the nest PCB inside the receptacle. Optionally, strengthen the base of the wire with a heat-shrink sleeve and small wire. This was added after an infant pulled on the wire, breaking the soldering connecting it to the nest PCB (see fig.3).

Figure 3: Picture of the 3D-printed eye-tracking module receptacle, to be attached to the front of the headband using Velcro, along with a nest PCB.

Screw the Neon eye-tracking module on the nest PCB and into the 3D-printed receptacle (see fig.4).

Figure 4: Picture of the 3D-printed eye-tracking module receptacle, to be attached to the front of the headband using Velcro, along with a Neon eye-tracking module.

The final result should look like figure 5, with the receptacle fixed to the front of the headband using the hook and loop surfaces, and the wire going through the back loop.



III. Procedure

During our studies, the infant is seated on their parent's lap, facing the experimenter. The infant is given a plush-toy meant to reassure and to distract its attention while the experimenter fits the headband and the eye-tracking module on its head. If possible, a second experimenter is present to play with the infant during procedure.

After a short moment of playing and engaging with the infant, the first experiment takes the elastic headband without the eye-tracking module, and approximately adjusts its circumference to be slightly wider than the infant's head's. At this stage, if the infant is showing more curiosity towards

Figure 2: Picture of the fully assembled headband.

the headband than towards the plush-toy, it is encouraged to manipulate and familiarize itself with it. The experimenter then carefully slips the headband on the infant's head, with the buckle to the back of the head and the rough (hook) side of the hook and loop strip tape to the front. The headband should run through the middle of the infant's forehead. Ideally, any adjustments to its position should be done at this point while the eye-tracking module is not yet attached. If necessary, the experimenter then tightens the headband by pulling on the elastic extending out of the buckle. The playing and engaging with the infant can then resume until the infant seems comfortable wearing the headband.

The next step will to be to attach the eye-tracking module to the infant's headband. Before starting, the eye-tracking module should be connected to the Android device and have been detected by the Neon Companion App. Inside the app, enable the sensor module camera view and position the Android device in a location that will be visually accessible while attaching the eye-tracking module to the infant's headband (i.e. the parent's chair's armrest). Lastly, open the small loop next to the buckle and close it around the eye-tracking module's wire, leaving just the right length for the module to reach the infant's forehead. This will ensure that the wire won't disturb the infant, or distract him by entering in its field of vision.

At this point, the eye-tracking module should be held above the infant's head. The main or the second experimenter should then attempt to catch the infant's attention. Whenever the infant's head appears to be still, the

Figure 6: ***Below:*** *Infants sitting on their parent's lap, wearing a Pupil Labs' Neon eye-tracking module attached to a headband during a study. Ages from left to right: 9 months, 9 months, 6 months.* ***Above:*** *visual feedback provided live from the sensor module camera view via the Neon Companion App.*

main experimenter swiftly attaches the eye-tracking module receptacle to the hook and loop surface on the headband. The sensor module camera view from the Neon Companion App should be visible during this process, and be used as a positioning guide for the experimenter. Once positioned, both eyes should be visible in the feedback (see fig.6). Ideally, the eyes should be well centered along the vertical axis of the visual feedback (as in the left and central examples of fig.6). In the correct position, the module receptacle nose pads should hover above the nose.

Once the position is correct, the recording can be started from the Neon Companion App.

IV. Limitations

A. Module positioning

One of the main challenges of this approach to using Pupil Labs' Neon eye-tracking module with infants, is the labile nature of the module's positioning. The reason behind this 2-step approach (first fitting the empty headband, then attaching the module), was that it greatly increased the acceptance rate with infants compared to our initial attempts with the module pre-attached to the headband. It does however have the downside of requiring a certain amount training before the experimenter can correctly position the module in most trials. In most cases, if the module positioning takes a bit of time, or is attempted more than once or twice to correct a wrong initial position, the infant will get distraught and refuse wearing the module altogether. A second version of the headband meant to simplify this process is currently being developed.

B. Infant reactions

During the recording, some infants will also attempt to touch the module, either to remove it or from simple curiosity. If the action seems to stem from simple curiosity, and the infant does not seem upset, the experimenter might gently push the infant's hand away from the module.

Occasionally, parents also will also spontaneously grab their infant's hands to prevent them from moving the module (see fig.6, right example). However, if the infant does seem upset while attempting to remove the module, the experimenter helps to remove it and stops the recording.

C. Infant movements

During the recording, the infant might make sudden movements that, though unrelated to the module, may vertically shift the position of the headband and the module. This might occur if, for instance, the child leans backwards and the buckle gets pushed against the parent's clothing. In these cases, the infant will often become bothered by the module's movement, and the calibration will no longer be valid. In this case, the experimenter removes the headband and ends the recording.

D. Data accuracy

So far, this headband system is the best and only way we have found to use Pupil Labs' Neon eye-tracker with infants. However, the headband does not precisely reproduce the optimal module position relative to the user's eyes that actual Pupil Labs' frames implement. Therefore, though we have been able to extract analyzable gaze data with this method, the accuracy of the data is somewhat varying and dependent the precision of each particular module positioning. We have particularly noticed what seems to be a lateral shift occasionally affect the gaze points. This entails that each recording needs to be rated for accuracy and included or excluded on that basis. In the study for which this method was developed, a subjective rating of each main camera and sensor module videos was used to decide whether the module was sufficiently well-positioned for the data to be included. However, any future studies should ideally include a more robust process of calibration confirmation and gaze shift measurement.

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