Development of Facial Recognition Algorithm in Infants

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Abstract

Humans recognize a face as a special kind of object. We don't recognize a book as a face, nor vice versa. The algorithm behind this develops over the lifetime, especially during infancy. Infants' preference for faces is influenced both by the visibility of the stimuli and by their resemblance to a human face. However, as they grow, infants' preferences will once be solely influenced by the attraction toward faces and then again be influenced by the resemblance of the face. In addition, the preferential tracking of faces declines between 4 and 6 weeks after birth.

Keywords: face recognition, algorithm, infants development

1. Introduction

How do you know that a laptop you are looking at right now is not a face? Why do you even need to know if it is a face or not?

We need to be able to recognize faces since faces include a lot of crucial information. For instance, we live in a place where emotion is an absolute component, and this world is based on one's emotions. People always make sure that others are not feeling uncomfortable, angry, or sad; recognizing others' emotions is one form of caring for others. This very basic ability- the recognition of faces- is inherited from birth. However, the algorithm behind facial recognition changes across development as well.

Face recognition is special in two ways. First, unlike other objects, infants develop their ability to recognize faces at an early age, even right after they are born. In the experiment done by Goren CC, Sarty M, and Wu PY(1975), newborns who were tested as soon after as possible turned their heads and tracked the face stimuli the most, compared to other stimuli including moderately scrambled face, scrambled face, and blank stimuli (figure 1). This result shows that not only newborns are already able to distinguish face stimuli from other stimuli but also they are able to track face-like stimuli, which indicates that the ability to recognize and track face-like stimuli is inherited from birth.

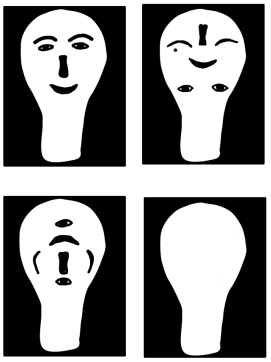


Fig 1. The stimuli: face (top left), moderately scrambled face (top right), scrambled face (bottom left), and blank (bottom right)Goren CC, Sarty M, Wu PY, 1975

Secondly, face recognition and object recognition appear to use different systems in the brain (Farah, M. J., 1996). The experiment that used subjects with prosopagnosia, a neurological disorder characterized by the inability to recognize faces, showed that they are better at recognizing and distinguishing two different objects than two different faces. These results support "the existence of functional specialization for face representation" and that we possess these specialized systems to recognize faces (Farah, M. J., 1996). These two pieces of evidence support the idea

that face recognition is different from regular object recognition, and it emerges when we are really young, which in most cases is when we are newborns.

Now, if we have the ability to recognize faces from birth, does that algorithm never changes and newborns recognize faces as we recognize faces? The answer is no. The algorithm controlling face recognition might be different in newborns than in older infants. One of the possible reasons we have different algorithms is that younger infants have poor eyesight, contrast sensitivity, and ability to resolve the high spatial frequencies so they find it difficult to focus on small details such as parts of the faces (i.e. nose, mouth, eyes). Newborns have trouble focusing, and are only able to see very close; but within a week, the baby can focus on objects about 8 to 10 inches from his face (*Infant Vision Birth to One Year*, n.d.). For instance, few-day-old infants effectively rely on low spatial frequency (LSF) rather than high spatial frequency (HSF) bands to recognize faces (Simion F, et al, 2007). Here, LSF corresponds to the overall features such as shapes, whereas HSF corresponds to specific features such as sharp edges. This result shows how younger infants prefer recognizing faces based on coarse information instead of specific information, which supports the claim of how younger infants' poor eyesight might hinder them from using specific details in terms of face recognition.

Morton and Johnson (1991) introduced two separate mechanisms in terms of face recognition during infancy: CONSPEC and CONLERN. CONSPEC, according to them, is "some knowledge concerning the visual structure of the human face that infants are born with." This mechanism guides infants to pay attention to faces over objects, which helps researchers to understand if infants recognize faces or not by measuring the fixation time for each stimulus. CONLERN, on the other hand, is a learning mechanism that learns about the characteristics of faces as infants focus a lot on them (Morton and Johnson, 1991). Through this CONLERN infants develop their facial recognition algorithm and are more accurate at recognizing faces. As for face recognition, we will examine the algorithm infants use and develop over their infancy (newborn - 12 months).

2. **Face-like configurations**

Many studies showed that newborns prefer face-like stimuli over non-face-like stimuli. (figure 2) (Goren et al., 1975; Johnson et al., 1990) Moreover, Valenza et al. (1996) showed that they are also able to distinguish between

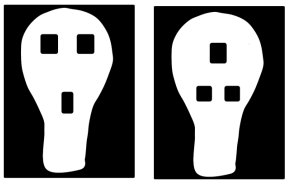


Figure 2. (Valenza et al., 1996)
Face-like stimuli (right) and non face-like stimuli (left)

configurations of face-like stimuli and non-face-like stimuli. Here, the procedure was the same for every study. Infants were sat on the experimenter's lap and the stimulus was held by the experimenters around 20cm in front of the infants' faces. Either the mean fixation time or the mean degree of rotation was measured. In every study, results strongly supported the hypothesis that newborns are already able to recognize both regular and config face-like stimuli as a face. However, this ability to track a configuration of face-like stimuli significantly decreases between 4-6 weeks old (Johnson et al., 1990). Johnson et al. (1990) did an experiment measuring the mean degree of rotation of newborns, 3-month-olds, and 5-month-old infants using four stimuli: Face, Config, Linear, and Scrambled (figure 3). The result showed that infants and newborns will track a schematic face further than they will track stimuli with non-face-like stimuli (Johnson et al., 1990).
On the other hand, 3- and 5-month-old infants didn't show

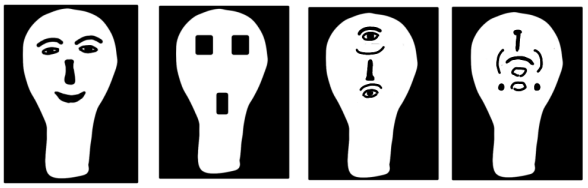


Figure 3. Johnson et al., 1990

any preference for the four stimuli. In addition, when they subdivided their 1-month-old group into an "older" and "younger" group, the graph showed that while the younger group followed the face-like stimuli significantly further than the other stimuli, the older group did not show any difference between the four stimuli. These entire results suggest that the preferential tracking of faces declines between 4 and 6 weeks after birth. A similar result of fixation data for habituation and test phases can be seen in the study with 8-month-old infants done by Schwarzer and Zauner (2003). After the habituation to two faces presented sequentially as photos, 8-month-old infants dishabituate to the faces if the eyes or mouth have been exchanged. However, when the same experiment with drawings was done, this dishabituation only happened when the mouth was switched from the habituated face that was shown in pictures. In other words, they did not recognize the difference between drawings that they were habituated to and the stimuli that possess different features besides the mouth. (Schwarzer, G., & Zauner, N, 2003) Here, based on these results, one interesting conclusion can be drawn. 8-month-old infants are able to process "single facial features such as the eyes and mouth in conjunction with the context of the face when the faces were shown as photos i.e., they processed the faces as a configuration", but when drawings were presented, infants only processed mouth

together with the context of the face, not other parts. (Schwarzer, G., & Zauner, N, 2003). Even though the drawings of Schwarzer & Zauner's study is more detailed than Johnson et al. (1990) study, these two studies' conclusions indicate that even when infants become 8-month-olds, they still struggle to recognize face-like stimuli that are represented as drawings as an actual face.

3. Possible Explanation

Now, there are a few possibilities of how infants' ability to recognize configurations of face-like stimuli significantly declines; improvement of eyesight, and preference toward upper-heavy configuration. As we have already mentioned, newborns have very poor eyesight, and it improves as they grow. At six weeks of age, which is when infants' ability to recognize the configuration of face-like stimuli decreases, they are able to see up to 12 inches in front of them, while newborns are only able to see blurry shapes as they are nearsighted (*Infant Vision Birth to One Year*, n.d.). There is a possibility that newborns can't recognize face-like configurations as faces, but they are only able to distinguish face-like and non-face-like stimuli so vaguely that for them, pictures of the face and drawings of the face are the same thing. Then, when infants start being able to see things more clearly, they can distinguish between pictures and drawings, which will hinder them from recognizing only the drawings. If this is the case, the ability to recognize config might not decline between 4 and 6 weeks of age, but humans acquire it as we grow older.

Another possibility is that newborns recognize config as a face because it has more elements in the upper part compared to a blank paper or a scrambled face. One study showed that newborns prefer a non-face-like stimulus with more elements in the upper part over a non-face-like stimulus with more elements in the lower part (Turati et al., 2002). If this is true, as mentioned in the first hypothesis as well, infants might not innate ability to recognize config, and they just tracked the face-like stimuli because they preferred stimuli that contained more elements in the upper part over stimuli that contained fewer. However, this hypothesis will contradict the finding of Farroni et al. (2005). In their study, infants preferred upright schematic faces only under positive polarity conditions (i.e., black internal features against a white head shape background) (Farroni et al., 2005). If the second hypothesis of preference of the upper part for newborns is true, this result will not make sense as they sometimes looked longer at lower part heavy stimulus when it is in negative polar condition (i.e., white internal features against a black head shape background). Therefore, even if newborns' preference for upper-heavy configuration is true, that will not be an explanation for the subsequent decline of the ability to track face-like configuration between 4 to 6 weeks of age. Moreover, for both of the hypotheses, regardless of what the explanation is, that will not mean newborns cannot recognize faces since in both of the cases, no matter what the reason is, studies show that newborns can track face-like stimuli.

4. Inner and Outer Features

Another common aspect of face recognition that newborns possess is face recognition based on the outer and inner features of the face. Here, the inner feature means the parts of a face (i.e., nose, mouth, eyes) and the outer feature means the hair and shape of a face. Even though the ability to recognize faces is solely based on both inner and outer features inherited from birth, outer features have an advantage. This is supported by a study done by Turati et al. (2006); in their first experiment, newborns' ability to discriminate and recognize familiar faces based on 1) full-face condition, 2) inner features condition, and 3) outer features condition was examined using the habituation paradigm. The data showed that newborns are able to recognize faces solely based on information from inner and outer features (Turati et al., 2006). Despite this result, their next experiment, in which newborns were habituated with full-face and tested with only a portion of such a face and vice versa, showed that newborns failed to recognize the familiar face "when the presence versus absence of the outer features was manipulated between the habituation and the test phase in the inner features condition" (Turati et al., 2006). In other words, while in the first experiment newborns were able to recognize faces solely based on inner and outer features, they failed to use inner features as a cue to recognize full-face and vice versa. These two data show that even though an ability to recognize faces based on both inner and outer features of the face is innate, the outer features predominate over inner features in face recognition.

This is also proven by the study that measured the infants' looking time at their mother and the stranger with a scarf attached under the chin. In this experiment, while infants were able to discriminate between strangers' and their mothers' faces when they are not wearing a scarf, their visual preference for their mother disappeared when the hair and the outer contour of the mother's head were hidden (Pascalis et al., 2008). This result also suggests how newborns recognize their mother's face based on their outer features, instead of inner features.

However, this predominance of outer features will gradually fade as infants grow (Maurer & Barrera, 1981; Maurer & Salapatek, 1976; Blass & Camp, 2004). One study showed that 2-month-olds could not only identify scrambled face stimuli from a natural stimulus but could also

distinguish between two different scrambled stimuli (Maurer & Barrera, 1981). Here, the same study showed that 1-month-old infants cannot discriminate natural from scrambled arrangements as they rarely use inner features when they recognize faces. These two data illustrate how at least 1-month-old infants still rely on outer features to recognize faces, but at one point, before becoming 2-month-olds, they switch to relying on inner features. In addition, another study reported that 2-month-olds were more likely than 1-month-olds to fixate on the inside of the face, especially the eyes (Maurer & Salapatek, 1976). This also shows how between 1- and 2 months of age, infants start focusing more on inner features than outer features. This does not mean the ability to recognize faces based on the outer feature disappeared, according to Blass and Camp (2004). Based on their experiments, when 8- to 19-week-old infants encounter a new face, they are able to learn and identify the face based on both inner and outer features. Overall, these data show 1) newborns have the ability to recognize faces based on inner and outer features, but they rely more on outer features, and 2) between 1 and 2 months of age, their algorithm of face recognition changes, and they become able to recognize faces solely based on inner features as well.

We can conclude the same from some studies that examined newborns' preference between a face with phase information and amplitude information (Valenza et al., 2007; Mondloch et al., 1999). In Mondloch et al. (1999) experiment, they investigated the visual preference of newborns, 6-week-olds, and 12-week-old infants between a stimulus with the phase spectrum of a face but the amplitude spectrum of a lattice and a stimulus with the amplitude spectrum of a face but the phase spectrum of a lattice. The phase spectrum contains the pattern of the face while the amplitude spectrum contains the contrast sensitivity, which gives more overall information about the face. The data showed that while newborns preferred a stimulus with the amplitude of the face, 6- and 12-week-old infants preferred a stimulus with the phase of the face. This indicates that newborns use overall information instead of facial inner pattern to recognize faces, but as they grow and become 6-week-old of age, they start focusing more on the inner feature of the face. This finding is consistent with the other findings.

Therefore, it is evident that newborns innate ability to recognize faces based on both inner and outer features, but they prefer to focus more on outer features; as they grow and become around 2 months of age, their algorithm develops and they will start looking more at inner features in order to recognize a face.

5. Other Algorithms

Besides the basic algorithms that are innate to recognize faces, there are other algorithms that develop over infancy. One of them is the positive contrast versus the negative contrast. Here, face stimuli with positive contrast have black inner/outer features (i.e., eyes, nose, mouth) with a white face, while stimuli with negative contrast have white inner/outer features with black faces. Mondolch et al. study reported that while newborns and 6-week-olds don't have a preference between positive and negative contrast, 12-week-olds may have difficulty recognizing a negative-contrast face as adults do (Mondolch et al., 1999). This indicates that while newborns and 6-month-olds don't distinguish faces based on the contrast of the faces, 12-month-olds and older rely on shading when processing the shape of a face. Moreover, Farroni et al. reported newborns' "lack of preference for the upright configuration in the negative polarity condition" (Farroni et al., 2005). Even though newborns fixated longer to the upright configuration than to the inverse configuration in the positive polarity condition, the preference reversed in the negative polarity condition. This shows that newborns only recognize face-like configurations in the positive polarity; when the stimulus is in negative polarity, even if it's the schematic face, they cannot recognize it as a face. The contradiction between Farroni et al. study and Mondolch et al. study may be explained by the difference between the stimuli they used in each experiment; while Farroni et al. used a very simple schematic face (two blobs for eyes and one blob for a mouth), Mondolch et al. used more detailed schematic face (i.e., hair, nose, eyebrows). For newborns, because of their poor eyesight, they might rely on shading only when the configurations are too simple that they need other features to recognize a face. No matter the reason for the contradiction, it is evident that at some point during infancy, newborns start using shading as an element for face recognition.

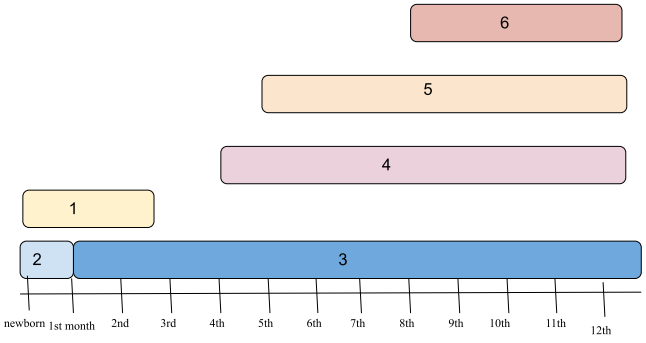
Another algorithm is the orientation of the face. Newborns and younger infants are only able to distinguish individuals based on front- and three-quarter-view faces (Turati et al., 2006; Kelly et al., 2009). However, as infants grow, between 5 and 8 months of age, they start to acquire the ability to recognize faces even when they can only see a part of them. (Cohen & Strauss, 1979; Nakato et al., 2009). Cohen and Strauss's (1979) study supports this by carrying out experiments using infants 18, 24, and 30 weeks of age. Using 12 stimuli -four 3/4-side orientations with three expressions- with a habituation paradigm, the ability to learn conceptual categories was examined. The result of this study showed that at 30 weeks of age, "infants can acquire a variety of categories ranging from a particular orientation of a face

to a particular face regardless of orientation, to face (or at least female faces) in general." In other words, 30-week-old infants are able to recognize and acquire information from the face regardless of orientation. On the other hand, 18 and 24 weeks infants responded similarly in all conditions, which indicates that they are still not able to distinguish faces based on the information they gained from faces with different orientations.

Terms of recognition of faces in profile based on the information acquired from the front or three-quarter view is not found in newborns (Turati et al., 2008), but it is found in 12-month-old infants (Roes, Jankowski, & Feldman, 2002). This shows that at one point, probably as infants grow older, they acquire an algorithm to recognize profile of faces based on the information that they already have; the front or three-quarter view.

6. Data Table

The following table shows the algorithm for facial recognition in infants. As the table shows, the ability to recognize configs and distinguish faces based on both inner and outer features but mainly on inner features is innate, and that algorithm will gradually fade at around 1 to 3 months of age. Infants will acquire some of the ability including relying on shading and they become able to recognize faces regardless of orientation at 8 months of age.



1; configuration of eyes and a mouth
2; Inner and Outer features, but mainly **outer**
3: inner and outer features, mainly in **inner**
4; shading
5; inner feature movement
6; regardless of orientation

(Figure 6) this figure shows the development of facial recognition algorithm over the infancy

7. Conclusion

The evidence reviewed here suggests that algorithms for facial recognition are both innate and developed. Throughout infancy, we gained, and sometimes lost, algorithms to be able to fully recognize human faces. While there are a lot of algorithms that infants acquire through development, two of the main algorithms that change over time are recognition of inner and outer features of the faces and recognition of face-like configurations. The predominance of inner and outer features switches around the first month, and the ability to recognize configs as faces decreases at around 4 to 6 weeks after birth. These algorithms are crucial in our everyday life as our society builds on human emotions; we always make sure everyone is happy and satisfied through their facial expression and to do that, we first need to recognize faces.

As infants grow older, they begin gaining new algorithms that will further help their ability to recognize faces- around 4 months of age, they start relying on shading, at 5th months, inner feature movements, and at 8th months, they are able to recognize faces regardless of the orientation and angle. How and why they acquire new algorithms during infancy is still unclear. Some of the studies reported the newborns' preference for top-heavy stimuli, and that is the reason for them to track face-like stimuli. However, as this contradicts some of the other studies, we believe it might be because of the improvement in their eyesight. Newborns are only able to see things blurry, while as they grow, their eyesight significantly improves. Interestingly, the time when infants become able to look at least 20cm away vividly overlaps with the time when infants stop tracking configs. This supports the possibility of the lack of ability to track config in the first place, but newborns were tracking the config because they are only able to see things blurry and they thought the config is an actual face. If this is the case, we propose an experiment that uses glasses to blur older infants' eyesight in order to create the same condition as newborns' eyesight, to see if older infants recognize config as a face if they can only see it blurry.

If this is not the right explanation, however, what will be another possibility for gaining new algorithms? The most common and simple answer will be "experience". We see, hear, and learn a lot of things every day, and through that knowledge that infants gained, their brains might create a new algorithm for facial recognition in order to make facial recognition more smooth and easy. For example, for infants and toddlers, one of the most crucial parts of their life is the emotions of their parents. Especially for toddlers, doing something fun but try not to get mad at their mother is their mission in their everyday life. In order to understand their mothers' emotions, they need to recognize faces under any circumstances. This urgency of recognizing faces might develop and improve the facial recognition algorithm.

As they grow further, appealingly, the cultural difference will show up in the algorithm of facial recognition. One study reported that Japanese adults tend to focus more on the eyes to percept emotion while Dutch adults tend to focus more on the shape of a mouth (Yamamoto et al., 2020). This result shows even though

people all recognize faces based on inner features and their movement, there is a cultural difference in which inner part they use to understand others' emotions. This might be because at some point people start focusing more on either one's eyes or a mouth to recognize a face, depending on their cultural background. However, the time period human algorithms of facial recognition start getting affected by the environment they live in is still unclear. Future research about toddlers' and adults' algorithms of facial recognition could help find the exact time period.

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