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Perceptual Narrowing in Face Processing: Reviewing the Factors Influencing its Onset and Offset

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Abstract: An infant's face- and speech-processing system develops during the first year from broad and non-specific to becoming a system that is tuned to the faces and languages to which they are most exposed. This phenomenon is called perceptual narrowing. Before 9 months of age, infants are capable of discriminating and recognizing individuals from any type of race/species faces. However, with increased exposure to own-race and own-species faces and lack of exposure to other types of faces, by 9 months of age, they have improved their ability to discriminate own-race faces, while they show increased difficulty in the discrimination of faces from other races and species. According to the literature, we can conclude that, by 12 months of age, most human perceptual systems have become perceptually tuned and adult-like; however, this is not true. In the following sections, we will argue that perceptual narrowing for faces occurs during the same developmental period as it does for language, and that it can be prevented or modulated with sufficient exposure to unfamiliar sounds or face types. We conclude that narrowing has been designed by natural selection to tailor an individual's cognition to their local social context. It might occur for every domain pertaining to social communication—from speech processing to emotion or gesture perception—in a process that gradually adapts the infant to their native social group.

Key words: face, infant, perceptual narrowing.

As Europeans, the authors may find it difficult to hear the difference between the Japanese words 箸 (*baguette*) and 橋 (*pont*): both of which are perceived as “Hashi.” Moreover, they may be less efficient in recognizing Japanese faces as compared to European faces. This phenomenon is linked to our face- and speech-processing system, which develops during the first year from broad and non-specific to becoming a system that is tuned to the faces and languages to which

infants are most exposed. It is called perceptual narrowing or perceptual attunement.

Perceptual narrowing in face processing has first been observed at individual face recognition. Six- to nine-month-old infants recognize individual faces from any species and from their own race and another race. However, with increased exposure to human and own-race faces and lack of exposure to other types of faces, from 10 months of age, infants have improved their ability to discriminate own-race

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faces, while they show increased difficulty in the discrimination of faces from other races and species (Kelly et al., 2007; Pascalis et al., 2002; Simpson et al., 2014; for a meta-analysis, see Sugden & Marquis, 2017).

Interestingly, perceptual narrowing affects other aspects of face processing beyond recognition. First, increased expertise with only one category of faces has an impact on infants' face visual scanning (Wheeler et al., 2011; W. S. Xiao et al., 2013). Contrary to 6-month-olds, 9-month-old infants look longer to the eye region when observing own-race faces compared to other-race faces (Wheeler et al., 2011).

Additionally, in a recent cross-cultural study, Haensel et al. (2020) showed that infants brought up in Japan exhibit a differential exploration of faces compared to infants brought up in England, reflecting that cultural and linguistic background can also influence infants' perceptual narrowing to the faces and type of interactions in their environment.

Second, perceptual narrowing also influences how young infants categorize in- and out-group faces (Quinn et al., 2016). In their study Quinn et al. (2016) showed that before the onset of perceptual narrowing, 6-month-old Caucasian infants categorize both in-group (own-race) and out-group (other-race) faces in a similar manner, based on facial physiognomy (e.g., skin tone, features' shapes). This categorization is irrespective of the social component in- or out-group (see also Anzures et al., 2010). However, after perceptual narrowing, Caucasian 9-month-olds categorize in-group (own-race) faces as a single in-group category. In contrast, they categorize Asian and African faces as a broader "out-group" category. In other words, they no longer rely only on perceptual differences (e.g., skin color) between different other-race faces to categorize them, but they also consider their social component/value. This transition to a more mature conceptualization of in- versus out-grouping may reflect the infant's representation of the "others," which evolves from separate perceptual representations of face (age, gender, race) and the language they speak (native,

foreign) to an integrated and multimodal representation of conspecifics.

Can Face Perceptual Narrowing be Modulated or Even Overcome?

When reading the literature on perceptual narrowing, we can mistakenly conclude that, by 12 months of age, most human perceptual systems have become perceptually tuned and adult-like. However, this is of course not the case. In the following sections, we will review several factors, such as language and facial expressions, that have been shown to modulate infants' face perceptual narrowing.

Language

In real life, infants are rarely exposed to static and silent faces, or to speech without the face that produces it. Instead, they mainly perceive talking faces. This prompts the following question: Does the language spoken by a face influence infants' ability to process and learn that face?

Historically, perceptual narrowing has first been studied in the case of language acquisition. At birth, newborns show broadly based, universal speech perception abilities. For instance, they show discrimination sensitivity to speech sound differences that belong to their native language (Dehaene-Lambertz & Gliga, 2004) and to a certain number of non-native speech contrasts, to which the young infant has never been exposed (Eimas et al., 1971; Streeter, 1976; Trehub, 1976; Werker & Tees, 1984, 1999). Then, during their first year, two processes develop in parallel. First, infants' ability to discriminate non-native phoneme contrasts—those irrelevant to their native language(s)—weakens considerably, while their native phoneme discrimination improves. Second, by 12 months, infants get perceptually attuned to most of the phonemes of their native language(s) (Kuhl, 2004; and see Singh et al., 2022, for a review). Importantly, this phenomenon is driven by infants' specific language experience: If infants are exposed to non-native speech sounds through repeated social

interactions with a speaker of that non-native language, they maintain their ability to discriminate such non-native contrast (Kuhl et al., 2003). In a similar vein, infants growing up in dual- (or multi-) language environments become concomitantly sensitive to the phonemic contrasts of all their languages (Byers-Heinlein & Fennell, 2014). Moreover, such increased phonetic variation inherent in bilingual environments elicits infants to maintain their sensitivity to non-native contrasts—those not used in either of their native languages—for a slightly longer period of time, and to follow different developmental patterns of perceptual specialization in both of their languages than do monolingual infants (Byers-Heinlein & Fennell, 2014; Singh et al., 2017; Singh et al., 2022; Singh & Tan, 2021). In sum, these studies suggest that an infant's phonetic system undergoes a perceptual narrowing during the first year of life, which allows them to optimize the processing of their native-language (s) sounds, while narrowing the perception of non-native speech sounds. This process is modulated by their language experience(s) (e.g., exposure to a foreign language, bilingualism) and is considered as an important cornerstone for later language development as it has cascading effects on lexical segmentation and word learning (Tsao et al., 2004).

If both face and language development undergo the same phenomenon, that is, perceptual narrowing, do they interact during development? First, two studies suggest that this is indeed the case. They showed that from 9 months of age, perceptual narrowing scores for individual face recognition (own vs. other) and language (native vs. non-native phonemes) are correlated (Krasotkina et al., 2018; N. G. Xiao et al., 2018). For instance, N. G. Xiao et al. (2018) found that these scores were negatively correlated at 9 months, and positively correlated at 12 months. This suggests that perceptual narrowing for language and face interact with each other in different ways as a function of age and experience. The negative correlation at 9 months could mean that they initially compete with one another, due to limited attentional resources. Conversely, at

12 months, with increased attentional resources, the positive correlation suggests that later on they facilitate each other. The stimulation of one system would lead to the stimulation of the other (see Pascalis et al., 2020, for more details).

Recently, two additional studies focused on the impact of language familiarity (i.e., native French or a non-native language, German) on how Caucasian French-learning 9- and 12-month-olds memorize own-race faces (Hillairet de Boisferon et al., 2021) and other-race faces (Clerc et al., 2022). These studies showed that infants could recognize the face of an own-race speaker only if she spoke in their native language and, surprisingly, they could recognize the face of the other-race speaker only when she spoke the non-native language. Thus, they showed that at least from 9 months of age, infants have developed coherent cross-modal representations of how face and language features are associated in their daily environment.

Bilingualism

If face and language systems interact during their sensitive period, we can ask whether exposure to a bilingual environment, instead of a monolingual one, influences how individuals pay attention to and recognize human faces.

Studies in adults have been found to influence face processing (Baus et al., 2017; Kandel et al., 2016). For instance, Kandel et al. (2016) conducted a study in bilinguals suggesting that bilingualism influences face recognition. With the use of a classical other-race effect (ORE) paradigm, they found that bilingual adults exhibit a weaker ORE than their monolingual peers. This finding suggests that exposure to more than one language leads, at least in adulthood, to a specific perceptual organization that goes beyond language processing and extends to the analysis of faces, and that such experience can reduce the ORE (see also Burns et al., 2019).

In infants, prior studies also suggest that dual-language experience modulates the way they attend to and process human faces. For instance, bilingual infants exhibit an enhanced attention to faces—among other objects—

compared to monolingual infants (Mercure et al., 2018), as well as a differential visual exploration of the internal features of faces. That is, bilingual infants deploy greater attention to a talker's mouth than do their monolingual peers, in both speech (Birulés et al., 2018; Pons et al., 2015) and non-speech situations (Ayneto & Sebastian-Galles, 2017; Fort et al., 2018). However, do these different attention patterns imply a differential processing of faces (i.e., of their indexical cues, such as a talker's face and voice properties) in bilingual infants?

Regarding the association of a speaker's face and voice, evidence suggests that bilingual children and adults outperform monolinguals at identifying face-voice pairings (Levi, 2018; Orena et al., 2019). This has also been shown in infants, as 9-month-old bilinguals but not monolinguals could detect a change in a face-voice pairing in an unfamiliar language (Fecher & Johnson, 2019).

Additionally, previous studies also show differences in the processing of other-race faces as a function of linguistic background. Studies by Singh and collaborators showed that, in contrast to monolingual infants, bilingual infants are not influenced by the race of a face (own vs. other race) when processing gaze direction or when processing correctly pronounced versus mispronounced labels (Singh et al., 2019; Singh et al., 2020).

If faces are often associated with the language they speak, it is likely that they are also associated with the label provided by the caregiver (e.g., "Say Hi to Olivier").

Labelling

Several studies have focused on the role of labelling/naming individuals in perceptual narrowing. The most familiar individuals (in-group) encountered by an infant are labeled with individual names (e.g., Joan, Mathilde), whereas the most novel individuals (out-group) might either be labeled by category (e.g., Chinese, woman) or just not labeled. When parents of Caucasian infants were provided with picture books of individually named Asian faces and they were asked

to present those faces to their infants starting at 6 months, the infants were able to differentiate among Asian faces at 9 months of age (Heron-Delaney et al., 2011). The same was observed for monkey faces (Pascalis et al., 2005). Interestingly, however, others (Scott & Monesson, 2009) have shown that using category labels (monkey) instead of individual names in the same paradigm hampered infants' face discrimination. As infants are still going through narrowing, these results showed that it was not just an increase of familiarization that was responsible for the effect.

As previously demonstrated in the case of language, it is also possible to reverse narrowing of faces after it has occurred. When parents of Caucasian infants were given videos of Asian women introducing themselves to show to their infants, 2–3 weeks of daily exposure to the videos were sufficient to restore infant ability to differentiate among Asian faces (Anzures et al., 2012). These findings suggest that the recognition portion of the perceptual bias that favors own-race faces can be prevented or undone by providing sufficient experience with the other race.

However, in all of those studies, the faces used always exhibited a neutral expression. Could this be a limitation?

Facial Expressions

In adults, angry other-race faces improve recognition of those faces (Ackerman et al., 2006): Whereas White participants have difficulty recognizing neutral Black faces, they have no difficulty doing so when the faces display angry expressions. Moreover, developmental evidence indicates that both angry and happy facial expressions facilitate own-race face recognition in infants (Gross & Schwarzer, 2010; Turati et al., 2011). Crucially, others have shown that when other-race faces were presented with either a negative (angry) or positive (happy) expression, perceptual narrowing was not observed, as infants older than 9 months of age could still recognize other-race faces (Quinn et al., 2020).

Increased Experience of Other-Species Faces

Using an in-lab setting, Fair et al. (2012) investigated if longer familiarization time with monkey faces in a classic visual paired-comparison task would prevent perceptual narrowing in infants at 12 months of age. They found that doubling the familiarization time allowed infants to succeed in discriminating other species' faces. However, the duration of this effect remains unknown. Could 24-month-olds be sensitive to the longer familiarization time, or could they behave in the same way as primatologists who see monkeys daily and are unable to recognize individual faces (as found by Dufour & Petit, 2010)? The latter possibility would reflect the fact that at some point in development, reversing perceptual narrowing is no longer possible (Dufour & Petit, 2010). In the next section, we explore whether face perceptual narrowing can be reverted/modulated by natural experience (i.e., induced by naturalistic everyday experience with real faces rather than in-lab induced artificial experience). This question is important, as naturalistic and in-lab approaches estimating attention and exposure to faces in infancy can yield different results (see Birulés et al., 2023, for a review).

Natural Experience

Tham et al. (2019) investigated the development of the ORE in face recognition in 4- and 9-month-old Chinese infants from Kuala Lumpur (Malaysia) a multiracial city where people are exposed to Malay, Chinese, and Indian faces on a daily basis. Malaysian infants tested were exposed to both female and male faces, both from own-race (Chinese) and other-race faces (Malay). The first important result is that 4-month-old infants only recognized own-race female faces, probably due to their increased experience with own-race female rather than male faces. Surprisingly, after perceptual narrowing, at 9 months of age, infants could recognize both own-race and other-race female faces, suggesting that their experience with other-race female faces was sufficient to overcome their perceptual narrowing for this category of faces.

Interestingly, they did not find evidence of own-race or other-race male face recognition in either age group. This finding contrasts with the literature of 9-month-olds exposed to single-race populations who are able to recognize both female and male own-race faces (Tham et al., 2015; see also Quinn et al., 2019, for more discussion on the effect of gender on infant face processing). Thus, similar to the findings in infants exposed to two languages, early exposure to two categories of faces (i.e., a multi-racial environment) allowed infants to process and recognize other-race faces after narrowing had happened.

McKone et al. (2019) were interested in whether infant narrowing prevented the learning of other-race faces at a later age, during childhood or adolescence. They investigated this question by comparing adults who had different levels of experience with other-race faces during their primary school years. McKone et al. (2019) found that a reduced ORE correlated with the amount of exposure time to other-race faces. It is important to note that a reduction of the ORE is found only if this contact occurs before 12 years of age. If adults are exposed to other-race faces even for a long period (up to 5 years), they still have difficulties recognizing them. From these results we can conclude that the perceptual narrowing is not permanent and can be modulated by experience until 12 years of age.

Similarly, Sangrigoli et al. (2005) showed that South Korean adults who had been adopted by white families in France during their childhood (between the ages of 3 and 9 years) showed a reversed ORE in adulthood. That is, they were better at recognizing faces from their adoptive parents' type than from their own type, likely resulting from their extensive exposure to other-race faces during development. Those individuals had completely lost their native language. De Heering et al. (2010) also tested the ORE in 6–14-year-old Asian children who had been adopted between 2 and 26 months by white families. They found comparable recognition memory for white and Asian faces as compared to age-matched white children, who showed an own-race advantage. It will be

interesting to find out if the ability to process White faces in the adopted children increases with their experience.

Wan et al. (2015) found that White adults raised in Australia and Asian adults raised in their native country exhibited a reliable ORE, whereas ORE was not present in Asian adults who went to school in Australia (Wan et al., 2015). More recently, a study done in Toronto—a city with a large Asian community—compared own- and other-race face recognition in three groups of participants: one of White individuals, and two groups of Asian individuals. Of these two, half were born and schooled in Canada, and the other half were born in an Asian country where there was no exposure to White faces, and had arrived in Canada during their childhood, so they had had experience with other-race faces at an older age. As expected, a robust ORE was found in the participants who had low experience with other-race faces, but the individuals who had been exposed to both types of faces from an early age showed no ORE. This study also revealed that the age of arrival in Canada positively predicted the magnitude of the ORE, supporting the idea of a sensitive period, like in McKone et al. (2019).

Conclusions

We have argued that perceptual narrowing for faces occurs during the same developmental period as it does for language, and that it can be prevented or modulated with sufficient early exposure to unfamiliar sounds or face types. There is thus consensus regarding the existence of the perceptual narrowing phenomenon, but the question of why it occurs remains unanswered. From a functional perspective, it may be that it has been selected by evolution. Narrowing is indeed not restricted to humans. An influential study by Sugita (2008) illustrated the critical role of experience in the development of face processing in macaques. Infant Japanese macaques, separated from their parents at birth and reared by humans in a faceless environment for a minimal period of 6–

24 months showed a preference for both monkey and human faces over objects, but no preference for either category of faces when tested in a visual preference task. Furthermore, they were able to recognize both monkey and human faces. Following the face-deprivation period, half of the monkeys were introduced to macaques, and the other half to humans. When tested following a minimum of 1 month of exposure to faces, monkeys exposed to human faces displayed a preference for human faces over objects, and also for human over monkey faces. They displayed no preference between monkey faces and objects. Consistent with this pattern of results, monkeys exposed to monkey faces preferred monkey faces over objects and over human faces, but showed no preference when human faces and objects were presented simultaneously. Furthermore, when tested for recognition, monkeys were only able to recognize faces from the category to which they were exposed. This indicates that Japanese macaques do not display a hard-wired preference for their own species, but rather develop an experience-dependent preference.

These results help gain a more nuanced insight on the existing knowledge of infants' development, suggesting that each domain, face and language, follows a different perceptual specialization and narrowing trajectory, generally following the classic patterns from general to specific. However, the results from Hillairet de Boisferon et al. (2021) and Clerc et al. (2022) show the importance of associations between faces and spoken language, as well as the importance of the congruence of these associations. The interaction between face and language narrowing and processing during development is evidence of the relationship between the different communication systems in humans as stated by Pascalis et al. (2014). Pascalis et al. (2014) hypothesized that face and language processing have been selected by evolution to allow individuals to adapt the system to their local social context as fast as possible via their cognitive–communication systems. Narrowing will then occur not only in face processing but in every domain pertaining to social communication, such as speech

processing or emotion categorization. Narrowing can then be understood as a process that rapidly adapts the infants to their native social group during the first 2 years after birth. Being able to smile like your parents, to have the same accent when speaking, and to have the same communication rules is important for a better bonding between the caretakers and the child, leading perhaps to better care and increasing the chance of survival. The narrowing of each communication ability might interact with others, helping to better adapt to the group.

In this context, it would be interesting to examine the impact of language on face processing. So far, studies have shown that infants have developed coherent cross-modal representations of how face and language features are associated, but we do not yet know the degree to which these modalities influence each other. Discovering whether language can modify categorical representations based on observed face types would help us learn more about perceptual narrowing.

As stated above, narrowing is highly influenced and modulated by multiple factors from an infant's early experience. The results presented in the Bilingualism section indicate that exposure to a multiracial (different types of faces) or multilingual (different languages) environment can reduce ORE in adulthood and enables infants to process and recognize the faces of other races after the age of 9 months. Thus, it might be interesting to ask whether similar results could be obtained in the categorization of face in- and out-group members. Will hearing native or non-native language modulate an in- or out-group categorization of own- or other-race faces? These behavioral studies should be followed by implicit quantifiable measures, such as fast periodic visual stimulation, which elicits periodic responses that can be recorded from the electroencephalogram and can be objectively compared across development, and test for evidence of interactions between face and speech processing in the context of the in- and out-group categorization. The results from such research will increase our understanding of the

developmental trajectory of perceptual narrowing for different domains (face and language) that can be useful to understanding when and how we could intervene to prevent the loss of perceptual sensitivity to categories of stimuli that we think will be important in later development. Moreover, the results could lead to the development of new educational practices to reduce ORE in mono-ethnic and mono-lingual environments.

Conflict of Interest

The authors declare no conflicts of interest associated with this manuscript.

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