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Do infants discriminate non-linguistic vocal expressions of positive emotions?

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Abstract

Adults are highly proficient in understanding emotional signals from both facial and vocal cues, including when communicating across cultural boundaries. However, the developmental origin of this ability is poorly understood, and in particular, little is known about the ontogeny of differentiation of signals with the same valence. The studies reported here employed a habituation paradigm to test whether preverbal infants discriminate between non-linguistic vocal expressions of relief and triumph. Infants as young as 6 months who had habituated to relief or triumph showed significant discrimination of relief and triumph tokens at test (i.e. greater recovery to the unhabituated stimulus type), when exposed to tokens from a single individual (Study 1). Infants habituated to expressions from multiple individuals showed less consistent discrimination in that consistent discrimination was only found when infants were habituated to relief tokens (Study 2). Further, infants tested with tokens from individuals from different cultures showed dishabituation only when habituated to relief tokens and only at 10–12 months (Study 3). These findings suggest that discrimination between positive emotional expressions develops early and is modulated by learning. Further, infants' categorical representations of emotional expressions, like those of speech sounds, are influenced by speaker-specific information.

Keywords

Infant discrimination; positive emotion; vocalisations; cross-cultural differences

Introduction

Infants' developing ability to discriminate emotional expressions has been a topic of considerable research in the past few decades (e.g. Grossman, 2010; Walker-Andrews, 1997). Most research has focused on infants' perception of facial expressions and/or emotional content within the prosodic characteristics of spoken language (Hoel & Striano, 2010; Montague & Walker-Andrews, 2002; Singh, Morgan, & Best, 2002; Walker-Andrews, Krogh-Jespersen, Mayhew, & Coffield, 2011). This work has shown that by 6–7 months,

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infants show consistent discrimination of positive and negative emotional content, with a preference for positive emotional stimuli (Singh et al., 2002; Walker-Andrews, 1986), and less robust abilities before this age (Fernald, 1993; Montague & Walker-Andrews, 2002). Brain-imaging work supports the idea that the ability to perceive emotion develops early, during a period in which rapid language development also occurs (Blasi et al., 2011; Grossman, Oberecker, Koch, & Friederici, 2010).

Auditory perception may be privileged over visual perception early in development (Bugental, Kaswan, Love, & Fox, 1970; Flom & Bahrick, 2007; Vaish & Striano, 2004), but the ontogeny of processing auditory emotional information is still poorly understood (Grossman & Johnson, 2007). Previous research has largely viewed vocal emotional expression as being a paralinguistic feature of spoken language. However, auditory expressions of emotion can occur in the absence of clear linguistic expressions. It is well established that adults and children from five years of age can infer a range of emotional states from non-linguistic vocalisations, such as screams, laughs, and sighs (Sauter, Eisner, Calder, & Scott, 2010; Sauter, Panattoni, & Happe, 2013; Sauter & Scott, 2007). In addition to negative states including fear, disgust, and sadness, children and adults can recognise positive emotions from non-linguistic sounds (Sauter et al., 2013). Most obviously, laughter can signal a state of amusement. Adults and children also judge non-linguistic cheers as communicating triumph, and some sighs are perceived as expressing relief (Sauter et al., 2013). Listeners judge vocalisations as more triumphant when the sounds are characterised by high mean pitch, a low minimum pitch, and substantial spectral variation, while sounds are perceived as more relieved when they have a high mean pitch as well as a high spectral centre of gravity, as well as substantial spectral variation (Sauter, Eisner, Calder, et al., 2010).

Within the domain of positive emotions, different kinds of expressions vary with respect to how universal they are across cultures. A cross-cultural study examining the expression and recognition of non-linguistic vocalisations has found that relief appears to be expressed in similar ways across cultures (Sauter, Eisner, Ekman, & Scott, 2010). In contrast, the ways in which triumph is communicated using non-linguistic vocalisations varies across cultures; while some cheer or whoop, others ululate or chant (Sauter, Eisner, Ekman, et al., 2010). Nevertheless, some acoustic features may be shared, and recognition across cultural groups is sometimes possible: Vocalisations of triumph by Western and non-Western individuals have high pitch and rapid pitch modulations, which allow Western participants to infer triumph from non-Western vocalisations (Sauter, Eisner, Ekman, et al., 2010). If adults show some degree of cross-cultural recognition of these features, young infants may as well. In this article, we examine infants' discrimination of non-linguistic emotional vocal expressions within and across cultures.

To our knowledge, only one study has examined infants' perception of non-linguistic vocal expressions. Zieber, Kangas, Hock, and Bhatt (2014) found that 6-month-old infants could match happy and angry non-linguistic expressions with associated body movements. This suggests that positive and negative emotional information are discriminable from each other, and furthermore that their expressions across different modalities are on some level recognised by infants as being related. It is noteworthy that much of the existing research on

infant discrimination of emotional expressions has specifically compared positive and negative emotions. However, adults and young children are also able to discriminate expressions of the same valence from another, and five-year-olds have been found to differentiate non-linguistic vocalisations of several positive emotions—specifically, amusement, contentment, relief and triumph (Sauter et al., 2013). In the current study, we examined infants' ability to discriminate non-linguistic vocal expressions of positive emotions, namely those of relief and triumph.

Using a habituation paradigm in which the auditory stimulus was paired with a checkerboard display, we ask the following questions across three experiments: Do infants discriminate between expressions of relief and triumph, and if so, when does this discrimination emerge (Experiment 1)? How robust is this discrimination—that is, does this ability extend to discrimination across multiple voices within a given cultural group (Experiment 2)? Does this ability extend to discrimination across multiple voices when habituated with one cultural group and tested on another (Experiment 3)?

Experiment 1

Infants were habituated to instances of a single person non-linguistically expressing either relief or triumph, and were then tested on new exemplars from the same voice expressing relief and triumph in separate test trials. If infants discriminate between the two emotional expressions, and associate the test exemplars from the familiar emotion category with the habituated tokens, they should show greater dishabituation to the test items from the novel emotion category. Infants who were habituated to relief should thus show greater attention to triumph samples and vice versa.

Method

As per journal policy, we report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study, for all three experiments.

Participants.—Participants were 16 infants aged 3 months (96–128 days, $M = 113$ days, $SD = 11.7$, 8M/8F), 16 infants aged 6 months (159–202 days, $M = 182$ days, $SD = 11.3$, 6M/10F), and 32 infants aged 8 months (241–292 days, $M = 263$ days, $SD = 12.5$, 14M/18F), recruited from the Providence, RI area. Of these, the majority were Caucasian, with 2 participants identified by their parents as Black, 3 as Hispanic, 2 Asian and 10 unidentified. Only the two Asian participants were reported as having more than 20% language input other than English (1 participant reported 40% Mongolian and the other 50% Twi). An additional 37 participants (12 3-month-olds, 11 6-month-olds, and 14 8-month-olds) were tested but not included in the sample due to fussiness or looking judged to be uncodeable (14), preterm birth (1), technical difficulties (5), and failure to show increased looking during a post-test trial compared with the habituation (17). The 8-month-olds were tested first, and a smaller sample was collected for the younger two age ranges due to limits on access to participants.

Stimuli.—The stimuli were taken from a published set of non-linguistic vocal expressions of emotions (Sauter & Scott, 2007), which have been shown to be well recognised as

communicating the intended emotional states by adult listeners (Sauter, Eisner, Ekman, et al., 2010; Sauter & Scott, 2007). Vocalisations were produced by an adult male native British English speaker. Note that the speaker's cultural community is not identical to that of the test infants, but (for adults) the effect of culture for closely related groups is small (Sauter & Scott, 2007). Relief sounds consisted of sighs, and triumph sounds were non-linguistic cheers. Vocalisations from the speaker were selected because he provided a good variety both within and across the two categories with respect to length and general features of the non-linguistic expressions. Two instances of triumph and four instances of relief were excluded either because they were deemed not representative of the category, and/or they were too short/quiet. This left 13 instances of triumph and 12 instances of relief. For each category, one instance was selected to be the test item for that category and was not heard during the habituation phase. Given differences in onset amplitude between instances, sample amplitudes were modified to ensure that all tokens were heard clearly during the testing. See Table 1 for acoustic details regarding the stimuli (see Sauter, Eisner, Calder, et al., 2010 for full details on stimulus production and validation, including the calculations of amplitude onsets per sound).

Procedure.—The infant was seated on their parent's lap in a testing booth facing a single screen. Each trial was initiated with a flashing yellow circle to capture the infant's attention. When the infant was oriented forward, a checkerboard pattern appeared, and the audio began to play. During habituation, audio stimuli comprised instances of a particular emotion. For the relief group, this consisted of the habituation relief tokens described above, presented in random order within each trial, with a 500 ms interstimulus interval between tokens. For the triumph group, this consisted of the habituation triumph tokens presented in similar fashion. Each trial lasted for 15 s or until the infant looked away for 2 consecutive seconds. Look-away times that were shorter than 2 s did not result in ending the trial, but were excluded from the infant's looking time for a given trial. Habituation was calculated by a floating window of three trials, and consisted of a decrease to 65% of initial looking times. A minimum of six habituation trials were administered, with the final three trials providing a habituation baseline for comparison with the test trials. A maximum of 20 habituation trials was allowed, at which point the test trials were given even if the habituation criterion had not been reached. One 3-month-old and two 8-month-olds failed to reach the habituation criterion (all from the triumph group). See supplemental data for analyses excluding these participants.

There was one "same" test trial and one "different" test trial (as described above), presented in random order together with the same checkerboard pattern as during habituation. Following this, a single post-test trial was given, consisting of a female from upstate New York producing the word "leek". Infants whose looking time on this post-test trial was not higher than the average of the test trials were excluded from the analysis, as reported above. Infant looking times were coded online via mouse press by an experimenter in an adjacent room viewing the infant over a closed-circuit video system. The experimenter was blind to the group (relief or triumph) of the infant being tested and to whether a given test trial was a "same" or "different" trial.

Results and discussion

Habituation.—All three age groups showed significant decreases in looking time across the habituation phase (Table 2 and Figure 1). There were no group-related main effects or interactions in habituation looking times, and there were no significant differences in the number of trials to habituate. For the 3-month-olds, the mean number of habituation trials for the relief group was 7.9, whereas for the triumph group it was 11.9 trials, $t(14) = 2.08$, $p = .056$. For the 6-month-olds, the mean number of habituation trials for the relief group was 10.1 trials, and 10.5 trials for the triumph group, $t(14) = -0.209$, $p = .838$. For the 8-month-olds, the mean number of habituation trials for the relief group was 11.3, and 11.8 trials for the triumph group, $t(30) = -0.334$, $p = .429$.

Discrimination analyses.—Dishabituation was tested with two 2 X 2 repeated measures ANOVAs at each age group, with trial type as a within-subjects repeated measure and habituation emotion group (relief/triumph) as a between-subjects measure. For the trial type measure, we separately ran two different comparisons—one comparing the habituation *baseline* (mean across the last three habituation trials) to *different* test trials (henceforth the baseline/different ANOVA), and one comparing the *same* test trial with the *different* test trial (henceforth the same/different ANOVA). For each of these tests, a main effect of trial type (longer looking times to the *different* test trials) indicates discrimination of the stimuli. The baseline/different ANOVA examines whether infants dishabituate to the novel category items compared with a baseline from their habituation. The same/different test may be viewed as a more stringent test of category discrimination in that infants must show significantly *more* dishabituation to the new tokens from the new category than to new tokens from the habituated category. For all analyses, null statistics are reported in the supplemental data.

Baseline/different analysis.—For the 3-month-olds and the 6-month-olds, there were no significant main effects or interaction. For the 8-month-olds, there was a main effect of trial type, $F(1, 30) = 30.8$, $p < .001$, with longer looks to the different trials, and a main effect of habituation emotion group, $F(1, 30) = 5.54$, $p = .025$, with longer overall looks from the relief group, but no interaction. By 8 months, infants dishabituated to the different category test items compared with the baseline.

Same/different analysis.—For the 3-month-olds, there were no significant main effects or interaction. However, for the 6-month-olds, there was a main effect of trial type with longer looking times for the different trials, $F(1, 14) = 11.5$, $p = .004$, but no main effect of habituation emotion group or interaction. For the 8-month-olds, there was a significant main effect of trial type with longer looking times for the different trials, $F(1, 30) = 13.1$, $p = .001$, and a main effect of habituation emotion group, $F(1, 30) = 8.3$, $p = .007$, with overall looking times longer in the relief condition, but no interaction. In sum, 6- and 8-month-olds, but not 3-month-olds, demonstrated significant discrimination of the relief and triumph stimuli.

Discussion.—Consistent with findings that 5-month-olds do not discriminate happy from sad or angry vocal expression except in the presence of affective visual stimuli (Walker-

Andrews & Lennon, 1991), 3-month-olds did not show evidence of discriminating non-linguistic expressions of triumph and relief. However, our results suggest that by 6 months, infants are able to discriminate between non-linguistic expressions of triumph and relief by a single speaker from a similar cultural background to themselves. This finding was more robust by 8 months, emerging in the baseline/different test in addition to the same/different test. Conceptually, the same/different test may be viewed as a more stringent test, in that it compares new test tokens from the familiar category to new-category test tokens, rather than to the baseline familiar tokens. Yet the same/different discrimination emerged at a younger age. As can be seen from Figure 1, this significant result emerged due to a continued decrease in looking time to the new tokens from the familiar category, despite their novelty as tokens. This suggests that infants grouped the novel, same-category, test items together with the habituation items, and continued a pattern of decreased looking compared with the baseline habituation trials. Equally noteworthy, this discrimination occurred in the context of a male speaker. Given that most existing research has been conducted using female voices (and faces), this finding provides an important extension of emotion discrimination across gender lines. In Experiment 2, we examine whether this discrimination is robust across multiple voices from the same cultural background.

Experiment 2

In Experiment 1, infants showed discrimination of expressions of two positive emotions by age 6 months. During the habituation period, a number of different exemplars were presented. To generalise from these to the test items and to differentiate these from expression of another emotion, infants must extract something invariant across the habituation tokens. However, the fact that all the stimuli came from a single speaker reduced the variability of the habituation tokens and meant high similarity between the habituation and test tokens. A more stringent test of the claim that the infants discriminated based on identification of the categories of relief and triumph would involve increasing variability among the tokens, both between the tokens in the habituation set and between the habituation stimuli and the test stimuli. One way to accomplish this is to include habituation stimuli from several speakers, in order to provide greater variability in the samples within a given category. This would not rule out the possibility that infants are responding purely on acoustic similarity, given that the variability across categories may well be greater than the variability within a category across speakers. Nonetheless, evidence showing discrimination in a multi-speaker context would suggest the possibility that infants were responding with respect to the underlying emotional content inherent in the stimuli and not simply to low-level acoustic similarity.

In Experiment 2, we used four speakers rather than one during the habituation phase, in order to test whether infants' ability to discriminate the emotion categories was robust across speakers. In previous work on speech perception (Houston & Jusczyk, 2000), gender has been shown to be associated with similarity in acoustic space of spoken language word tokens, and such similarity may affect infants' ability to detect familiar words. We therefore included two female and two male speakers in the sample in order to increase the acoustic variability of the habituation sounds. Given the findings in Experiment 1, we focused on a

sample of 6-month-olds. In addition, we collected a sample of infants older than 6 months in order to examine possible developmental changes.

Method

Participants.—We tested 57 infants aged 6 months (164–205 days, $M = 182$ days, $SD = 10.6$, 31M/26F), as a comparison group to the 6-month-olds who showed discrimination of the emotion categories in Experiment 1. Unlike in Experiment 1, we had access to a much wider spectrum of ages of infants for the study. Therefore, rather than limit data collection to a narrow age range, we collected data from infants from 7 months up to 24 months in order to gain a broader developmental perspective. There were 43 infants aged 7–12 months (208–364 days, $M = 283$ days, $SD = 52.4$, 21M/22F), who were analysed as a group. In addition, data from 15 toddlers aged 12–24 months (384–672 days, $M = 499$ days, $SD = 92.3$, 12M/3F) were also collected (reported in the supplemental data). All participants were recruited from the Winnipeg, Manitoba area. Of these, the majority were Caucasian, with 2 participants identified by their parents as Black or African, 5 as Hispanic, 12 as Asian, 4 as Canadian First Nations and 5 unidentified. Forty-six participants were reported as more than 20% language input other than English. See the supplemental data for analysis of language input as a variable. An additional 39 participants were tested but not included in the analyses due to fussiness or looking judged to be uncodeable (13), technical difficulties or experimenter error (13), parental interference (2), infant younger than 5.5 months (5), deaf parent discovered after the study was run (2). Nineteen additional infants were excluded due to having been run in a prior version of the habituation software, as described in more detail below.

Stimuli.—Audio files were selected as described in Experiment 1. Tokens from three additional speakers from the same stimulus set (Sauter, Eisner, Calder, et al., 2010) were included, resulting in a total of two male and two female voices. There were 15 tokens for each of relief and triumph, with 3–5 tokens from each speaker of each category. Test tokens were again new exemplars that were not heard during habituation. See Table 1 for acoustic details regarding the stimuli.

Procedure.—The basic procedure was identical to Experiment 1. However, these infants were tested in a different laboratory. Consequently, although the same software and basic equipment set-up and methodology were used, minor procedural changes resulted. Specifically, a post-test trial was not used, and the number of habituation trials was reduced from 20 to 15, while the number of test trials was increased to two each. Most notably, due to the change in software, a different dependent measure was used—the total run time (i.e. the length of each trial), rather than looking time (see supplemental data for further explanation and procedures implemented to examine comparability of results produced by analyses using the different dependent measures).

As with Experiment 1, infants who did not reach the habituation criterion after 15 trials continued on to the test phase. There were 33 infants who did not reach criterion (13 in the triumph group and 20 in the relief group). See supplemental data for an analysis excluding these participants.

Results and discussion

Habituation.—Both age groups showed significant decreases in run time across the habituation phase (Table 2, Figure 2). There were no habituation emotion group-related main effects or interactions in habituation run times. There were no differences in number of trials to habituate across habituation condition for either age group. For the 6-month-olds, the mean number of habituation trials was 11.3 trials for the relief group, while for the triumph group it was 10.7, $t(55) = -0.642$, $p = .524$. For the 7–12-month-olds, the mean number of trials to habituate for the relief group was 10.9, while for the triumph group it was 12.0, $t(41) = 1.08$, $p = .285$.

Analysis of 6-month-olds.—We first examined whether 6-month-olds dishabituated to the novel stimulus with two separate 2 X 2 ANOVAs with trial type (baseline or different; same or different) as within subjects and habituation emotion group (triumph or relief) as between subjects. For the baseline/different analysis, there was no main effect of trial type or interaction, but a main effect of habituation emotion group, $F(1, 55) = 5.3$, $p = .026$, with longer run times in the relief group. For the same/different analysis, however, there was a significant effect of trial type, $F(1, 55) = 9.4$, $p = .003$, with longer run time to the different trials, but no interaction (however, see supplemental Analysis 4) or main effect of habituation emotion group. Consistent with Experiment 1, 6-month-olds showed discrimination of the same and different trials, but did not show dishabituation in the baseline/different analysis (although see supplemental Analysis 4 for evidence of dishabituation in the relief group).

Analysis of 7–12-month-olds.—Given that 6-month-olds succeeded at discriminating same from different test trials, but that they did not show dishabituation in the baseline/different analysis, we next examined the 7–12-month-old age group, again with two separate 2 X 2 ANOVAs with trial type (baseline or different; same or different) as within subjects and habituation emotion group (triumph or relief) as between subjects. For the baseline/different analysis, there was no main effect of trial type or of habituation emotion group, but there was a significant interaction between trial type and habituation emotion group, $F(1, 41) = 4.75$, $p = .035$. We therefore analysed each habituation emotion group separately with a paired-samples t -test. Neither group showed significantly different run times between the baseline and the different trials. Consistent with the 6-month-olds in both Experiments 1 and 2, the 7–12-month-olds did not show dishabituation in the baseline/different analysis.

For the same/different analysis, as with the 6-month-olds, there was a significant effect of trial type, $F(1, 41) = 13.75$, $p = .001$, with longer run time to the different trials, and no main effect of habituation emotion group, but unlike with the 6-month-olds, there was a significant interaction between trial type and group, $F(1, 41) = 9.86$, $p = .003$. Given the interaction effect, we analysed each habituation emotion group separately with a paired-samples t -test. Infants in the relief group had longer run times to the different trials, $t(20) = 4.12$, $p = .001$, but there was no significant run time difference for infants in the triumph group.

Discussion.—Discrimination of the same/different test trials was found in both Experiments 1 and 2 by 6 months. However, the triumph group in the 7–12-month-old age range did not show discrimination of the same and different test trials. While a similar significant interaction effect was not found in our primary analysis at 6 months, this statistic just missed significance ($p = .053$), and as shown in our supplemental data, significant interactions were found with other ways of analysing the 6-month-olds' data (e.g. excluding infants who failed to habituate). This suggests a less robust discrimination effect after habituation to triumph tokens. Such asymmetrical responses have been found in other research on infant perception of non-linguistic emotional expressions (e.g. Kotsoni, de Haan, & Johnson, 2001; Walker-Andrews et al., 2011). We return to this issue in the General Discussion. We also found minor differences between the 8-month-olds in Experiment 1 and the 7–12-month-olds in Experiment 2—specifically, in addition to the group difference just discussed, the latter group did not show dishabituation in the baseline/different analysis. It is possible that the difference in size of the age ranges in the two experiments contributed to these differences, although it is not clear why older infants would show *less* robust discrimination.

Experiment 2 provides additional evidence that by 6 months, infants discriminate between non-linguistic expressions of emotion. However, the tokens from Experiment 2, despite being from multiple speakers, were still quite similar, and infants' responding could still have been made based on basic acoustic similarities between the tokens within a category. Experiment 3 examined whether infants would discriminate these categories across not only speakers from the same culture, but across cultural/linguistic contexts, with much more varied acoustic characteristics.

Experiment 3

Infants' overall sensitivity in Experiment 2 to the difference between relief and triumph tokens produced by multiple speakers lends support to the idea that infants are responding at the level of emotion categories, not simply to basic acoustic differences. However, these findings do not rule out the possibility that low-level acoustic differences are driving infants' responses. Additional support for the possibility that infants are responding based on categories would be found if infants discriminate these categories across not only speakers from the same language/culture, but across speakers from different languages and cultures. In Experiment 3, therefore, we gave infants tokens at test that were very different to those heard during habituation; infants heard test tokens produced by a Himba individual.

The Himba people are a semi-nomadic, pastoral group of approximately 20,000 people living in a remote region of northern Namibia in Africa. In addition to providing a strong test of infants' ability to discriminate the categories of triumph and relief, providing test samples produced from a very different cultural context will also contribute to the understanding of whether infants are sensitive to the acoustic cues that are cross-culturally consistent in the vocal signals of these emotions.

Method

Participants.—We tested 46 infants aged 6 months (152–204 days, $M = 180$ days, $SD = 11.8$, 22M/24F). We also tested 55 infants aged 7–12 months (208–363 days, $M = 289$ days, $SD = 46.7$, 31M/24F). A sample of 37 toddlers aged 12–24 months (372–717 days, $M = 511$ days, $SD = 98.3$, 18M/19F) was also collected (data from this older age range are reported in the supplemental data). All participants were recruited from the Winnipeg, Manitoba area. Of these, the majority were Caucasian, with 3 participants identified by their parents as Black or Mulatto, 2 as Hispanic, 23 as Asian, 7 as Canadian First Nations, 1 as “minority”, and 18 unidentified. Forty-six participants were reported as more than 20% language input other than English. See the supplemental data for analysis of language input as a variable. An additional 36 participants were tested but not included in the sample due to fussiness or looking judged to be uncodeable (8), technical difficulties or experimenter error (10), parental interference (3), infant younger than 5.5 months or older than 24 months (5), construction noise during testing (10), and infant born preterm (2). One additional infant was excluded from the main analysis due to having been run in a prior version of the habituation software.

Stimuli.—Habituation trials were the same as for Experiment 2. Test trials were two new tokens from a Himba male individual (see Sauter, Eisner, Ekman, et al., 2010 for full details on stimulus production and validation). See Table 1 for acoustic details regarding the stimuli.

Procedure.—The basic procedure was identical to Experiment 2. There were 20 infants who did not reach criterion (13 in the triumph group and 7 in the relief group). See supplemental data for an analysis excluding these participants.

Results and discussion

Habituation.—Both age groups showed significant decreases in run time across the habituation phase (Table 2, Figure 3). There were no habituation emotion-related main effects or interactions in habituation run times. There were no differences in number of trials to habituate across habituation condition for any age group. For the 6-month-olds, the mean number of habituation trials was 9.5 trials for the relief group, while for the triumph group it was 10.7, $t(43) = 1.20$, $p = .235$. For the 7–12-month-olds, the mean number of trials to habituate for the relief group was 9.6 while for the triumph group it was 10.3, $t(53) = .794$, $p = .431$.

Analysis of 6-month-olds.—As with Experiment 2, we first examined whether 6-month-olds dishabituated to the novel stimulus with two separate 2 X 2 ANOVAs with trial type (baseline or different; same or different) as within subjects and habituation emotion group (triumph or relief) as between subjects. For the baseline/different analysis, there was a main effect of trial type, $F(1, 43) = 7.68$, $p = .008$, with longer run times to the different trials over baseline, but no interaction or main effect of habituation emotion group. For the same/different analysis, however, there were no main effects or interaction. In other words, unlike in Experiments 1 and 2, 6-month-olds showed dishabituation to the different trials compared with baseline. However, again unlike Experiments 1 and 2, they did not show discrimination

of the same and different test trials, suggesting that the dishabituation between different trials and baseline was due to the cultural/linguistic differences across baseline and test, and not due to the emotion category change.

Analysis of 7–12-month-olds.—Given that the 6-month-olds did not show discrimination of the same and different test trials, we next examined the 7–12-month-old age group, again with two separate 2 X 2 ANOVAs with trial type (baseline or different; same or different) as within subjects and habituation emotion group (triumph or relief) as between subjects. For the baseline/different analysis, there was a main effect of trial type, $F(1, 53) = 64.9, p < .001$, with longer run times for the different trials over baseline, and a significant interaction between trial type and habituation emotion group, $F(1, 53) = 17.0, p < .001$, but no effect of habituation emotion group. We therefore analysed each habituation emotion group separately with a paired-samples *t*-test. Both the relief group, $t(25) = 13.9, p < .001$, and the triumph group, $t(28) = 2.29, p = .030$, individually showed a significant dishabituation effect between the test trials and the baseline.

For the same/different analysis, there was a significant main effect of trial type, $F(1, 53) = 4.05, p = .049$, and a significant effect of group, $F(1, 53) = 5.22, p = .026$, but no interaction, suggesting that these infants, unlike the 6-month-olds, discriminated the same and different test trials. This suggests that the ability to discriminate non-linguistic expressions of emotion across cultural/linguistic contexts emerges after 6 months and before 12 months.

Given the large age range in this older sample, we divided the infants into a “younger” (7–9 months) and an “older” (10–12 months) sample based on the middle of the age range (i.e. 208–286, $N_{\text{relief}} = 10, N_{\text{triumph}} = 14$; 287–363, $N_{\text{relief}} = 16, N_{\text{triumph}} = 15$) (Figure 4). We first ran a 2 X 2 same/different analysis as above on the younger sample, to determine whether the effect would hold within the more constrained younger age range. There were no main effects or interactions. We therefore ran the same analysis with the older sample. There was a main effect of trial type, $F(1, 29) = 6.37, p = .017$, but no effect of habituation emotion group or interaction. Although it is possible that the somewhat smaller N (24 versus 31) contributed to the failure to find significant discrimination in the 7-9-month-olds, a significant discrimination effect in our analysis emerged only by 10–12 months.

Discussion.—In Experiment 3, unlike Experiments 1 and 2, discrimination of the same and different test trials was not shown until 10–12 months. This suggests that by 10–12 months, infants are able to discriminate non-linguistic emotional expressions across cultural/linguistic contexts. However, younger infants may not be able to do so.

Also noteworthy is the dishabituation effect (the baseline/different analysis) in Experiment 3 at 6 months. Together with the fact that the 6-month-olds did not discriminate the same and different trials at test, this suggests that the 6-month-olds attended to the cultural/linguistic differences between the stimuli, but not the emotional content.

By 10–12 months, infants attended to both the cultural/linguistic and emotional properties of the test stimuli. There are two possible interpretations of the 6-month-old data. One possibility is that 6-month-olds are not able to detect the emotional content in the Himba

stimuli, and that this ability only emerges by 10–12 months. Alternatively, 6-month-olds may have the underlying capability to detect the emotional content of the Himba stimuli, but may be less capable than older infants to track multiple sources of variation simultaneously. In this explanation, the infants were attending to the change from British to Himba tokens, preventing them from responding to the emotional content within the Himba tokens.

General discussion

Across three experiments, we examined infants' discrimination of non-linguistic vocal expressions of two positive emotions – relief and triumph. In the first experiment, 6- and 8-month-olds, but not 3-month-olds, discriminated tokens of relief and triumph from a single individual. In Experiment 2, 6-month-olds discriminated relief and triumph across speakers (although this effect was less robust in the triumph group). In Experiment 3, where the test items differed from the habituation items in the cultural and linguistic identity of the individual vocalising, infants only discriminated the two emotion categories at the 10–12-month age group. We also found evidence for an asymmetry in infants' discrimination of these tokens depending on the category used for habituation.

Before exploring the implications of these findings, it is necessary to discuss some limitations of our study. First, for the habituation stimuli, and for the test stimuli in Experiments 1 and 2, we were using a validated set of recordings of British individuals rather than recordings made in the area in North America where the research took place. There was therefore the possibility that cultural/linguistic variations between North America and England may have influenced the infants' behaviour. While infants were successful in showing discrimination in Experiments 1 and 2 despite these potential differences, it is possible that we might have found discrimination at a younger age or more robust discrimination in the triumph group if recordings taken from the infants' own region had been used. Relatedly, although our focus in Experiment 3 was on cultural variation in non-linguistic expressions of emotion, we cannot rule out the possibility that linguistic variations may have influenced these non-linguistic expressions, given that they contain some quasi-linguistic characteristics. Third, although we characterise the findings as showing that infants discriminate the *categories* of relief and triumph, our findings do not directly address the extent to which infants perceive the groups of tokens in our study as meaningful categories. Even in Experiment 3, it is possible to interpret the infants' behaviour as stemming entirely from responding to basic acoustic similarities across the tokens rather than emotional categories per se. Ruling out this alternative explanation entirely would be difficult, although Zieber et al. (2014) have showed that infants intermodally associated happy and angry vocal expressions with the relevant body movements. However, this relies on infants' ability to identify the categories of the stimuli across modalities, which may or may not be the case for relief and triumph. Finally, differences in methodology mean that caution must be taken in directly comparing the findings from Experiment 1 with those of Experiments 2 and 3.

The asymmetry between the relief and triumph group is worth considering further. One possibility is that the triumph tokens may be intrinsically more engaging to the listener, since they are perceived as more aroused and more positive (Sauter, Eisner, Calder, et al., 2010).

Similarly, the order of presentation (from less to more salient for the relief group) rather than the intrinsic salience of the test stimuli, may have driven the asymmetry in responding. However, this asymmetry did not appear in Experiment 1, despite similar stimulus properties to the later studies, which is inconsistent with this explanation. Similarly, the possibility that differences in time to habituate due to differential salience might drive the asymmetry is also not supported by our analyses.

Alternatively, habituation tokens of relief may be more similar to each other than those of triumph. This might cause infants in the relief condition to form a category with smaller boundaries than that formed by the triumph group. In other words, the category of triumph may potentially include tokens of relief, while the category of relief does not include triumph. Similar asymmetries in infant discrimination of visual categories (cats vs. dogs) have been ascribed to comparable statistical properties of the categories in question, in that there is greater variation within one category, and features from the other category may be subsumed within this variation (Mareschal, Quinn, & French, 2002; Quinn, Eimas, & Rosenkrantz, 1993). Such a difference between the categories may be formed online based on the tokens selected, or may be an underlying property of the categories in question. Additionally, infants may be more sensitive to variability on some acoustic features as compared to others.

The current findings indicate that infants as young as 6 months perceptually discriminate non-linguistic vocal expressions of positive emotions. However, this capability is limited, and develops in scope over time. Notably, in Experiment 3, 6-month-olds showed a dishabituation effect but not a discrimination effect, because infants recovered to both the “same” and “different” tokens compared with baseline. This suggests that infants were sensitive to the difference between the habituation and test tokens—namely the cultural/linguistic context of the individual producing them (although the tokens were “non-linguistic”, they may have contained elements of the speaker’s specific linguistic background in addition to non-linguistic culturally driven differences in vocalisation). In addition, this created the potential for a ceiling effect—in order to show dishabituation to the “different” tokens compared with the “same” tokens, infants needed to show additional dishabituation beyond that associated with the novelty of the cultural/linguistic origin of the tokens. Nonetheless, 10–12-month-olds did show this additional dishabituation effect, demonstrating sensitivity to the relationship between these two categories of triumph and relief across cultures and underlying linguistic context. This suggests that while there is a learned component to the perception of these categories, there is also a component of underlying similarity across cultural/linguistic contexts. Note that while 10–12-month-olds are more developmentally mature, it is extremely unlikely that they would have had any exposure to Himba expressions of emotion prior to the testing in our lab. Therefore, while this may be interpreted as indication of a learned component to the infants’ responses, this would not be learning that was specific to the acoustic properties of emotional vocalisations of this particular cultural group. In other words, our findings may be interpreted in support of a limited, but not negligible, notion of the universality of basic features of these vocalisation categories. This would be consistent with previous results that have suggested a shared component across cultures for vocalisations of some positive emotions, including relief (Laukka et al., 2013; Sauter, Eisner, Ekman, et al., 2010).

Our findings with respect to the learned component of infants' responding to these emotional expressions are consistent with findings in related developmental literatures on category formation, particularly that in the domain of infant speech perception. Research in infants' perception of speech sounds shows a similar change in the formation of categories away from speaker or group-specific information toward a generalisation based on meaningful categories that abstract from basic acoustic features at around 10–11 months of age (Houston & Jusczyk, 2000). Similarly, our findings point to a growing ability on the part of the infants to detect the category-specific information relevant to discriminating emotions amid the “noise” of cultural variation. The similarity in the ages that this emerges for speech perception suggests that a shared underlying mechanism of abstracting from acoustic information may be at play, although of course additional research would be necessary to explore this claim. In addition, it is unknown the extent to which the developing ability is related to abilities in forming categories in other domains, such as object categories (e.g. Quinn, 2002), or whether it represents a separate developmental process.

To what extent can it be argued that the infants' capability represents an underlying innate knowledge of emotions? Our findings show a clear developmental progression. The lack of evidence for discrimination within even a single speaker at 3 months, and further development of this discrimination between 6 and 10 months, suggests that some knowledge of emotional signals develops through experience. In particular, the capacity to notice the appropriate acoustic features in the presence of competing ones appears to develop over time, and at least some acoustic features themselves likely need to be learned, particularly those that vary across cultures. However, this does not rule out a non-learned component. That older infants were able to discriminate the emotions produced by an individual from an unfamiliar cultural context is suggestive that the underlying knowledge of emotion may have a significant universal component.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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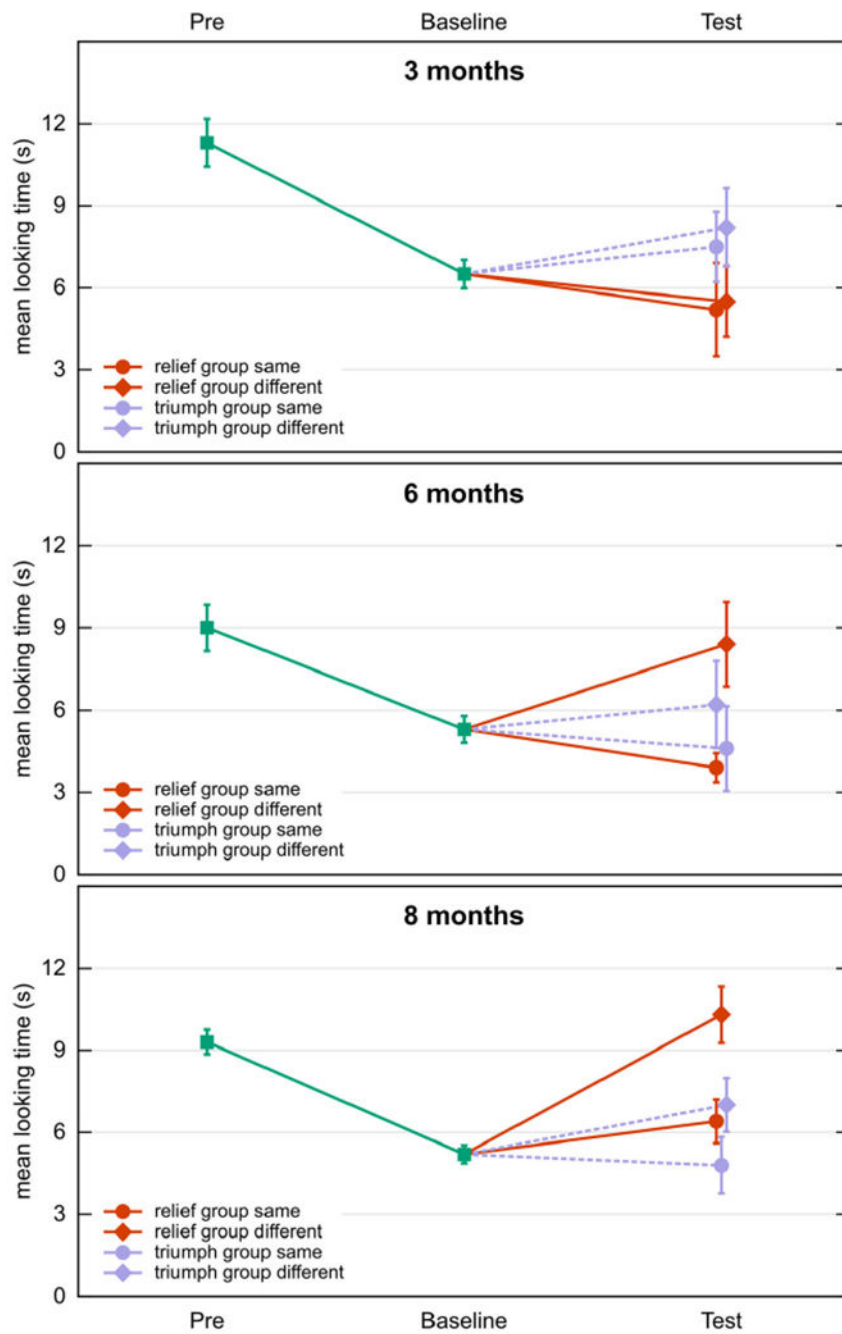


Figure 1. Pre-habituation (first three trials of habituation), baseline (last three trials of habituation) and test looking time means for Experiment 1 for 3-month-olds, 6-month-olds and 8-month-olds. Error bars represent one standard error.

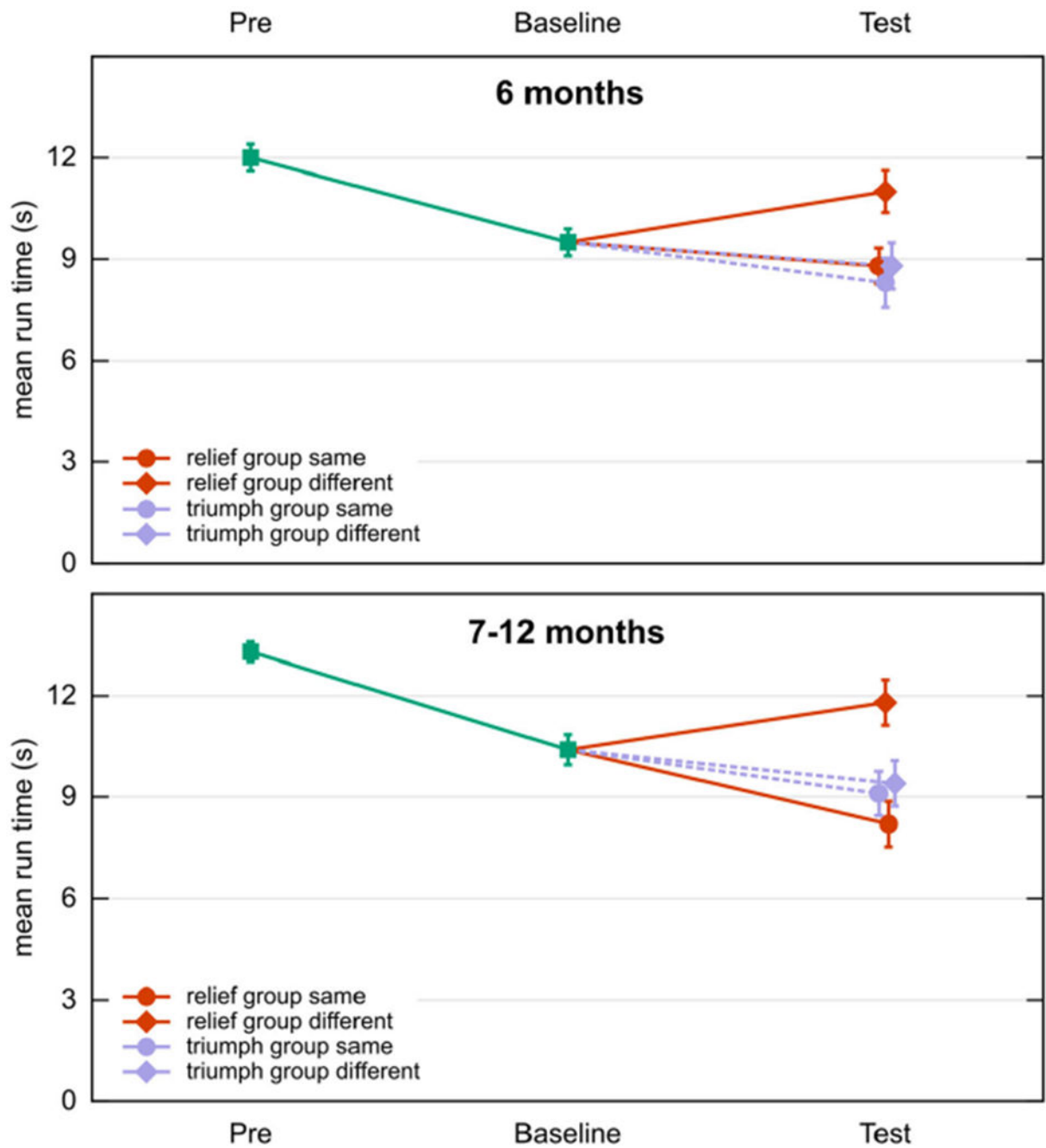


Figure 2.

Pre-habituation (first three trials of habituation), baseline (last three trials of habituation) and test looking time means for Experiment 2 for 6-month-olds and 7–12-month-olds. Error bars represent one standard error.

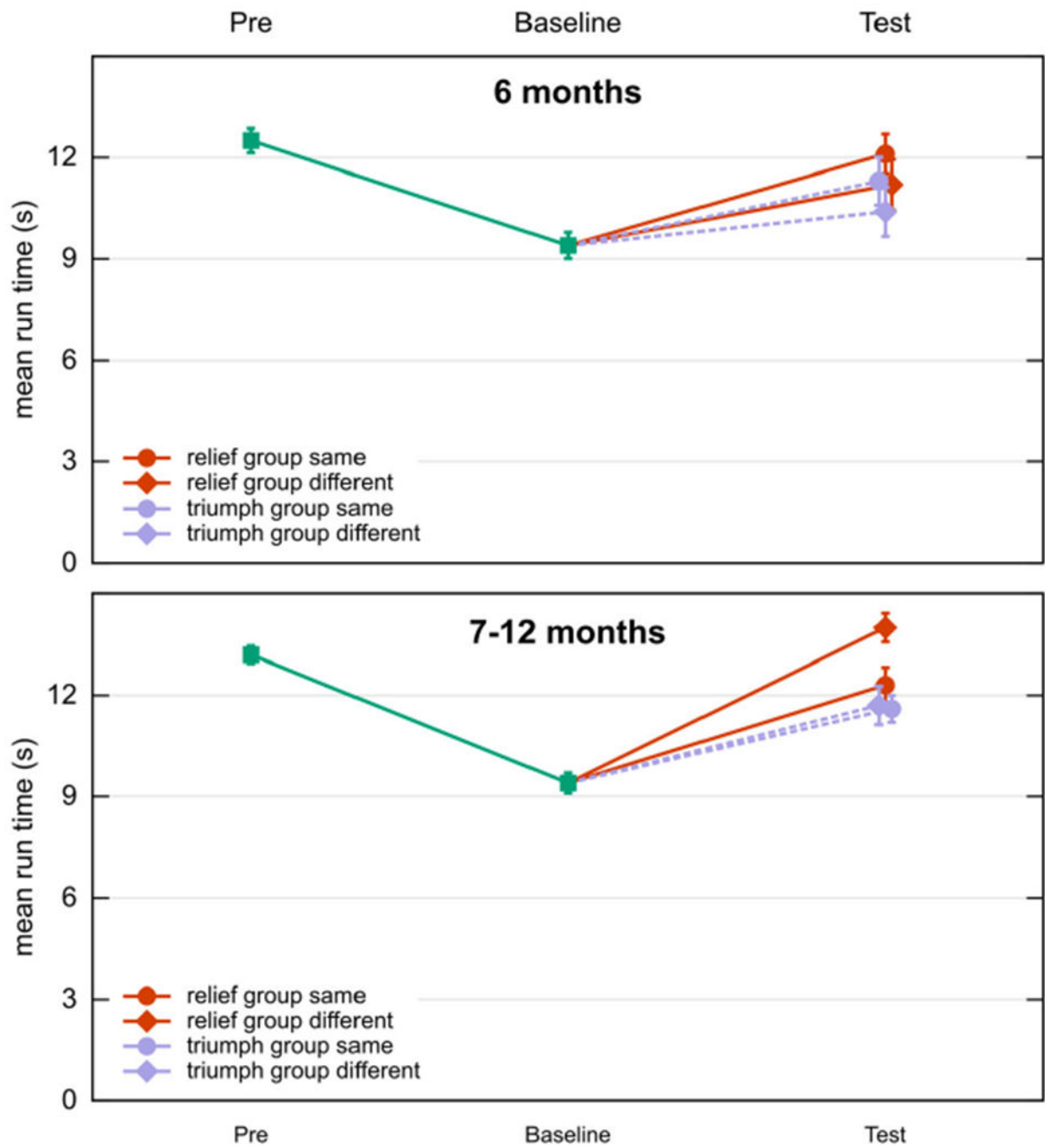


Figure 3.

Pre-habituation (first three trials of habituation), baseline (last three trials of habituation) and test looking time means for Experiment 3 for 6-month-olds and 7–12-month-olds. Error bars represent one standard error.

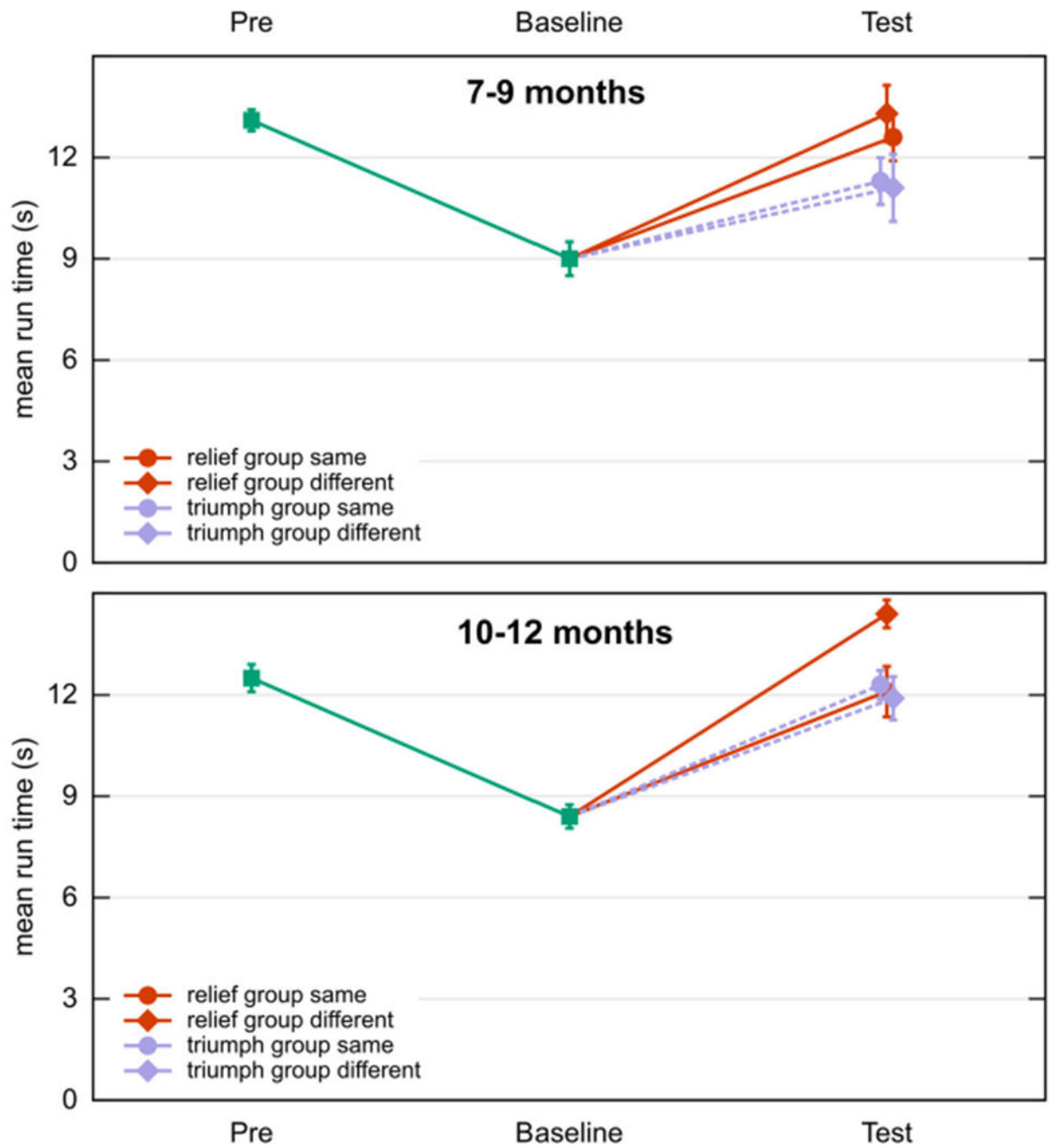


Figure 4.

Pre-habituation (first three trials of habituation), baseline (last three trials of habituation) and test looking time means for Experiment 3 for the sub-groups 7-9-month-olds and 10-12 months. Error bars represent one standard error.

Table 1.

Means (standard deviations) of acoustic measures for habituation and test stimuli. See Sauter, Eisner, Calder, et al. (2010) for details regarding the calculations of these measures. “Onsets” is a measure roughly equivalent to the number of syllables.

Stimuli	Duration (s)	RMS amplitude (pascal)	Onsets (N)	Modified intensity (dB SPL)
Experiment 1				
Triumph				
Habituation	0.77 (0.20)	0.13 (0.06)	1.92 (0.79)	75.11 (4.05)
Test	0.72	0.15	1	77.26
Relief				
Habituation	0.81 (0.44)	0.06 (0.02)	2.27 (1.74)	68.12 (3.85)
Test	0.71	0.06	1	69.05
Experiment 2				
Triumph				
Habituation	0.80 (0.28)	0.05 (0.03)	1.60 (1.08)	66.86 (5.11)
Test	1.18	0.03	3	63.68
Relief				
Habituation	0.83 (0.35)	0.03 (0.02)	1.40 (0.63)	60.20 (6.15)
Test	0.74	0.02	1	60.06
Experiment 3				
Triumph test	1.04	0.06	2	69.12
Relief test	1.11	0.10	3	74.10

Means (standard deviations) of looking time (Experiment 1) or run time (Experiments 2 and 3) for each experiment by age. “Pre” is the average across the first three trials of the habituation phase, “baseline” is the average across the last three trials of the habituation phase. “Same” and “different” are means for the test trials, separately for each habituation group. “ N_T ” is number of participants in the triumph group, “ N_R ” is the number of participants in the relief group.

Table 2.

Experiment Age	Pre (s)	Baseline (s)	<i>t</i> -Statistic	<i>p</i> -Value	Habituation		Relief group		Triumph group	
					Same (s)	Different (s)	Same (s)	Different (s)	Same (s)	Different (s)
Experiment 1 3 months $N_R = 8, N_T = 8$	11.3 (3.4)	6.5 (2.0)	<i>t</i> (15) = 9.3	<i>p</i> < .001	5.2 (4.5)	5.5 (3.4)	7.5 (4.1)	8.2 (3.8)	7.5 (4.1)	8.2 (3.8)
6 months $N_R = 8, N_T = 8$	9.0 (3.3)	5.3 (1.9)	<i>t</i> (15) = 7.4	<i>p</i> < .001	3.9 (1.4)	8.4 (4.1)	4.6 (2.9)	6.2 (4.2)	4.6 (2.9)	6.2 (4.2)
8 months $N_R = 16, N_T = 16$	9.3 (2.5)	5.2 (1.8)	<i>t</i> (31) = 11.9	<i>p</i> < .001	6.4 (3.1)	10.3 (4.0)	4.8 (2.2)	7.0 (3.8)	4.8 (2.2)	7.0 (3.8)
Experiment 2 6 months $N_R = 33, N_T = 24$	12.0 (3.0)	9.5 (3.0)	<i>t</i> (56) = 4.7	<i>p</i> < .001	8.8 (3.0)	11.0 (3.5)	8.3 (2.4)	8.8 (3.3)	8.3 (2.4)	8.8 (3.3)
7–12 months $N_R = 21, N_T = 22$	13.3 (1.9)	10.4 (2.9)	<i>t</i> (42) = 6.9	<i>p</i> < .001	8.2 (3.0)	11.8 (3.0)	9.1 (2.9)	9.4 (3.1)	9.1 (2.9)	9.4 (3.1)
Experiment 3 6 months $N_R = 22, N_T = 24$	12.5 (2.4)	9.4 (2.6)	<i>t</i> (45) = 9.0	<i>p</i> < .001	12.1 (2.7)	11.2 (3.4)	11.3 (3.7)	10.4 (3.5)	11.3 (3.7)	10.4 (3.5)
7–12 months $N_R = 26, N_T = 29$	13.2 (1.9)	9.4 (2.2)	<i>t</i> (54) = 16.6	<i>p</i> < .001	12.3 (2.6)	14.0 (2.1)	11.6 (3.5)	11.7 (3.0)	11.6 (3.5)	11.7 (3.0)