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Preterm infant showed better object handling skills in a neonatal intensive care unit during silence than with a recorded female voice

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Short title: Female voice influenced tactile abilities of preterm infants

ABSTRACT

Aim: This study compared whether preterm infants showed better tactile abilities during silence or when they heard a pre-recorded female voice at different intensities.

Methods: We studied 74 preterm infants of 28-35 weeks post-conceptional age who were admitted to a French neonatal intensive care unit from 2014-2017. They were presented with wooden objects, one smooth and one angled, at various points during silence (n=26) or while listening to a female voice at +5 (n=24) or +15 decibels (n=24) inside their incubator. We compared the conditions to see if there was any difference in how the infants handled the objects and also compared familiar and unfamiliar objects.

Results: The preterm infants showed better handling skills, and only displayed effective discrimination, during silence. We found that 27.1% of the infants exposed to female voices failed to get habituated to the object, compared to 7.7% in the silence condition ($p < 0.05$) and success during the voice conditions required more trials (6.1 versus 5.3) than the silence condition ($p = 0.05$). The different voice intensities made no difference.

Conclusion: Being exposed to a female voice had a negative impact on preterm infants' tactile sensory learning, regardless of its intensity

Key notes:

- We compared whether 74 preterm infants showed better tactile abilities during silence or when they heard a pre-recorded female voice.
- They were presented with two wooden objects at various points during silence (n=26) or while listening to a female voice at +5 (n=24) or +15 decibels (n=24) inside their incubator.
- Being exposed to a female voice had a negative impact on their tactile sensory learning, regardless of its intensity

Key words: auditory modality, female voice, neonatal intensive care unit, preterm infant, tactile abilities

INTRODUCTION

Touch is the first sense to develop in utero. The tactile receptors appear at the 7th week of gestation and develop all over the body until the 20th week of gestation (1-4). Moreover, pressure exerted by an object placed in the hand triggers the grasping reflex, which appears around 18 weeks of gestation (1). However, grasping at birth is not just a pure reflex. Studies have revealed that preterm human infants display early tactile manual abilities (5-8). Indeed, from a post-conceptional age of 28 weeks, preterm infants were able to memorise tactile information about specific shape features, prisms or cylinders and to detect differences between the two shapes with either the right or left hand without visual control. As a consequence, an effective, passive and active tactile perception is present from birth, even when a baby is born premature.

The development of the sensory system in utero follows a predetermined sequence and depends on endogenous and exogenous factors that could be affected by a preterm birth. While exogenous factors are regulated by the womb in utero, newborn preterm infants are hospitalised in a neonatal intensive care unit (NICU) where they are exposed to many inappropriate stimuli, particularly sounds. Indeed, the acoustic environment of the NICU contains many high frequency sounds (9) and the sound levels significantly exceed the limit of less than < 45dBA recommended by the American Academy of Pediatrics (10). These intense sounds have been shown to act as stressful events on physiological self-regulatory skills (11) and could contribute to sensory and developmental disorders (12,13).

A study conducted in 2016 revealed that when preterm infants were exposed to a high sound level of 63dBA on a daily basis it affected their early sensory functioning (14). More precisely, the early tactile abilities of preterm infants were altered when they were simultaneously exposed to the alarm sound of an enteral feeding pump, which was not related to the tactile test. These results highlighted the detrimental influence of an unpleasant, yet common, sound on sensory learning by preterm newborn infants. However, it remained, unclear if this alteration was due to the very stressful nature of the alarm sound and, or, to its high level, or more generally to the simultaneous presentation of an auditory stimulus, independent of its nature and intensity. Previous studies have revealed that being exposed to human voices had short-term clinical benefits on preterm infants during their NICU stay, such as physiological and behavioural stabilisation (15). That is why we chose a female voice reading a short text directed at the infant, as we felt this would be a pleasant auditory stimulus.

The aim of this study was to evaluate the impact that this female voice, or silence, had on an unrelated tactile test and whether the sound condition affected how preterm human infants got habituated to handling familiar and less familiar objects.

METHOD

Participants

This prospective, observational study was carried out between March 2014 and September 2017. The participants were preterm infants born between 24 and 34 weeks of gestation and assessed between 28 and 35 weeks of post-conceptional age. The study site was a level three NICU in Grenoble Hospital, France. We excluded preterm infants with a polymalformative syndrome, those with cystic periventricular leukomalacia or grade III or IV intraventricular haemorrhage based on their cranial ultrasound and those who were receiving sedatives or anticonvulsive treatment.

The infants in the silence condition were studied first and the results were published in 2016 (14). The data for the two voice conditions detailed below are published here for the first time for comparative purposes. Both studies were carried out under the same conditions and in the same NICU.

Ethical approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of the Faculty of Psychology and Educational Sciences at the University of Geneva and by the ethics committee of Grenoble Hospital. The parents gave written consent for their infant to participate in the study.

Stimuli

The stimuli consisted of a smooth curved wooden cylinder that was 35mm long and 6mm in diameter and a sharply angled wooden prism with a triangular base that measured 9 x 6 x 6mm. The test focused on the tactile stimulation of the left hand, as it was mostly free from any prosthesis and no hand differences have been found in previous studies (6,7). A catheter was often present in the right hand (Figure 1).

The female voice was recorded and played using a dictaphone. A woman working in the NICU at Grenoble read a short 22-second text in French that was directed at the subject, while imagining an infant: “Oh! Who's got those big eyes? And who has such a big smile? Is that you? Yes, it's you! Are you looking at me? That’s it! Are you looking at me? Good! Will you look at me again?” (16). The dictaphone was placed above the child’s head inside the incubator and the audio sequence ran in a loop. The sound level was recorded inside the incubator using a sound dosimeter. To control for the other sounds of the NICU, the researchers turned off the alarms from other medical equipment. Furthermore, if other people, such as medical staff or parents, were present in the room, they were asked to remain silent.

Procedure

Each infant was swaddled comfortably and assessed in their incubator just before or just after care and more than one hour after being fed. They were in a quiet wakefulness state, with an arousal state of four on the Brazelton scale (17). The whole test was videotaped and run without visual control. The preterm infants were divided into three different experimental conditions according to the auditory stimulation. The sound level in the two voice conditions were +5dBA (n=24) or +5dBA (n=24) above the background noise and the third condition was silence (n=26). It should be noted that the infants in the silence group had been evaluated in a previous study and a complete description of the procedure has previously been published (14).

The tactile tests consisted of two phases: habituation and discrimination. The habituation phase consisted of presenting one of the two objects repeatedly to the infant's hand during successive trials. Infants were randomly allocated to the silence condition, as previously described (14), to the +5dBA voice condition or to the +15dBA voice condition. In the two voice conditions, the background noise was first measured inside the incubator. Then, the first researcher activated the dictaphone and adjusted the sound level according to the voice condition: +5 or +15dBA above the background noise. The habituation trials continued until the duration of holding in any two consecutive trials, from the third trial onward, totalled a third or less of the total holding time in the first two trials. If the habituation criterion was not met by the 10th trial, the test was stopped, and the infant was recorded as not habituated.

The discrimination phase was conducted immediately after a successful habituation and consisted of two test trials. Half of the infants in each of the three groups (control group) were presented with the familiar object and the other half (experimental group) were given the new-shaped object. Half of the infants in each group were randomly presented with the smooth shaped object during the habituation phase and half of them were presented with the angular object.

Data collection

All the relevant general and medical characteristics were collected from the infants' medical records. The medical characteristics were: antenatal steroid treatment, small for gestational age, Caesarean delivery, Apgar score of less than seven at five and 10 minutes, intubation, nasal continuous positive airway pressure (nCPAP) during hospitalisation and during the test and the presence of any nasal cannula or central venous catheter. Three parameters of habituation were measured: mean total holding times until the habituation criterion was reached, total holding times for the first two trials and the mean number of trials conducted. The mean holding time for the last two habituation trials and the mean holding time for the two test trials were also calculated for the discrimination process.

Statistical analysis

All statistical analyses were conducted in two steps using SPSS 22.0 (IBM Corporation, New York, USA). The significant threshold was 0.05. The first step was to compare the +5dBA and the +15dBA voice conditions. To compare the sound levels and the general and medical characteristics, Pearson's chi-square was used for the qualitative variables and the Student t-test was used for the quantitative variables. Analysis of variance (ANOVA) was performed for each parameter of habituation, with the two voice conditions (+5dBA versus +15dBA) and shape (prism versus cylinder) as two between-subjects factors. ANOVA was also performed for each parameter of discrimination, with the two voice conditions (+5dBA versus +15dBA) and group (experimental versus control) as two between-subjects factors. The second step was to compare the silence and voice conditions. For the comparison of the general and medical characteristics, Pearson's chi-square was used for qualitative variables and Student t-test for quantitative variables. ANOVA was performed for each parameter of habituation, with condition (silence versus voice) and shape (prism versus cylinder) as two between-subjects factors. For each condition, the discrimination process was then examined by performing a repeated-measure ANOVA with the phase as a within-subjects factor (last two habituation trials versus test trials) and the group as a between-subjects factor (control versus experimental).

RESULTS

Figure 2 illustrates the flow chart of the participants in the study. The final sample consisted of 74 preterm infants in three groups: one silence (26) and two voice conditions of 24 infants each. The analyses were conducted in two steps. The first step was to compare the +5dBA and the +15dBA voice conditions. The second step was to compare the silence and the voice conditions.

Comparison between the two voice conditions

The results showed that the background noise did not differ between the two voice conditions at +5dBA and +15bdBA (Table 1). In contrast, and as expected, the sound level with the voice was significantly higher in the +15dBA voice condition compared to the +5dBA voice condition ($t(46) = 5.584$, $p < 0.001$).

The participants in the voice condition groups were 48 preterm infants (28 girls) and there were 24 in each voice condition group. An additional 20 preterm infants were excluded from the study after one trial because of drowsiness, sleep or technical problems. The results revealed that more infants in the + 5dBA voice condition (91.7%) had a central venous catheter during their hospitalisation than those in the +15dBA voice condition (66.7%) (chi-square = 4.55, $p = 0.033$) (Figure 2). No other significant difference was observed (Table 2).

For the habituation phase, a similar proportion of infants failed to habituate in the +5dBA (25.0%) condition than in the +15dBA voice condition (29.2%) (chi-square = 0.11, $p = 0.75$). Moreover, the general and medical characteristics did not differ significantly between the non-habituated and habituated infants (all $p > 0.05$). The presence of a central venous catheter during hospitalisation was added to the following analyses. For the habituated infants, there were no significant effects for the voice condition and the shape factors, nor for the voice condition × shape interaction for each habituation parameter (all $p > 0.05$) (Table 3).

For the discrimination phase, the preterm infants in the +15dBA voice condition group held the object for longer during the last two habituation trials ($F(1,34) = 6.04$, $p = 0.02$, $\eta^2_p = 0.17$) and the two test trials ($F(1,34) = 4.43$, $p = 0.044$, $\eta^2_p = 0.13$) than the preterm infants in the +5dBA voice condition group (Table 4). There were no other significant effects (all $p > 0.05$).

Comparison between the silence and the voice conditions

The previous results revealed that the preterm infants in the two voice conditions (+5dBA and +15dBA) did not differ significantly with regard to habituation parameters, but did differ with regard to discrimination parameters. The next analyses were conducted by bringing together the data for the two voice conditions for the habituation phase but not for the discrimination phase.

Consequently, the participants were 24 preterm infants in each of the two voice conditions (n=48) and 26 preterm infants in the silence condition. The data for the infants in the silence condition came from a previous study (14). The results revealed that more infants in the voice condition (91.7%) had an nCPAP during their hospitalisation than those in the silence condition (73.1%) (chi-square = 4.61, $p = 0.032$) (Table 5). No other significant difference was observed (all $p > 0.05$).

During the habituation phase, more of the infants failed to habituate in the two voice condition groups (27.1%) than in the silence condition (7.7%) (chi-square = 3.92, $p = 0.048$) (Figure 2). Moreover, the general and medical characteristics of the condition did not differ significantly between the habituated and the non-habituated infants (all $p > 0.05$). Having nCPAP during hospitalisation was added in the following analyses. Preterm infants in the voice condition needed significantly more trials to attain the habituation criterion than in the silence condition ($F(1,58) = 3.89$, $p = 0.05$, $\eta^2_p = 0.07$) (Table 6). There were no other significant effects (all $p > 0.05$).

Figure 3 illustrates the results of the discrimination process. For the silence condition, no significant effect of the group factor was found ($p > 0.05$). The results showed a significant effect of the phase factor ($F(1,22) = 22.3$, $p < 0.001$, $\eta^2_p = 0.5$), as well as a significant phase x group interaction ($F(1,22) = 5.3$, $p = 0.031$, $\eta^2_p = 0.19$). Planned comparisons revealed that the experimental group held the novel object significantly longer than in the last two habituation trials ($p < 0.001$, $\eta^2_p = 0.53$). However, in the control group, mean holding time for the familiar object and mean holding time for the last two habituation trials did not differ significantly ($p = 0.10$, $\eta^2_p = 0.12$). We considered the two voice conditions (+5dBA versus +15dBA) in the following analysis and the results showed a significant effect of the voice condition factor ($F(1,30) = 6.41$, $p = 0.017$, $\eta^2_p = 0.18$). The preterm infants in the +15dBA voice condition group held the object longer than those in the +5dBA voice condition group. However, the phase x group interaction was not significant ($F(1,30) = 0.93$, $p = 0.34$, $\eta^2_p = 0.03$), indicating that the discrimination abilities were not observed in the voice condition. No other significant effects were found (all $p > 0.05$).

DISCUSSION

The aim of this research was to investigate the impact of a female voice and its intensity on tactile sensory learning in preterm human infants. Overall, the results showed that the presence of a female voice interfered with their tactile manual abilities.

Firstly, more preterm infants failed to habituate to the object after 10 trials when they were exposed the female voice, than those in the silence condition. Moreover, preterm infants who succeeded in habituating to the object in the voice condition needed significantly more trials to achieve this. Finally, the preterm infants in the voice condition did not display any increased interest when they were presented with the new shaped object, as their holding times were similar to the infants who were presented with the familiar object. These infants failed to display any effective discrimination between the smooth and angular objects, unlike the infants in the silence group. Previous studies have shown that preterm infants do have the ability to memorise tactile information about the specific features of an object and to detect differences with another object (5-8). Our study revealed that the presence of a voice had a negative impact on their sensory learning.

A significant difference in medical characteristics was also observed between the two conditions: a higher proportion of infants in the voice condition had an nCPAP during their hospitalisation than those in the silence condition. nCPAP is a non-invasive pressure support ventilator that improves alveolar ventilation in neonates with respiratory distress, generally due to pulmonary immaturity. It improves gaseous exchange and reduces muscle work. The flow rates used in our NICU to generate nCPAP were around 8L/min, in order to obtain a positive expiratory pressure of 3 to 5mmHg, according to the infant's need. This is a noisy medical device that added about 10dBA to the background noise. It is therefore possible that a greater proportion of infants in the voice condition could have been exposed to a noisier environment during their hospitalisation compared to the silence condition. However, the proportion of infants with an nCPAP during the test did not differ between the two conditions, indicating that the auditory environment during the test was equivalent. In any event, this difference was controlled by its inclusion in the statistical analysis. Nevertheless, future research should distinguish infants with and without nCPAP due to the additional noise generated.

Similar results on preterm infants' tactile abilities were observed when they were exposed to a more unpleasant and stressful sound during our previous study, which provided the data on the silence condition, and this was the alarm of the enteral feeding pump (14). This was rather unexpected, as in this study the female voice was considered to be a pleasant auditory stimulus. One common characteristic of these two auditory stimuli was they were not contingent to the tactile task. Indeed, the perception of contingency of two events is essential to learning and memory from early infancy, since it gives a coherent sense of the multisensory environment (18). This detection of contingency allows infants to allocate limited attentional resources and increase opportunities for positive learning experiences during their development. It seems that the presence of a non-contingent sound, regardless of its pleasant or unpleasant nature, had a detrimental effect on the tactile learning process of habituation and impaired the ability of preterm infants to discriminate the features of shapes with their hands.

Activation of the auditory modality might have interfered with the allocation of the attentional resources necessary to process the tactile information for effective manual habituation and discrimination in our study. This was in line with studies of full-term children that indicated that irrelevant sounds interfered with the short-term storage and processing of verbal information (19,20). However, caution should be used before generalising this finding. Indeed, it is possible that the presentation of another pleasant, but less attractive auditory stimulation than speech, such as music, would be less disturbing for the tactile learning process. This hypothesis should be further examined.

Regarding the voice condition, habituation and discrimination abilities were not modulated by the intensity of the voice. However, one interesting result was that the preterm infants in the +15dBA voice condition group held the object longer than those in the +5dBA voice condition group. It is possible that they had more difficulty in disengaging their attention from the object they were exploring when the intensity was higher. With regard to the methodology of the present study, we decided to vary the intensity of the female voice in relation to the background noise measured inside the incubator, by using two volumes, , because it varies according to the infant's vulnerability, gestational age and post-conceptional age (10,21). This methodological choice also limits the generalisation of the results regarding the effect of the intensity.

Our study provided new insights into the understanding of when to offer pleasant auditory stimulation to preterm infants in the context of developmental care. It is well known that exposure to human voices was beneficial for the preterm infants (15,22), but it should not compete with another activity such as sensory learning. Indeed, other studies reported that when different sensory stimuli were presented at the same time this created interference when they were non-contingent. In the context of developmental care (23,24), the attention resources of preterm infants towards their sensory environment should be preserved by giving them coherent multisensory stimulation. However, it could be helpful to use auditory stimulation during painful procedures as that could divert the infant's attention. Further investigation is needed to identify the factors of vulnerability or maturation that might or might not allow exposure to the female voice, in order to adapt the stimulations provided to infants according to their stage of maturation and their capacities of attention and self-regulation.

The limitations of our findings should be acknowledged. One of the limits of this study was that we compared the two voice conditions with the silence condition that had already been included in a previous study (14). In addition, 20 infants were not included in the voice condition groups because of drowsiness, sleeping or technical problems. It revealed the difficulty of obtaining one stable and valid quiet waking state in immature infants from a few days to a few weeks of life. That is why we decided to use the silence condition from the previous study.

CONCLUSION

This research provided a different and complementary approach to other studies on the exposure of vulnerable newborn infants to the human voice. Physiological parameters have mainly been studied (15,22), because the data were quite easy to collect and because haemodynamic stability is one of the first parameters to be monitored in preterm infants. By using our subjects early tactile manual abilities, and a procedure of habituation and discrimination, this study showed the interplay between auditory and tactile skills. It provides important information about the factors that might hinder the development of preterm newborn infants' sensory skills and modify their neurobehavioral development.

ABBREVIATIONS

dBA, decibel; nCPAP, nasal continuous positive airway pressure; NICU, neonatal intensive care unit.

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CONFLICTS OF INTEREST

The authors have no conflict of interest to declare.

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Table 1. Sound level in dBAs inside the incubator with just the background noise and with the addition of the two voice conditions at +5dBA and +15dBA.

	+5dBA	+15dBA	*p*
	M (SD)	M (SD)	
Noise with no voice (dBA)	55.6 (6)	54.9 (5.2)	0.645
Noise with voice (dBA)	60.7 (5.7)	69.8 (5.2)	**< 0.001**

Table 2. Preterm infants' general and medical characteristics according to the voice condition: +5dBA versus +15dBA.

Characteristics	+5dBA (N = 24)	+15dBA (N = 24)	*p*
	n (%) or Mean (SD)	n (%) or Mean (SD)	
Gender			1
Girl	14 (58.3)	14 (58.3)	
Boy	10 (41.7)	10 (41.7)	
Gestational age (weeks)	29+4 (2.2)	30 (2.4)	0.43
Post-natal age (days)	22.6 (15.3)	19.2 (12.2)	0.40
Post-conceptional age (weeks)	32+5 (1.6)	32+5 (2)	0.92
Birth weight (grams)	1,205 (330)	1,370 (505)	0.19
Weight at test (grams)	1,593 (341)	1,679 (455)	0.46
nCPAP during hospitalisation	22 (91.7)	22 (91.7)	1
Central venous catheter	22 (91.7)	16 (66.7)	**0.033**

nCPAP, nasal continuous positive airway pressure.

Table 3.

Habituation according to the shape of the object and the voice condition, measured as means (standard deviations)

Habituation parameters	+5dBA			+15dBA			*p*
	Total	Prism (n=11)	Cylinder (n=7)	Total	Prism (n=9)	Cylinder (n=8)	
Total holding time (seconds)	133 (83)	109 (64)	170 (101)	142 (109)	116 (92)	171 (125)	0.64
First two trials (seconds)	46.6 (26)	44.2 (22)	50.4 (32)	62.9 (30)	55.6 (21)	71.1 (38)	0.10
Number of trials	6.2 (2)	5.6 (1.6)	7 (2.4)	6.1 (2.3)	5.4 (2)	6.8 (2.5)	0.81

Habituation parameters = total holding times, holding times for the first two trials and number of trials during habituation. Object shape = prism versus cylinder. Voice condition = +5dBA versus +15dBA.)

Table 4.

Discrimination parameters for the groups and voice conditions, measured as means (standard deviations).

Discrimination parameters	+5dBA		+15dBA		p
	Experimental (n=7)	Control (n=11)	Experimental (n=8)	Control (n=9)	
Last two habituation trials (s)	4.2 (3)	3.6 (2.7)	6.1 (5.5)	6.3 (4.4)	**0.020**
Two test trials (s)	14.7 (12.9)	9.6 (6.3)	19.5 (17.4)	17 (13.1)	**0.044**

Discrimination parameters = holding times for the last two habituation trials and holding times for two test trials). Group = experimental versus control. Voice condition = +5dBA versus +15dB.

Table 5. Preterm infants' general and medical characteristics according to silence versus voice conditions.

Characteristics	Silence (n = 26) n (%) or Mean (SD)	Voice (n = 48) n (%) or Mean (SD)	p
Gender			0.49
Girl	13 (50)	28 (58.3)	
Boy	13 (50)	20 (41.7)	
Gestational age (weeks)	30+3 (2.8)	29+6 (2.3)	0.30
Post-natal age (days)	18.8 (15)	20.9 (13.8)	0.55
Post-conceptional age (weeks)	33 (1.6)	32+5 (1.8)	0.42
Birth weight (grams)	1442 (467)	1284 (430)	0.16
Weight at test (grams)	1676 (316)	1636 (400)	0.66
nCPAP during hospitalisation	19 (73.1)	44 (91.7)	**0.032**
Central venous catheter	21 (80.8)	38 (79.2)	0.87

nCPAP, nasal continuous positive airway pressure.

Table 6. Parameters of habituation by object shape and condition, measured as means (standard deviations).

Habituation parameters	Silence condition			Voice condition			p
	Total	Prism (n=12)	Cylinder (n=12)	Total	Prism (n=20)	Cylinder (n=15)	
Total holding time (seconds)	106 (64)	108 (71)	105 (61)	137 (95)	112 (75)	171 (110)	0.09
First two trials (seconds)	59.7 (39)	56.1 (35)	63.3 (45)	54.5 (29)	49.3 (22)	61.4 (36)	0.80
Number of trials	5.3 (1.2)	5.1 (1.1)	5.4 (1.4)	6.1 (2.1)	5.6 (1.8)	6.9 (2.4)	**0.05**

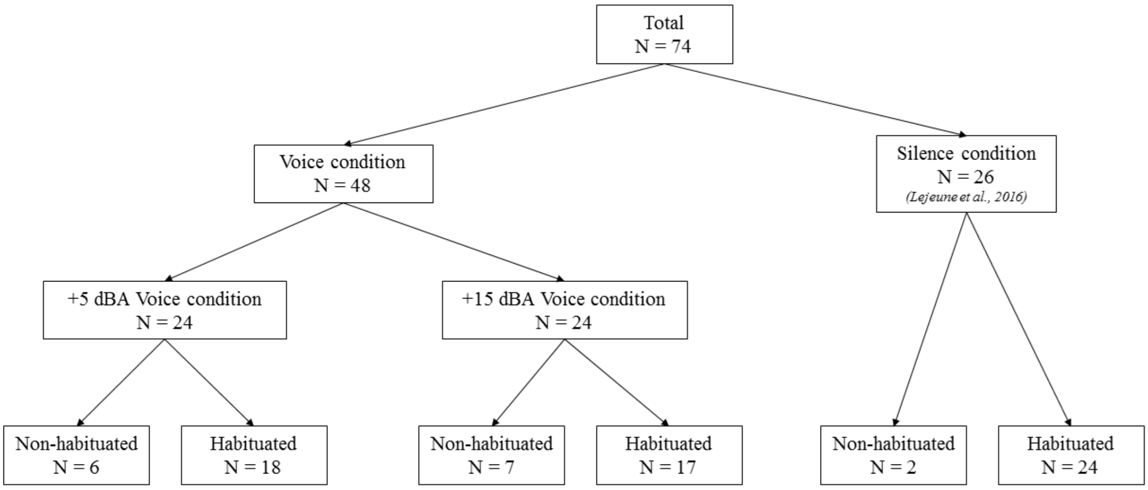
Parameters of habituation = (total holding times, holding times for the first two trials and number of trials during habituation. Object shape = prism versus cylinder. Condition = silence versus voice.

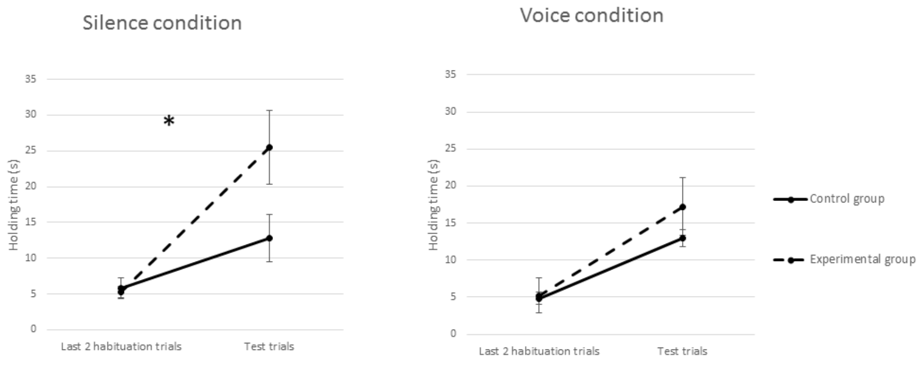
Figure legends

Figure 1. A preterm infant holding the cylinder

Figure 2. Flow chart of participants in the study

Figure 3. Means and standard errors of discrimination according to group (control/familiar object versus experimental/novel object) and condition (silence versus voice)


Total
N = 74
Voice condition
N = 48
Silence condition
N = 26
(Lejeune et al., 2016)
+5 dBA Voice condition
N = 24
+15 dBA Voice condition
N = 24
Non-habituated
N = 6
Habituated
N = 18
Non-habituated
N = 7
Habituated
N = 17
Non-habituated
N = 2
Habituated
N = 24



Silence condition
Voice condition
Holding time (s)
35
30
25
20
15
10
5
0
*
Last 2 habituation trials
Test trials
Control group
Experimental group