Interhemispheric integration of shapes in infancy

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Abstract

Integrating simultaneous stimuli presented in each visual field requires an efficient connection between the two brain hemispheres. A previous study showed that infants fail in this process before age two, suggesting an underdevelopment of the *corpus callosum*, which limits the information transmission between the two hemispheres. We hypothesize that infants under age two may have two types of experience at the same time, similar to split-brain patients. To explore this idea, we presented two matching or non-matching shapes as stimuli to 9-to-13-month-old infants and observed their looking behavior. The analysis of score preference shows a difference between the bilateral and unilateral conditions which confirms our hypothesis. However, the results of the looking-time mean show no effects, caused by the development of different types of preference.

Summary

The human visual system is reliant on the interaction of two visual fields. Stimuli from the left visual field are processed in the right hemisphere of the brain and vice versa. To integrate and compare this visual information, the two brain hemispheres are connected by the *corpus callosum*, a collection of fibers. However, the *corpus callosum* is not fully efficient during early infancy. This suggests that infants under age two cannot integrate stimuli when they are presented simultaneously in the two different visual fields. This study focuses on the perception of shapes across hemispheres in order to determine whether children can tell if shapes match or not when they are presented simultaneously. The results of score preference show a condition difference and confirm our prediction. Further work will continue in studying this hypothesis.

1 Introduction and Motivation

Humans have two brain hemispheres but experience just one interpretation of external stimuli. The left and right hemispheres have different functions and must be connected to exchange information in order to analyze a situation. The left hemisphere is generally dominant in speaking, communication and language while the right hemisphere is more active in vision and spatial cognition [1, 2]. Interhemispheric interactions are critical to the good functioning of the human brain [1]. The most important connection between the two hemispheres is the *corpus callosum* (see Figure 1) which is a collection of fibers with approximately 200 million axons that links the two hemispheres. Subcortical pathways also connect the two brain hemispheres.

Patients whose *corpus callosum* has been cut in order to control intractable epilepsy have reduced interhemispheric connections. They can live normally [1, 2] and learn to interact with the world around them and communicate; however, these split-brain patients suffer from perceptual interaction problems. They are not able to integrate the visual information between their two visual fields when stimuli appear simultaneously [3]. For example, the patients are not able to say if stimuli are same or different because the information does not transfer between the two sides of the brain.

Another phenomenon observed in split-brain patients is an emergence of hemispheric rivalry, where one hemisphere is unaware of the signals relayed by the other hemisphere. For example, a patient might unbutton his shirt with one hand while the second hand buttons it [4]. In this case, split-brain patient seem to have two conscious minds in one body. The separation of the two brain hemispheres by cutting the *corpus callosum* reveals the complexity of the human mind. Each brain part may have its own consciousness and a system of perceiving and thinking. When the hemispheres are normally connected together, they bind a single consciousness, but split-brain patients do not have this connection and therefore, experience the world as if they were separate people.

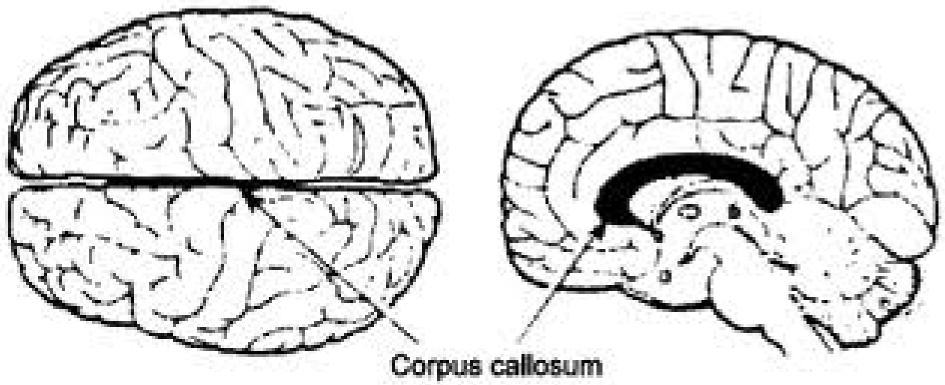

Figure 1: *The Corpus callosum* This collection of fiber located in the middle of the brain is constituted by 200 million axons, connects the left and right brain hemispheres and enables the interhemispheric information transfer.

1.1 Hemispheres interaction in infancy

How and how early do connections between the two hemispheres enable the brain to function as a unity? The study of infant brain interactions allows exploration of the process of interhemispheric connection.

Interhemispheric communication is not completely developed at birth. The transmission of information and coordination between the two hemispheres develop slowly during infancy while the *corpus callosum* grows. Its size doubles by the age of two and continues growing during childhood. Thus, it may be plausible that infant brain hemispheres function in tandem and infants may possibly share the same experience as split-brain patients.

Liegeois [5] showed that interhemispheric coordination of visual information emerges in development at the age of 24-28 months. The researchers found that younger infants could not compare simultaneous visual pictures in the bilateral condition, in which the two stimuli are processed in different hemispheres, but were able to integrate information in the unilateral condition, in which stimuli are processed in the same hemispheres. This failure is probably caused by the underdevelopment of the *corpus callosum*, which does not allow the coordination of the two hemispheres. However, the protocol of this study did not only focus on the integration of shapes, but was dependent on the process of face recognition, with stimuli consisting of faces whose eyes were either two matching or two non-matching shapes. Therefore, the younger infants (under the age of two) might have failed in integrating the identity of shapes because of the difficulty of processing two tasks at the same time - both facial and shape recognition. The operant conditioning protocol could also have been a reason of failure in younger infants because of the difficulty of learning more than one predictive rule at the same time. In our study, we will only focus on the integration of shapes in order to isolate the relevant effect and use a familiarization instead of an habituation process.

Studying infant's brain interactions can identify many applications clarifying the role of the *corpus callosum* and the information transfer between the two brain hemispheres. A better understanding of these mechanisms could help to develop strategies in treating psychiatric disorders and understanding the infant's experiences and development.

1.2 Infant perception

Infants must perceive the world in order to interact with it and learn. They perceive it better than most people think, probably because we primarily observe their motor abilities and cannot observe cognitive abilities directly. The key in studying the infant's perception abilities lies in nonverbal responses (behavioral and physiological measures) because infants cannot speak to transmit their experiences.

Robert Frantz [6] developed a *looking-time* method for studying infant perception and cognition. In this method, the researcher shows two types of pictures to the child, observes her/his looking behavior, and measures the looking-time for each. The looking-time is the time that the infant spent looking at the picture before looking away for more than a definite time threshold (usually one or two seconds).

If the infant looks longer at one type of picture, we can first say that the infant is able to discriminate the two types. We can also say that s/he has a preference for the picture at which s/he looked longer. There are two major types of preferences that develop due to exposure: familiarity preference (longer looking-time for familiar, already-known stimuli) or novelty preference (longer looking-time for new stimuli). However, we cannot predict what type of stimuli will be the preference, as this depends on the infant.

1.3 Infant visual integration

As the *corpus callosum* is developing in early childhood, and therefore the interhemispheric communication is not totally efficient yet, we suppose that young infants may have two different experiences of the world at the same time and have a double consciousness. The infants may have one view of the world with the left visual field processed by the right hemisphere and a different view with the right visual field processed by the left hemisphere. The goal of this study is to see if infants can transfer and process visual information across the two hemispheres and to study if they may have a double consciousness in early infancy.

In this study, during baseline and test, the infants will be shown pictures with two matching or non-matching shapes. During familiarization, matching shapes only will be shown, either both on one side of a fixation point (the unilateral condition) or one on each side of the same fixation point (the bilateral condition). If the stimulus is on the right side while infants are looking at the fixation point, the information are sent into the left hemisphere and vice versa (see Figure 2). Before familiarization (during the baseline test), we can expect to observe a preference for some pictures (matching or non-matching) [7]. However, we expect that the initial preference of the infants in the unilateral condition will change after familiarization because they can recognize and integrate the shapes, as explained in Turk-Browne, Scholl and Chun (2008) [8]. In the bilateral condition, we expect

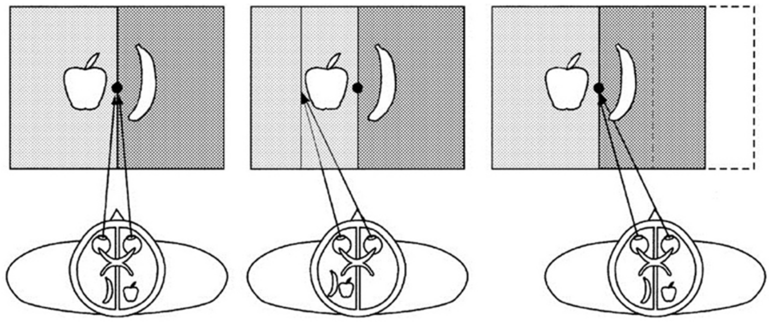

Figure 2: *Stimuli lateralization* By looking at a specific fixation point, we can control where the visual information is processed.

that the familiarization will not affect the looking-time at pictures with matching shapes. This expectation is based on the finding that, if the children cannot exchange and analyze both visual stimuli simultaneously (as in Liegeois, Bentejac and de Schoenen (2000) [5]), they cannot integrate whether the shapes are matching or not. This means that every new-presented stimulus will seem new for them and their looking-time at it will not be affected. However, it is possible that children get bored of shapes over time and a decrease of looking-time can be observed.

This study will also use the number of looks at each shape for each trial. The number of looks brings other perspectives on the analysis and is useful to understand the process of shape recognition and comparison.

If our expectations are confirmed, it will mean that 9-to-13-month-old infants cannot integrate two stimuli simultaneously across the two hemispheres and that the hypothesis of a split-brain experience in early childhood should be investigated further.

2 Methods

The experiments explored the effect on 9-to-13-month-old infants when they are familiarized with pictures with two matching shapes, either with both shapes on the same side (left or right, unilateral condition) of a fixation movie, or with one shape on each side of the same fixation movie (bilateral condition). The experiment included a baseline test with six trials, a familiarization period (unilateral or bilateral) and a test with six trials.

2.1 Participants

Fifty-two infants (28 males and 24 females) participated in this study. Twenty of them (11 males and 9 females) were excluded because of crying (n=4), fussiness (n=9), distraction (n=1) or disinterest before the end of the six test trials (n=6), with the experiment repeated under the same conditions with another infant in order to maintain counterbalancing factor. The mean age of the infants who were not excluded was 10 months and 28 days. The ages ranged from 8 months and 24 days to 13 months and 23 days.

2.2 Apparatus

The experiments were run in the Boston Children's Museum and in the Early Childhood Cognition Laboratory (ECCL) at the Massachusetts Institute of Technology (MIT). The testing room and apparatus had the same configuration in both locations. The room was dark and only indirectly lighted by two faint bulbs. Infants sat on a parent's lap. The parent sat on a chair facing a monitor of dimension 81cm x 30cm at a distance of 1.5m. The monitor was on a 50cm-high table and faced the child at eye level. The experimenters sat behind the monitor and were hidden by it so that the child could not see them. A webcam was placed in the middle of the top of the monitor to enable the experimenters to see the child during the experiment. A digital camera held by a tripod above the screen recorded the full experiment.

The videotape was used afterwards to analyze the infant's looking-time and eye movements (see appendix B).

2.3 Stimuli

The stimuli during baseline and experimental testing consisted of two black shapes, either matching or non-matching, projected on a white background on the screen. The stimuli during familiarization consisted of flashing two matching shapes on the screen in a random order while the child was looking at the fixation movie. In the bilateral condition, the two shapes were placed asymmetrically from the fixation movie to assure that infants cannot see them in both visual fields (see appendix A). Two different fixation movies were used: a colorful spinning ball and a laughing baby. Between 100 and 120 shapes were shown in this section, but no shapes were shown more than twice. We switched the fixation movie when the child seemed to be bored with it in order to keep her/his attention on the screen. The permutation of the fixation movie differed for every child, but we assume that it did not have any influence on the behavior and integration of visual information. A second option to keep the child's attention on the screen was to change the background music. We only used this method when the child seemed to become very bored and the switch of the fixation movie was not sufficient to retain her/his attention.

For this study, we used six matching pairs and six non-matching pairs of shapes for baseline and test. The pairs were divided into two sets (A, B) and each set consisted of three matching pairs and three non-matching pairs used during baseline and testing (see appendix B). 73 other shapes were used for the familiarization section. All the shapes were different from each other.

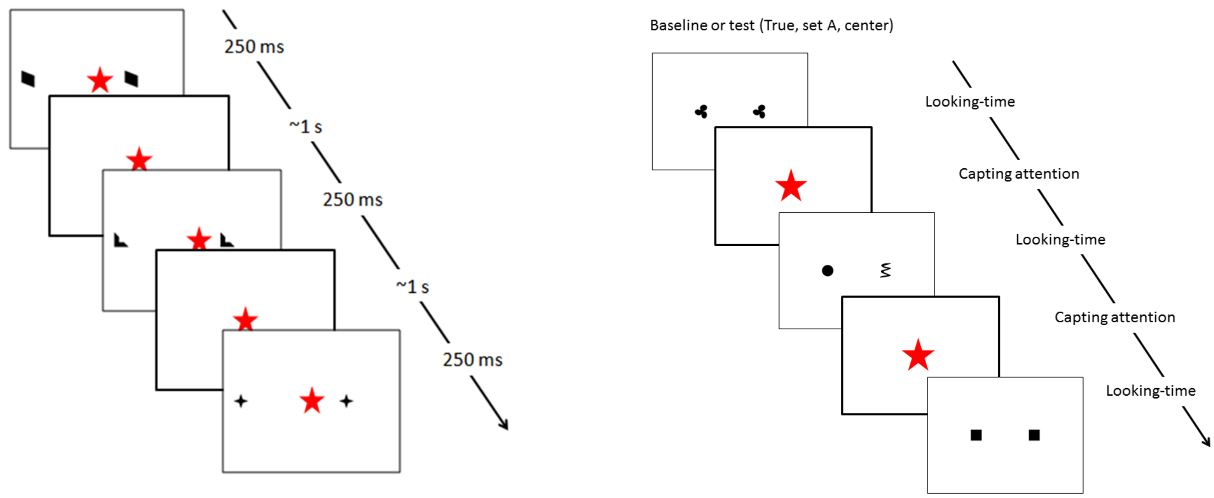

Figure 3: *Example of experiment procedure* During familiarization (figure on the left), about one picture per second was briefly presented (250ms) while the infant was looking at the fixation movie (shape(s) on the left of fixation movie are processed by the right hemisphere and shape(s) on the right are processed by the left hemisphere). During baseline and test (figure on the right), the infants were shown six pictures with matching and non-matching shapes alternatively. The red star represents the fixation movie.

2.4 Procedure

The experiment started with a baseline test. It included six trials in which pictures of either two matching or two non-matching shapes were shown alternatively in alternating order. Half of the children started with the matching shapes (true condition) and the second half started with the non-matching shapes (false condition) so that any preference caused by the starting order can be avoided.

Before starting the baseline test, we asked the parent and any other person present in the testing room to close their eyes and remain neutral to assure that the infant could not be influenced by their looks or reactions to the pictures. Before projecting the picture, we showed a fixation movie (colorful spinning ball) with bell music to attract the child's attention. Once s/he was looking at it, we projected the picture and let her/him look at it until s/he looked away for more than one second. Then we showed the fixation movie again and repeated the same procedure for the next five trials (see Figure 3).

After baseline, the second part consisted of a familiarization period. During this section, two matching shapes were flashed up quickly (250ms) on the screen (see Figure 3). This duration is less than the required time for an eye saccade, so we are sure that the infant cannot move her/his eyes during this duration (as in Liegeois, 2000).

Following familiarization, six test trials were done using the same procedure as the baseline, but the set of shapes was different. Half of the infants were shown set A during the baseline and set B during the test, the second half of them were shown set B during the baseline and set A during the test. We used two different sets to make sure that any preference or results could not be caused by the attraction or complexity of specific shapes. In each set, the infants were equally separated into the true and false condition and into the unilateral and bilateral condition (see Figure 4).

Condition	True						False					
Set	A			B			A			B		
Side	C	R	L	C	R	L	C	R	L	C	R	L
# infants	4	2	2	4	2	2	4	2	2	4	2	2

Figure 4: *Summary of the repartition of the infants for each condition* (Side corresponds to the position of the fixation movie during familiarization, C=center, R=right, L=left). Total number of infants=32.

The baseline test enables us to compare the looking-time before and after familiarization and to analyze if a difference in looking-time emerges.

2.5 Analysis

The videos were coded to extract the looking-time until the first continuous one-second-lookaway for each trial. Coding was performed by two separate coders (the author and another researcher from the ECCL). If they disagreed by more than 10 seconds on any trial, the video was recoded. The average of disagreement as a percentage of looking-time per trial is 13%. Data from each coder were averaged to obtain results.

The video was also used to count the number of looks at each pair of shapes. Two experimenters counted the number of times the child moved her/his eyes back and forth between the two shapes on each trial. The average was used for the results. Trials in which at least one coder could not count the number of looks were excluded (n=36 out of 384 trials).

3 Results

3.1 Change in preference

In Figure 5, we compare the proportion of looking-time spent on matching shapes between baseline and test only for the first four trials. We suppose that the four first trials are the most representative of the looking-behavior because infants can show a decline of attention or get bored over time. The sum of looking-time on matching shapes is divided by the total looking-time (sum of the looking-time at matching and non-matching) for each infant. A 0.5 proportion corresponds to an equal looking-time at matching vs. non-matching. The line (y=x) corresponds to an equal looking-time at matching during baseline and test.

The area under the diagonal line represents the infants who show a novelty preference, meaning that they spent less time looking at matching shapes after familiarization, becoming bored and showing a decline in interest for matching shapes. The area above the line represents the infants who show a familiarity preference, which means that they look longer at matching shapes after familiarization. According to our expectation, the infants in bilateral condition should be more broadly distributed since the preference should not change, and the infants in unilateral condition should be under or above the diagonal line since their looking-time on matching should change after familiarization.

In Figure 6, we compare the difference in proportion of looking-time and number of looks

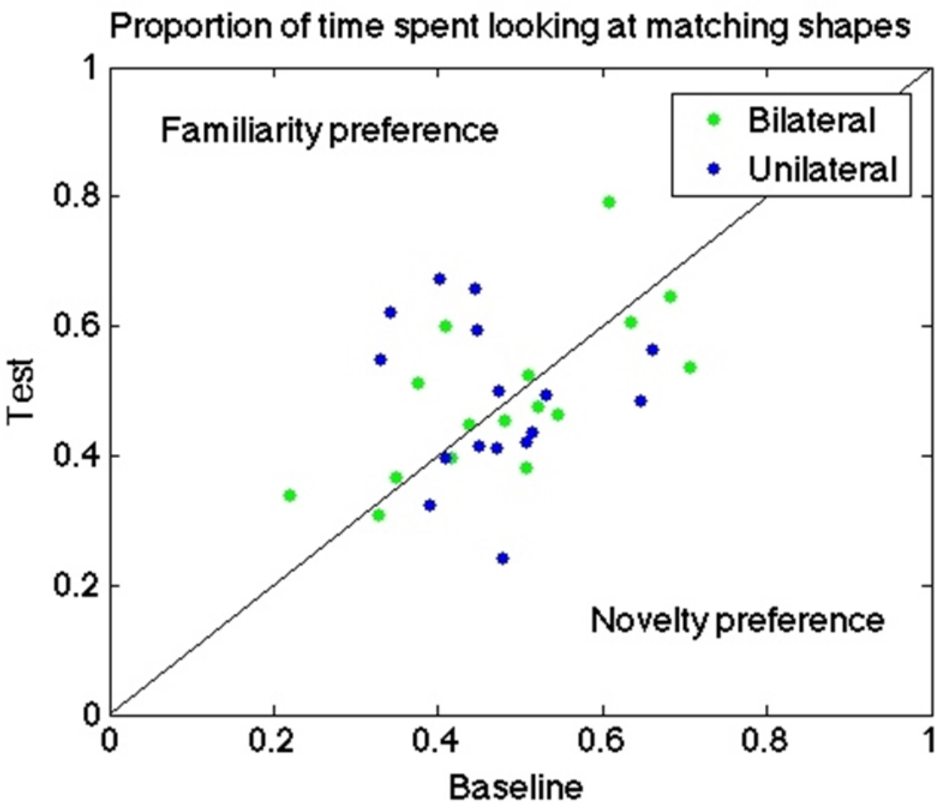

Figure 5: *Proportion of time spent looking at matching shapes during baseline and test* Each dot corresponds to an infant.

at matching shapes. The absolute value of the difference between proportion at baseline and test was averaged and compared. We predict that infants in the unilateral condition can recognize the identity of shapes and their preference after familiarization will change (either novelty or familiarity preference). On the other hand, we predict that infants in the bilateral condition cannot recognize the identity of shapes across hemispheres. Therefore, their preference will change less after familiarization. In such an analysis, we expect to observe a significant difference between the variation of the preference before and after familiarization for unilateral vs. bilateral condition and predict that the difference will be greater in the unilateral condition.

We can observe a significant difference ($p<0.05$, one tailed, Mann-Whitney U-test) be-

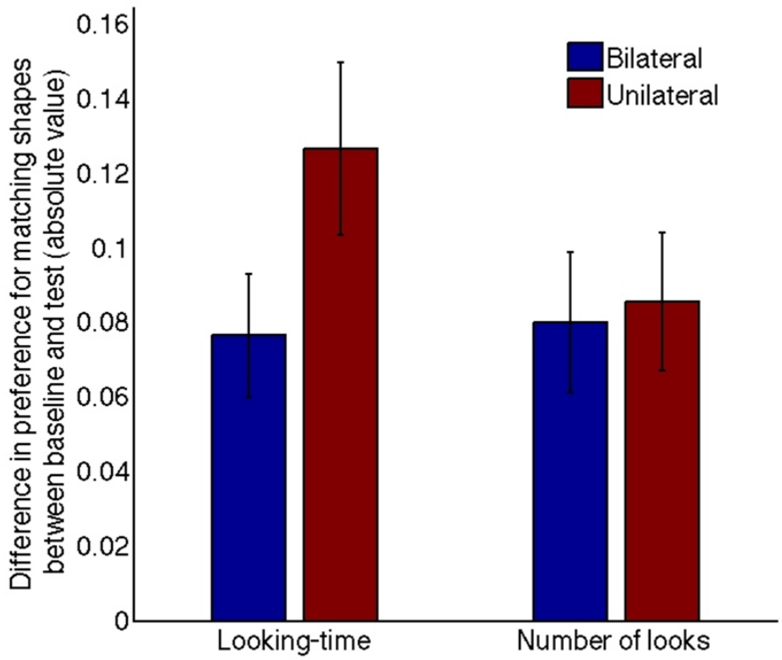

Figure 6: *Difference in proportion of looking-time at matching shapes between baseline and test*

tween the mean difference in preference in the bilateral condition (m=0.077, standard error= ±0.017) and unilateral condition (m=0.127, standard error= ±0.023).

We do not observe the same difference when computing the preference based on the number of looks. There is no difference (p=0.83, Mann-Whitney U-test) between bilateral (m=0.080, standard error= ±0.019) and unilateral condition (m=0.086, standard error= ±0.019). The change in preference that we observe is therefore only expressed in the lengths of individual looks, rather than as a tendency to look back and forth between the shapes. The reason of the difference between the results in looking-time and number of looks could not be explained so far.

3.2 Mean looking-time

The means of looking-times, in contrast to individual preferences, do not reveal any condition specific effects of familiarization on preferences.

Figure 7 shows the means of the looking-time on the first four trials during test and baseline. The counterbalanced conditions were arranged in order in this graph. Images 1 and 3 are matching; Images 2 and 4 are non-matching. For half of the infants, Image 1 is the first one they saw and for the second half Image 2 is the first one they saw. (Recall that during experimentation, half the infants started with matching and half with non-matching to avoid any preference for the first type that they saw.)

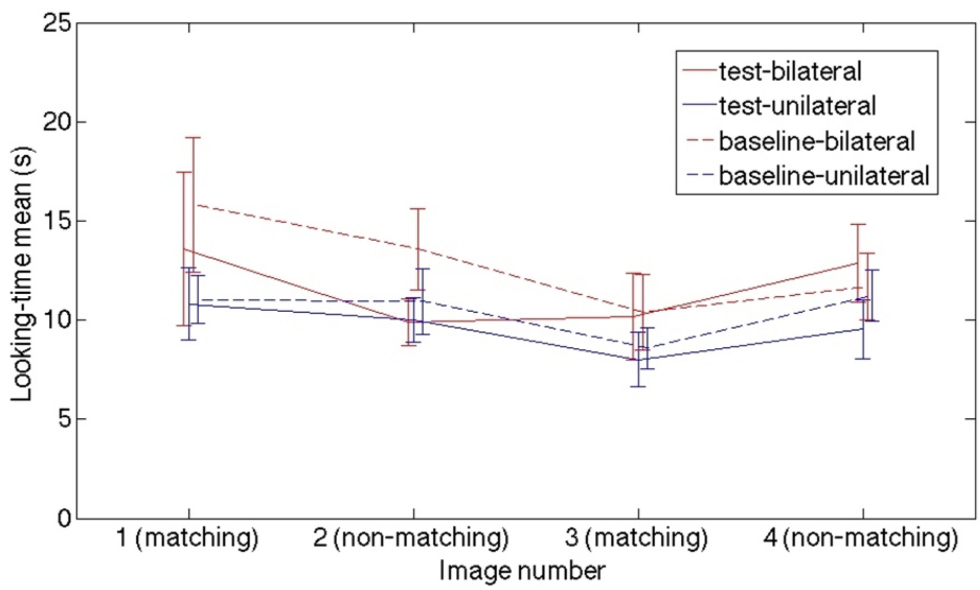

Figure 7: *Mean of the looking-time* The mean of looking-time is represented for the first four trials for baseline and test. The red line corresponds to the bilateral condition and the blue line to the unilateral condition.

We can observe a difference in the looking-time in baseline between unilateral and bilateral condition. The bilateral condition mean is greater than in unilateral condition. Always between bilateral and unilateral conditions, we can observe a greater decrease in bilateral condition after familiarization. These differences cannot be explained.

Furthermore, the mean of looking-time in bilateral condition is greater in baseline than in test and the looking-time decreases over time. This can be explained by the fact that infants get bored seeing shapes during the test. The looking-time in unilateral condition is stable and there is no significant difference between the baseline and test. The two lines are, surprisingly, parallel. The mean in the test trials is just under the mean in the baseline trials. This suggests a decline of attention over time.

We can observe a little preference for non-matching shapes; however, it does not change after familiarization. This preference can be caused by the fact that infants may need more time to compare and recognize the non-matching pairs compared with the time needed to recognize the matching pairs. Overall, the results do not show any significant difference regarding condition and type of shapes and we do not observe a change for preference between baseline and test.

Figure 8 shows the mean of the number of looks at the first four images during baseline and test. As in the previous figure (Figure 7), only the first four trials are represented. Images 1 and 3 are matching; Images 2 and 4 are non-matching.

In the bilateral condition, we can observe the same decline as in Figure 7 for the looking-time over trials. The baseline and the test differ little, except for the fourth trial. There is no tendency for any type of shapes. In the unilateral condition, we observe a decrease of the number of looks over trials, which is regular in test. In the baseline, we can observe a little but no significant difference between matching and non-matching. In general, infants in the bilateral condition tend to have a greater number of looks than infants in the unilateral condition. This is probably a random effect since the baseline test occurred without any previous habituation and the procedure and images were the same in both conditions.

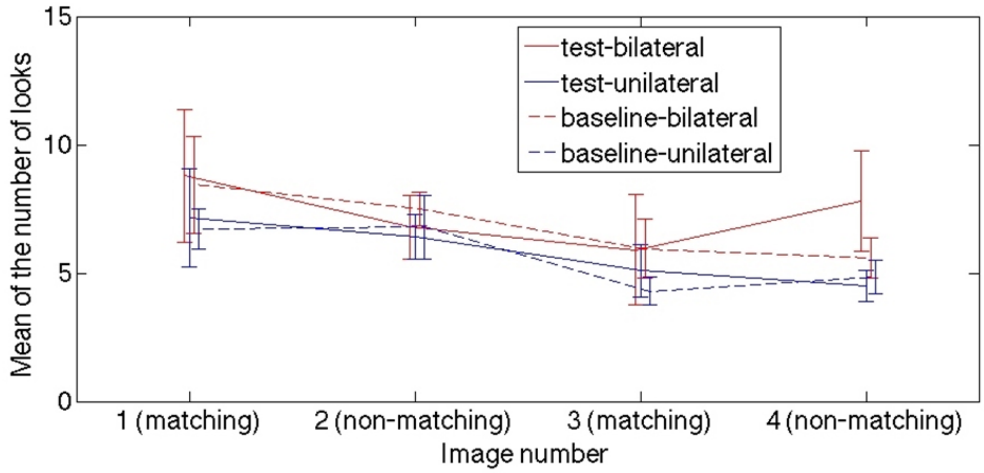

Figure 8: *Mean of number of looks* The mean of the number of looks is represented for the first four trials for baseline and test. The red line corresponds to the bilateral condition and the blue line to the unilateral condition.

Furthermore, this difference can also be observed in the mean of looking-time.

4 Discussion

The results support our hypothesis that infants between 9 and 13 months of age cannot integrate simultaneous stimuli when presented in the two different visual fields. Results based on the preferences for matching shapes show a tendency (more preference change in the unilateral condition) that can confirm our prediction. Analysis of looking-time and number of looks does not show any clear tendency. The present study included only 16 children per condition and may have been unable to detect a condition difference in looking-time. However, some individual children demonstrated clear effects of familiarization in the unilateral condition and no effects in the bilateral condition.

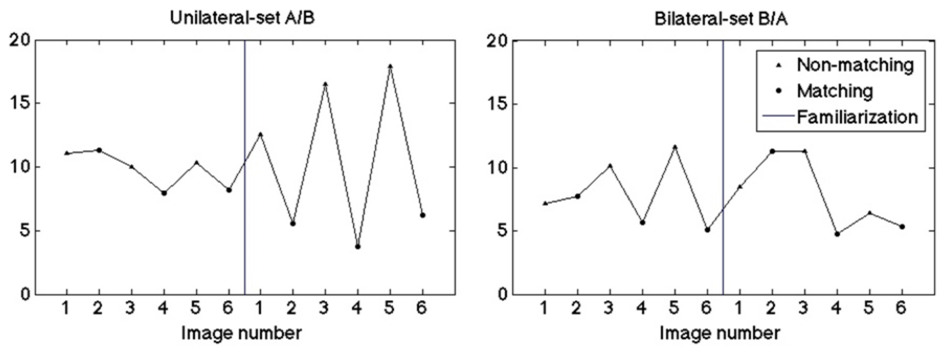

Figure 9: *Example of the looking-times of two infants: representative data*

Figure 9 shows the looking-times on each trial. The infant in the bilateral condition does not show any clear preference before or after familiarization for any types of pictures. The lack of preference may suggest that familiarization does not have any effect on this infant because s/he cannot process the identity of the shapes during familiarization. In the opposite condition (unilateral), the infant has no real preference during baseline but show a strong preference for non-matching shapes during test, potentially caused by familiarization.

However, we cannot rely on these two results. Our primary expectation suggested that infants in the unilateral condition would become less interested in matching shapes after familiarization. However, we also observe in Figure 5 preference changes for familiarity and for novelty. This phenomenon has already been observed in many previous studies [9, 10, 11]. Infants may show either novelty or familiarity preferences after a habituation or familiarization process. In the first few trials, infants may show a familiarity preference and then show a novelty preference. The preference change also with age. Rose et al. (1982) [10] compared preferences between 3.5-month-old and 6.5-month-old infants. They observed that the younger infants showed a preference for familiar stimuli whereas the older infants showed a preference for novel stimuli. They also observed that preference may depend on the duration of the familiarization. Infants can show a familiarity preference after a brief familiarization followed by a novelty preference after more experience. The development of two types of preference are not specific to infants. This phenomenon has also been observed in adults [9], which may explain the contrasted results.

Figure 10 confirms the results of the previously cited studies. It represents the difference in preference for each infant according to the age. The score preference is positive if the infant looks longer at matching shapes during test than during baseline (a familiarity preference) and negative if the infant looks less at matching during test than during baseline (novelty preference). Zero corresponds to no change.

We predict a change from familiarity to novelty preference with age, but only in the unilateral condition, where we believe that these changes are due to familiarization, and not in the bilateral condition where the changes are due to chance variation. Indeed, in the unilateral condition, we observe a significant negative correlation between age and change in preference (ρ=-0.55, p=<0.05, Spearman rank correlation), but in the bilateral condition, we observe no significant correlation (ρ=0.059, p=0.83, Spearman rank correlation).

This figure also shows that the value of the preference changes varies with the age of the sample. The younger infants seem to develop familiarity preferences whereas the older seem to develop novelty preference.

In order to obtain more significant data that support our hypothesis more strongly, we can adapt the procedure according to the present observations. First, we can reduce the age range according to the distribution of the infants in Figure 10. We can divide the infants into two groups according to the type of preference that they develop. We can take 12-to-14-month-

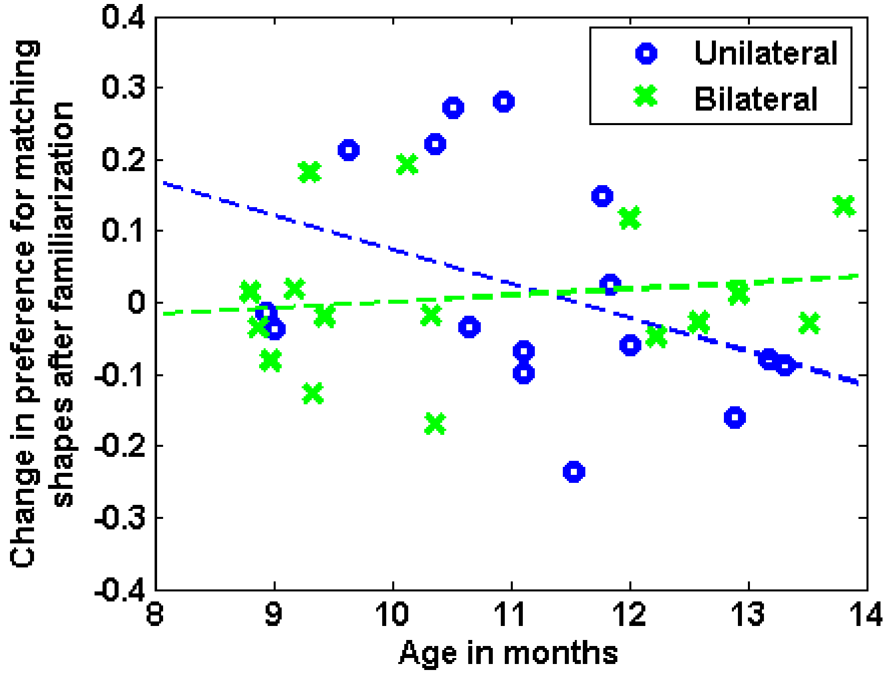

Figure 10: *Preference score according to the age* Each dot represents the score preference for one infant. The positive value corresponds to a familiarity preference, the negative value corresponds to a novelty preference. The infants are separated according to the conditions.

old infants, expected to show a novelty preference or 9-to-11-month-old infants, expected to show a familiarity preference. Another adaptation can be to add more familiarization to shift towards novelty [10].

Secondly, it may be possible that the familiarization procedure was too strenuous for the infants. The quick flashing of shapes may require a full concentration, and young infants may find this task difficult or the flashing time may be too short for infants can recognize the shapes. Let us note that the two youngest infants in the unilateral condition showed no change in preference, which illustrates this hypothesis.

The procedure of this study excluded a large number of infants (20 of 52 were excluded). Infants were mostly excluded because of fussiness or crying. This large number of excluded infants may be caused by many environmental effects. First, almost of all the infants were tested in the Boston Childrens Museum. The experiment took place in a dark room and the infant had to leave the place where s/he was playing to participate. Secondly, it may be possible that the procedure of the experiment was too long and required a lot of concentration, as explained before for familiarization.

Another hypothesis to explain the lack of variation in looking-time and number of looks results could be the number of different shapes used for the experiments. Since every trial in the baseline and test trials consisted of varied shapes, the stimuli might seem new in every trial. It may be possible that a pair of matching shapes appears more interesting or more complex than a non-matching pair with these differences overwhelming any difference in how interesting matching and non-matching shapes are. An alternative to avoid this effect can be found by using sets of dots (see Further work).

The present study confirm our prediction, but have to be explore further, improving the procedure to get more significant results.

5 Future work

Working with human beings can be difficult because many variables have to be taken into consideration. The Early Childhood Cognition Lab (ECCL) of MIT is continuing work to explore further the ideas behind this study. ECCL is working to set up such a program available online, allowing more samples to be collected in less time from a larger population as families can participate from home. Using webcams, experimenters can record the experiments remotely and analyze them as we did in present study.

This project also includes a second study about the hypothesis of split-brain babies, using the same procedure described here (without baseline) but with sets of dots instead of shapes. The split-brain hypothesis suggests that children who see eight dots on either side will have two experiences at seeing eight dots, rather than one experience at seeing sixteen dots. In order to use sets of dots, children must be able to discriminate them. There is clear evidence that infants can discriminate sets of eight vs. sixteen dots at the age of six months [12]. This study showed that 6-month-old infants can discriminate eight vs sixteen dots but cannot do the same discrimination with set of eight vs twelve dots, providing evidence that 6-month-old infants have a sensitivity for dot sets with a ratio of 1:2, disregarding the set size. A second study [13] showed that 5-month-old infants can discriminate sets of 8 vs 16 dots when the stimulus is presented during 2s. Both of these studies allow us to use sets of dots and associate them with lateralization of stimuli (flashing during familiarization by controlling the look with fixation movie).

We will explore in further work if older infants (11-to-12-month-old) can represent and integrate large numerosities across hemispheres. First, infants will be familiarized with either pictures of eight dots on either side of fixation movie, or sixteen dots on one side of fixation movie, or eight dots on one side of fixation movie. After familiarization, they will be shown a set of six pictures with either eight or sixteen dots in counterbalanced order. It is predicted that, after familiarization, we will observe a difference in the distribution of looking-time. If the interhemispheric connection is not efficient enough to enable the approximate number system working effectively, the infants in the condition with eight dots on either side will behave more like infants with eight dots on one side and not like infants with sixteen dots on one side.

6 Conclusion

The results of this study confirm our prediction. However, the procedure of the experiments has to be improved, as many factors can influence the infant's looking behavior and response. The large number of diverse shapes used in the procedure may have significant influence even if we are not able to show it for the moment. The preference that the infants developed changed with each infant. This can explain the lack of clear effect in the analysis of the looking-time and numbers of looks. Since the preferences vary, comparison of the looking-time means does not permit us to show a clear tendency. However, analysis of the preference scores confirm our expectation although the significance must be reduce to assert definitive evidence. For this reason, the present procedure has to be reviewed, including more samples, reducing and targeting more effectively the age range for further work.

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A Overlap phenomenon in visual midline

The visual field is divided into two halves: the left visual field which projects to the right hemisphere and the right which projects to the left hemisphere. In the middle, there may be up to a 1-2 degree overlap, where information is processed by both hemispheres (see Figure 11) [14].

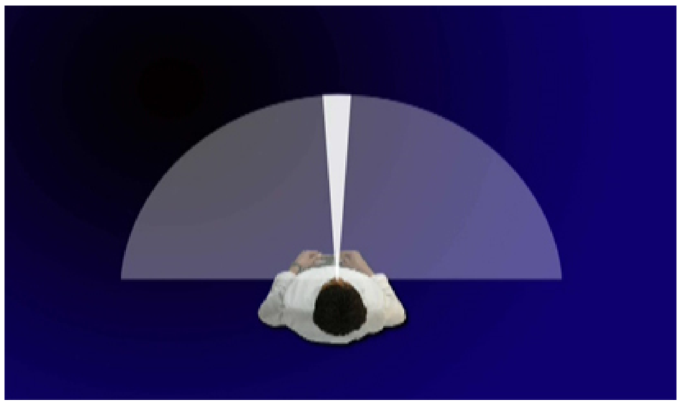

Figure 11: *Visual field* One-to-two degrees overlap in the middle. In this area, the visual information is sent to the two hemispheres.

During familiarization, we presented one shape on each side of the fixation movie or both on the same side. In order to make sure that the shapes are not processed in the two hemispheres (this means that they are in the area of visual fields overlap), the distance between the fixation movie and the shapes has to be bigger than the projection of the visual overlap on the screen at a distance of 1.5m. This projection corresponds to a 2.6cm-wide surface on the screen for a one-degree overlap and 5.2cm-wide for a two-degrees overlap. For our stimuli, the distance between the fixation movie and each shape was greater than 5.2cm to avoid any undesirable effects. In the bilateral condition, the two shapes were at the same distance as in the unilateral condition, but with one on either side of fixation movie. One was more distant from the fixation movie than the other (distance of more than 5.2cm however).

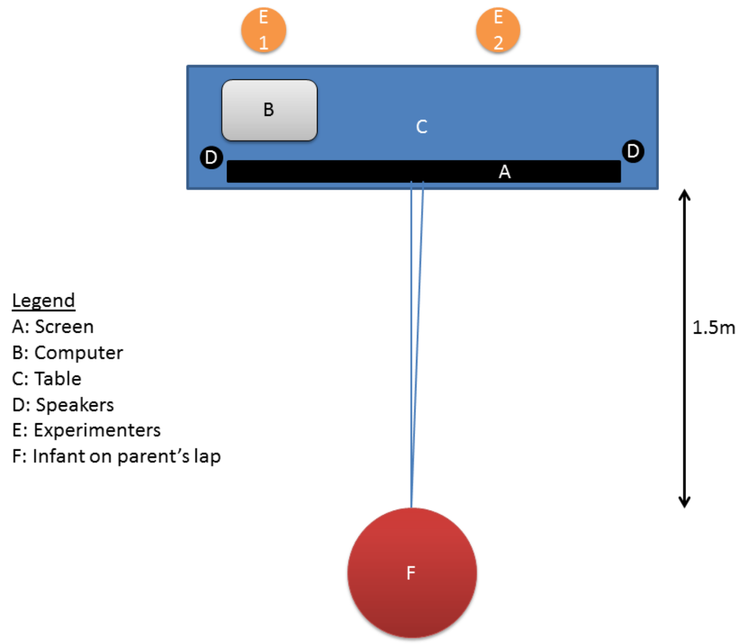

Figure 12: *Schematic apparatus presentation* The one-to-two degrees overlap corresponds to 2.6cm to 5.2cm on the screen at a distance of 1.5m.

B Methods

B.1 Apparatus

The experimenters sat behind the monitor and were hidden by it. The monitor stood on a 50cm-high table. The command computer was on the table and one of the experimenters projected the stimuli using MATLAB. The infant sat on his parent's lap at a distance of 1.5m from the monitor. Figure 12 gives a schematic outline of the organization of the apparatus during the experiments.

B.2 Stimuli

The stimuli used in baseline and test are presented in Figure 13. Set A and B consisted of 6 images (3 matching pairs and 3 non-matching pairs). The stimuli were presented in counterbalanced order, beginning with either the first picture with matching shapes or non-matching shapes and then alternating between matching and non-matching.

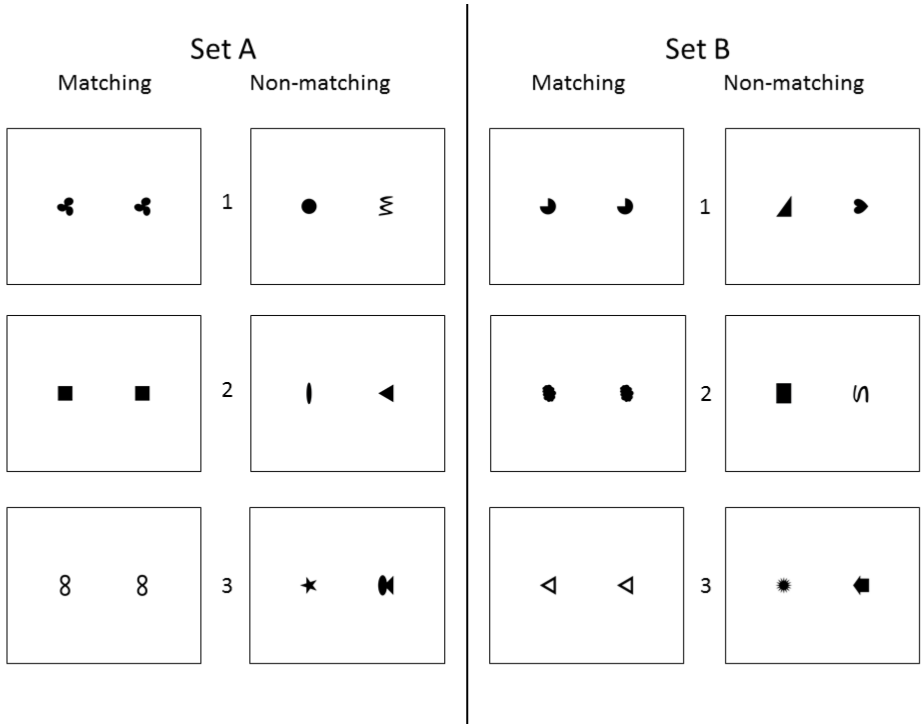

Figure 13: *Stimuli used in baseline and test.*