

	<p style="text-align: center;">ADAPT <i>IST-2001-37173</i> <i>Artificial Development Approach to Presence Technologies</i></p>
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Deliverable Item 4.3
Results of behavioral experiments with infants


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Short Description: This deliverable contains a full account of the developmental psychology experiments carried out during Adapt. This is also the final report of workpackage 4.

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Context

Behavioral experiments with infants were aimed at testing a hypothesis that can be modeled by robotics partners: the hypothesis of a primitive unity of senses. Integration can be tested either by studying the interaction with objects or during the interaction with other persons.

A. Intersensory integration in neonates during interaction with objects

The hypothesis of a primitive unity of senses at birth is held by several source researchers (see for instance Maurer, 1999). This would lead to postulate for instance that newborns are capable of intermodal transfer from hand to vision as well as from vision to hand. Several studies have demonstrated that neonates can coordinate information between vision and touch. Streri and Gentaz (2003; 2004) have shown that 3-day-old newborns can visually recognize the shape of a previously felt object. It remained to examine the hypothesis of a reverse transfer, i.e. a tactual recognition of an object seen. To this aim, a series of four experiments was led within ADAPT framework.

-Cross-modal transfer of shape from touch to vision and from vision to touch: Experiments 1 and 2

Two groups of 12 full-term newborns with an average weight of 3 kilos were randomly assigned to two habituation conditions. The 12 newborns of Group 1 (mean age: 49 hours) had a haptic habituation phase consisting in successive tactual presentation of a small wooden cylinder or a small prism in newborn's right hand until they reached habituation criterion. The test phase consisted in a visual presentation of familiar and novel objects during four trials. The 12 newborns of group 2 (mean age: 38 hours) had a visual habituation phase consisting in successive visual presentation of the big cylinder or prism until they reached habituation criterion. The test phase consisted in an alternative presentation in newborn's right hand of familiar and novel objects during four trials.

A cross-modal transfer from touch to vision is evidenced if newborns look longer at the object that was not previously held. A cross-model transfer from vision to touch is evidenced if newborns hold longer the object not previously seen.

Results

Eleven out of the 12 newborns in group 1 looked longer at the object that they had not held. This accounts for an intermodal transfer from touch to vision, thus replicating on a larger population previous findings by Streri (2000). However there was no evidence of a reverse transfer from vision to touch in group 2. These results suggest that the acquisition and nature of information about shape gathered by vision and touch are different. This led us to examine cross-modal transfer between vision and touch for another property of object, such as texture. Newborns are able to compare texture density information across modalities (Molina & Jouen, 2001). Shape and texture are both amodal object properties, shared by vision and touch. Whereas shape is a structural property and is essential to object identification, texture is a material property that allows object identification when shapes are similar. A comparison between shape and texture properties in a cross-modal transfer task would allow us to understand how the visual and haptic modalities process information concerning object properties.

-Cross-modal transfer of texture from touch to vision and from vision to touch : Experiments 3 and 4

Two groups of 16 newborns full-term newborns were randomly assigned to two habituation conditions. The 16 newborns of Group 1 (mean age: 45 hours) had a haptic habituation phase consisting in successive tactual presentation in newborn's right hand of a small wooden cylinder or prism with pearls on it until newborns reached habituation criterion. The test phase consisted in a visual presentation of familiar and novel objects during four trials. The 16 newborns of group 2 (mean age: 60 hours) had a visual habituation phase consisting in successive visual presentation of the big cylinder or prism with pearl on it, until newborns reached habituation criterion. The test phase consisted in an alternative presentation in newborn's right hand of familiar and novel objects during four trials.

Results

Thirteen out of 16 newborns of group 1 looked longer to the object to texture of which they had not felt previously. Thirteen out of 16 newborns of group 2 held longer the object they had not previously seen. These results show a cross-modal transfer of texture from touch to vision and the reverse. This suggests that information about texture is equivalent when gathered by touch

and when gathered by vision. Texture might require low level process. Taken together, results support the hypothesis that newborns are able or not to coordinate information between tactual and visual modalities depending of the object property concerned.

Cross-modal transfer of texture from vision to touch in newborns:

Experiment 5

Previously, we evidenced a reverse cross-modal transfer of texture between vision and touch at birth. However, we presented shapes (cylinder) with texture (granular vs smooth) and it is difficult to assess if cross-modal transfer observed from vision to touch was due to shape plus texture or to texture alone. We conducted an additional experiment with 16 newborns aged less than 3 days who were presented a wide surface (smooth vs granular). The visual habituation phase consisted in successive presentation of a granular plate or a smooth plate in slight motion for several trials. The test phase consisted in alternate presentation in the right hand of two objects, a flat smooth texture and a granular texture for 4 trials.. Results revealed no significant difference in holding time between the two objects. . There was no evidence of a cross-modal transfer of texture from vision to touch when shape information was reduced. This failure could be explained by the fact that “lateral motion”, an exploratory procedure efficient in adult’s exploration of texture, is absent in newborns. Newborns display only grasping and sometimes squeeze/release procedures. It is thus more difficult for newborns to process texture information when the object is flat than when volumetric. Further experiments are thus planned, using volumetric objects varying only in texture.

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B. Intersensory integration in young infants during interaction with persons

The hypothesis of a primary unity of senses was also tested when interaction concerned persons. Two series of experiments were led: one series dealt with the ability of very young infants to perceive, react and understand people as coherent multimodal entities; the second series investigated the hypothesis of a primitive awareness of being imitated in 2-month-old infants interacting with an imitative partner.

- The ability of very young infants to perceive, react and understand people as coherent multimodal entities

Do infants develop an early awareness of mother as a contingent multimodal entity? Do they capture contingency as a synchronic combination of different sensory modalities converging to produce an online interaction? Do they detect and expect partner's multimodal contingency? Those questions have been examined with different methodologies. With classical experimental procedures using static displays and speech sounds, young infants have been shown to be sensitive to relationships between facial and vocal features of an adult (Bahrick, 2000). For instance, Kuhl and Meltzoff (1982) have shown that 4 month-olds can match a vowel sound with a facial pattern miming the vowel speech. A first methodological advance toward the study of social perception has been to shift from static to dynamic displays. A good example of this shift is given by Walker-Andrews's presentation of two pre-recorded faces expressing different emotions accompanied by a voice matching the emotion of one of the two faces (Walker-Andrews, 1997). Infants around 6 months looked longer to the emotional face matching the voice, showing that they have somehow formed a representation of visual and auditory signals as a coherent multimodal dynamics. What is the influence of this knowledge on unimodal and bimodal interaction with a partner? A step in this direction was provided by the use of face-to-face interaction procedures with TV displays. TV manipulations allow to suppress a channel, simulate a given disturbance of the partner (Murray & Trevarthen, 1985; Muir & Hains, 1999; Nadel, Carchon, Kervella *et al.*, 1999; Nadel, Soussignan, Canet, Libert

& Gérardin, 2005) or present to the infant a life-like adult driven by an experimenter that chooses relevant responses to infants' signals in a prerecorded emotional repertory (Muir, 2004). What does the use of these various displays teaches us? In the course of a TV interaction, if mother's voice is turned off but face remains contingently responsive, infants aged 5-6 months keep gazing and smiling to mother (Hains & Muir, 1996). However, if voice is altered, smile decreases and when mother's face is disturbed, her voice helps the infants to maintain visual attention (see Muir & Nadel, 1998, for a review). Put together, these findings suggest that face alone is sufficient for young infants to communicate but that intact voice is needed to keep or restore a positive emotional state if a disturbance is introduced in the partner's communication. In all cases, emotional state is modified, not visual attention.

Some of the above mentioned studies have shown that young infants detect correspondences or disruptions between face and voice, others have shown that infants are likely to exploit the resource of one channel if the other is disturbed. All these studies, however, have used static displays or face-to-face displays that do not maintain the dynamics of an interactive flow via mother's contingent responsiveness. Knowing that infants as young as 2-month-olds detect a non-contingent communication in the course on an on-going dynamic interaction (Murray & Trevarthen, 1985; Nadel, Carchon, Kervella *et al.*, 1999; Nadel, Soussignan, Canet, Libert & Gérardin, 2005), we suspect that processing bimodal communication should involve matching face and voice. What happens if the communication is partially contingent only? How do young infants process two sensory channels that emit simultaneously if one is contingent to their behavior and the other is not? Does it make a difference if the two disconnected channels come from the same source or come from two different sources?

To test this question, we have designed a model theorizing the dynamics of interaction between systems. Inspired by this general model, three experiments were set up that both provided disconnected visual and auditory inputs to the infant but differ in that the inputs came from a unique source or from two distinct sources.

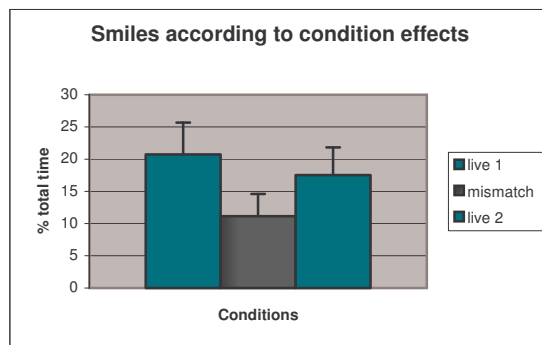
Experiment 1: The effect of a maternal mismatch between visual and auditory stimuli

In experiment 1, led during the first year of the program, infants were presented a three-episode TV interaction with their mother. Via our teleprompter design, we chose to maintain voice

contingent throughout the three episodes of the interaction session and to present a non-contingent (replayed) face of the mother during the experimental episode. Doing so, we did not expect a gaze effect since previous studies have shown that gaze is not modified by various perturbations of mother's face, but we hypothesized an emotional effect that will indicate a detection of incoherence in mother's facial message compared to the vocal message.

Nineteen infants aged 6 months interacted with their mother in 3 conditions: mother on-line, mother's interaction delayed, mother on-line. The presence/absence of Gaze to the screen, Smile, Grimace and self-centred movements were coded each 40/100th of a second for the three episodes.

Results show a significant curvilinear trend for smile: smile decreased significantly during the maternal episode of mismatch between face and voice, and increased significantly when mother was on line again. A significant inverted curvilinear trend was found for self-centred gestures, indicative of stress.



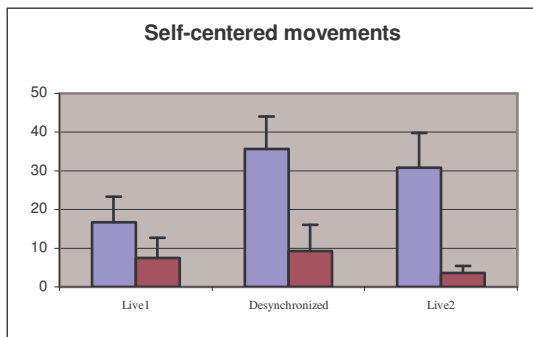
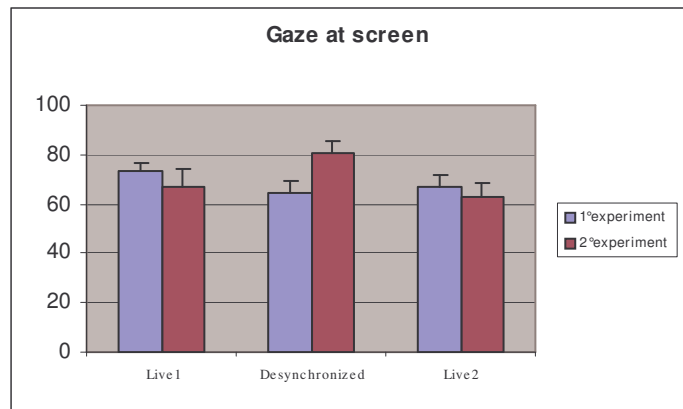
Experiment 2- Two co-occurring signals coming from different sources

Ten infants aged 6 months participated in this study. The experimental episode was composed of the contingent voice of the mother presented together with the pre-recorded face of a stranger. If there were no change in the infant's emotional state, we can conclude that the mismatch between the familiar voice and the unacquainted face is not attributed to an incoherent partner but to two distinct sources.

The presence/absence of Gaze to the screen, Smile, Grimace and self-centred movements were coded each 40/100th of a second for the three 30-second episodes.

Comparing the results of the two experiments for the four indices, we found no significant difference during the first live interaction. The infants' response to the perturbation episode (episode 2) however, was significantly different for gaze: while infants withdraw from the image of the dysfunctional mother, they maintained look at the screen in experiment 2, where mother's voice was coupled with a non-contingent stranger's face [$t(27) = 2.13, p < .04$]. Infants showed also a significantly higher amount of self-centred movements in experiment 1 [$t(27) = 2.07, p < .05$] and a marginally significant higher level of grimacing for experiment 1. Put together, these results show that infants were not disturbed by co-occurring signals coming from two different sources: mother's voice coupled with a stranger's face.

They also suggest that infants as young as 6 month-olds have formed the concept of mother as a multimodal entity whose co-occurring signals are



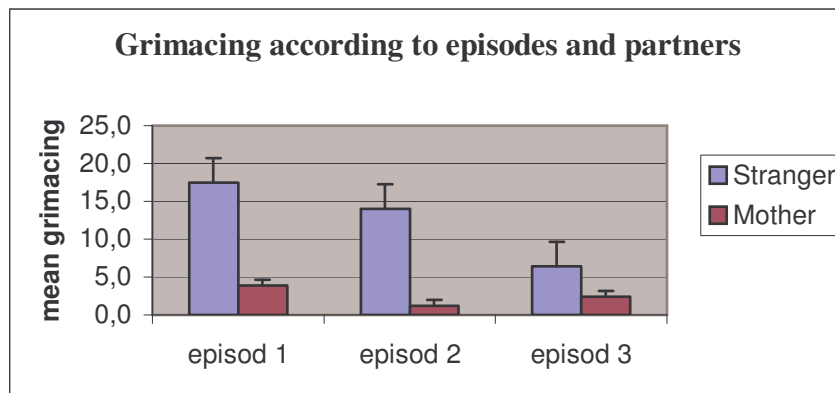
synchronized.

Note however that mother's face is so familiar that a test with stranger A's voice coupled with stranger B's face is needed to confirm those results. Experiment 3 was mainly aimed at examining whether infants have formed also the concept of mother as a multimodal entity.

Experiment 3

Sixteen infants aged 6 months participated in this study. They had a three-episode interaction with their mother and a female stranger. The infants were presented first an episode of interaction with one modality only (contingent voice of partner), the screen remaining blank, a second episode with contingent voice of partner and pre-recorded face of a stranger, and a third episode with contingent partner's face and voice. We were interested to see whether the

perception of a human partner as a multimodal entity extends to a stranger whose voice and face are unknown.



Infants grimaced more when interacting with a stranger during blank screen and during the coupling of voice with another face but not during the third episode when voice and face were

matched. This altogether with other results of this study supports the idea that they have detected the mismatch as well as the final matching between stranger's face and voice. It is thus suggested that 6-month-olds have formed the concept of persons as multipodal agents whose signals are co-occurring synchronously.

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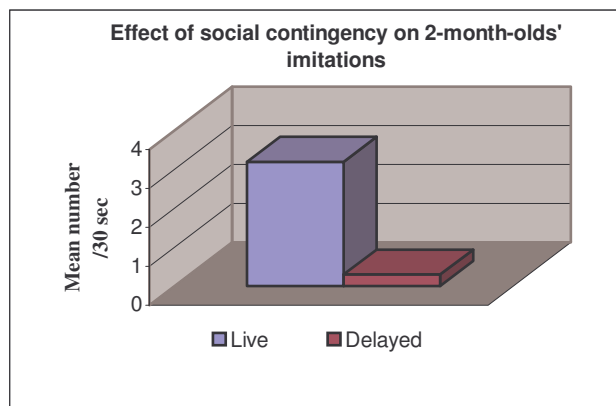
be presented at the XIIth European conference on Developmental Psychology (ECDP), Teneriffe, Spain, 22-26 Aug.

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- The hypothesis of a primitive awareness of being imitated Experiment 4

Detection of social contingency implies to establish relationships between ones' behaviour as perceived via proprioceptive information and the behaviour of another, as seen. It requires to establish relationships between what we see the other doing and what we feel being doing (cross-modal transfer between perception and proprioception). We test the development of this capacity in young infants through our teleprompter device. Mother (or experimenter) and infant (a 2 or 6 month old infant) can hear and see each other through TV monitors. The device generates a seamless shift from maternal contingency to non-contingency and from non-contingency to contingency again. Thus the infant faces sometimes a contingent mother and sometimes a non-contingent mother. In a version of the method, the non-contingent episode experienced by the child is a replay of a previous contingent communication of the mother. This allows to compare the behaviour of the infant facing the same gestural and verbal behaviour of mother or experimenter in two conditions: when the partner's behaviour is contingent to the infant's behaviour, and when it is not.

Fifteen 2 month-olds reacted to non-contingent episode by a decrease of gazing to mother, a disappearance of smile, a dramatic increase of frowning (Nadel *et al.*, 2005) thus replicating



Nadel's previous results (Nadel *et al.*, 1999). Exploring which parameters account for such a precocious detection of non-contingency, we found that the infants did not imitate during the non-contingent episode, whilst numerous imitations were coded during the contingent episode. We interpret this results as providing evidence

that non-contingent behaviour is an obstacle for experiencing a visual and auditory perception of what we are doing (i.e. experiencing other's agency in their mirroring of one's own behaviour), which in turn is an obstacle to experience one's own agency in mirroring the other's behaviour.

Results of this experiment were reported in several conferences and published in Nadel *et al.*, 2004. The data of the twin experiment conducted with an experimenter imitating the infant according to an experimental protocol are currently being coded.

References (with mention of ADAPT contract)

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C. Intersensory integration in grasping

Experiment 5

During the third year of the contract we have paralleled with infants aged 6 to 12 months an experiment conducted in Genoa by Giorgio Metta with his autonomous robot. In this experiment, the robot has to find a relationship between visual information about an object and proprioceptive anticipation of the grasping to operate. Our aim is to follow the development of

perception action- coupling leading to reaching strategies that generate an affordant grasping of different kinds of objects. Manual skills increase with the emergence of the capacity to grasp an object, at around 5 months of age. Adaptation of reaching and grasping to object characteristics improves considerably over the next few months (von Hofsten, C., 1979. Development of visually guided reaching: The approach phase. *Journal of Human Movement Studies*, 5, 160-178). First imitation of actions appears at around 6 months and is easier when objects are involved, but only in case of affordant relationships between object and action (Nadel, J. & Butterworth, G.1999. *Imitation in infancy*. Cambridge: CUP). A non-affordant modelling is not expected to lead to imitation in 6 months (following Von Hofsten's data with 6 month-olds in close experimental conditions), but we expect to observe the beginning of hand preparation according to size and shape.

Population

Twenty full-term infants aged 6 month-olds were recruited.

Material

The objects are similar to those used in Genoa, though adapted to six-month-olds' hands (see developmental set-up).

Procedure

The infant is sitting on mother's lap in front of a table. The object is placed in the centre at such a distance of the infant's hands that (s) he should reach the object first in order to grasp it. The experiment consists in two short episodes:

1) spontaneous grasping

The objects are presented one after the other in a counterbalanced order.

2) grasping after a model

An experimenter grasps the object in a non-affordant way (i.e.: the bottle as a box ; the small ball as a cylinder, etc.)

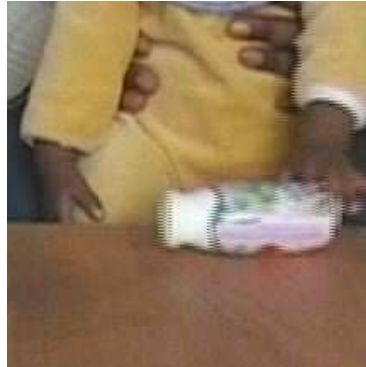
The data are currently digitalized, classified and coded. Roughly we found 3 groups of infants: those who are not yet able to grasp, those who grasp after trials and without any account of

object properties and those who configure their hand according to the object to be grasped. This extended heterogeneity in behavior reveals that age 6 months is a cornerstone in the development of a coupling of perception and goal-directed action. We found no example of an effect of modelling a non-affordant grasping on the infants' grasping procedure.

Examples of calibration, reaching and grasping in a 6-month-old



calibrating



reaching



grasping

the bottle



calibrating



reaching



grasping

the cylinder