Give Children Toys Robots to Educate and/or NeuroEducate: the exemple of PEKOPPA in Neurotypical and Atypical Children Aged 6 Years

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ABSTRACT
Using an InterActor toy robot named PEKOPPA in a “speaker-listener” situation, we have compared the verbal and the emotional expressions of neurotypical and autistic children aged 6 to 7 years. The speaker was always a child (neurotypical or autistic); the listener was a human or the toy robot which reacts to speech expression by nodding only. The results appear to indicate that minimalistic artificial environments could be considered as the root of neuronal organization and reorganization with the potential to improve brain activity. They support the embrainment of cognitive verbal and nonverbal emotional information processing.

INTRODUCTION

Development is the result of a complex process with three foci at least, one in the central nervous system, one in the mind and one in the child’s dynamic interactions with the natural vs. artificial environment, that is, robots [1]. Verbal and nonverbal cognition as well as emotion develop at the interface between neural processes. Toys have a central role. Toys seem provide an interesting account of “how” physical objects are able to act as support for the symbolic play of children. With development, symbolic play with action grows into language. Note that children access language because of their capacity to construct coherent multimodal interactions which are based on the links between the symbolized toys [1]. This is of great interest, particularly when considering that nonverbal multimodal behavior is probably at the origin of what is arguably one of the trademarks of human cognition: the capacity to generate thoughts and concepts for ourselves and for the others which can be verbally expressed with the aim to communicate.

With that in mind, imagine a scenery of communication between two people, one speaking the other listening. The speaker is elaborating a multivariable equation. S/he is trying to conceptualize within her/his brain and encode according to rules of semantics and syntax, and then externalize into spoken form. Speech engenders an avalanche of neuronal responses in the listener. The listener is computing and trying to solve the proposed equation displaying various verbal and nonverbal reactions in response to the utterances of the speaker. Verbal reaction necessitates the elaboration of coherent (grammatical and syntactically) sentence. Nonverbal reaction takes the form of head nods and/or various kinds of facial expressions. Intimately connected with the utterances of the speaker, these responses signify that the utterance is being accepted, understood, integrated [2, 3]. Successful communication requires that both speaker and listener accurately interpret (via verbal and nonverbal emotional processes) the meaning of each other referential statement.

Neurotypically developing listener and speaker are able to consider verbal, nonverbal (i.e, head nods), emotional (i.e., facial expressions) conventions and rules as well as each other referential statement. Using a modeling approach, recent neuroimaging studies have reported that both speech comprehension and speech expression activate a bilateral fronto-temporo-parietal network in the brain, fully characterized by the dynamic interaction among all the components (production and reception of speech but also for cognitive nonverbal emotional processes) [4]. Failure of the exterior superior temporal sulcus [5], of the interior temporal lobe, amygdala included [6], of the connectivity between temporal regions [7] as well as of the inferior prefrontal cortex [8] i.e., the mirror neurone system, is accepted as an explanation for atypical neurodevelopment, such as autism [9]. The atypical neural architecture causes impairment in social interaction, in communications skills and interests and reduces the ability of mentalizing, i.e., represent the referential statement of other people [10].

Imagine now that in the aforementioned situation of “speaker and listener”, the speaker is an autistic child trying to elaborate a multivariable equation. Complex in nature, the elaboration of this equation becomes more complex notably when the listener is a human, who is characterized by a high degree of variability on verbal and nonverbal reactions, (i.e., unpredictable reactions) [11]. Adding the fact that the child is impaired in interpreting the referential statement of other people [10], listener’s verbal and nonverbal contributions are not always scrutinized.

Different studies have shown that animate robots using different stimulation encourage interaction in autistic children [12]. Despite these studies, only marginal attention has been paid to the comparison of neurotypical and autistic children in human-human and human-robot interaction. Using a “speaker-listener” situation, we have compared the verbal and nonverbal emotional expressions of neurotypical and autistic children aged 6 years. The speaker was always a child (neurotypical or autistic); the listener was a human or an InterActor robot, i.e., a toy robot which reacts to speech expression by nodding only. Given the fact that the InterActor robot is characterized by a low degree of variability in reactions (i.e., predictable reactions) and the human by a high degree of variability in reactions (i.e., unpredictable reactions), our general hypothesis is that verbal and emotional expressions of autistic children could better be facilitated by the InterActor Robot than by the human.

METHOD

Participants

Two groups of children, one “neurotypical” and one “autistic” participated in the study. Twenty neurotypical children (10 boys and 10 girls) composed the “neurotypical group”; twenty children (14 boys and 6 girls) composed the “autistic group”. The developmental age of typical children ranged from 6 to 7 years old (mean 6.1 years; sd 7 months). The developmental age of autistic children ranged from 6 to 7 years old (mean 6 years; sd 8 months). Their mean age when first words appeared was 28 months (sd 7 months). The autistic children were diagnosed according to the DSM IV-TR criteria of autism [13]. The Childhood Autism Rating Scale-CARS [14] has been administrated by an experienced psychiatrist. The scores varied from 31 to 35 points signifying that the autistic population was composed of middle autistic children. They were all verbal. All autistic children were attending typical school classes with typical educational arrangements. The study was approved by the local ethics committee and was in accordance with the Helsinki convention. Anonymity was guaranteed.

Robot

An InterActor robot, i.e., a small toy robot, called "Pekoppa", was used as a listener (figure 1) [26] (see 16).

Figure 1. Pekoppa

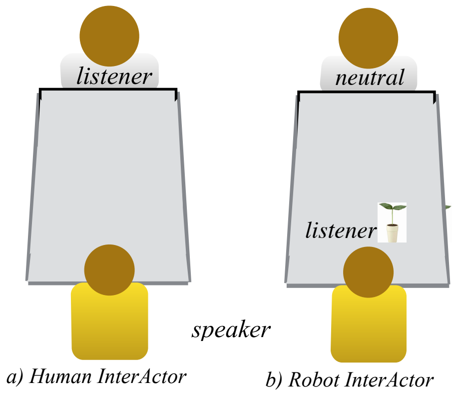

Figure 2. Listener-Speaker Situation

Procedure

For both groups, the study took place in a room which was familiar to the children. We defined three conditions: the first one was called "rest condition", the second was named "with human" (child-adult) and the third one was called "with robot" (child-Pekoppa). The second and third conditions were counterbalanced across the children. The duration of the "rest condition" was 1 minute; the second and third conditions each lasted approximately 7 minutes. The inter-condition interval was approximately about 30 seconds. For each child, the whole experimental session lasted 15 minutes (Figure 2) (see also 16).

RESULTS

The distributions of heart rate and words in both age groups approximate a parametric shape. With such distributions, the mean was been chosen as central index for comparisons. We performed statistic of comparisons using the chi-square test ($\chi2$ Test) to examine differences in heart rate[1], and number of words between the two experimental conditions ("with human" and "with robot"), for neurotypical and autistic children.

Figure 3 represents the mean heart rate of neurotypical and autistic children both at inter-individual and intra-individual levels.

At the intra-individual level, the statistical analysis showed that relative to the "rest condition", the mean heart rate of neurotypical children was higher when the children were in contact with the InterActor robot ($\chi2=6.68$, $p<0.01$) than when they were in contact with the human ($\chi2=4.09$, $p<0.05$). However, the mean heart rate of neurotypical children didn't differ when they interacted with the human or with the InterActor robot ($\chi2=2.83$, $p>0.05$). Similarly, relative to the "rest condition", the mean heart rate of autistic children was higher when they interacted with the InterActor robot ($\chi2=7.01$, $p<0.01$) than when they interacted with the human ($\chi2=5.01$, $p<0.05$). Finally, the mean heart rate of autistic children was higher when they were with the InterActor robot than when they were with the human ($\chi2=7.84$, $p<0.01$).

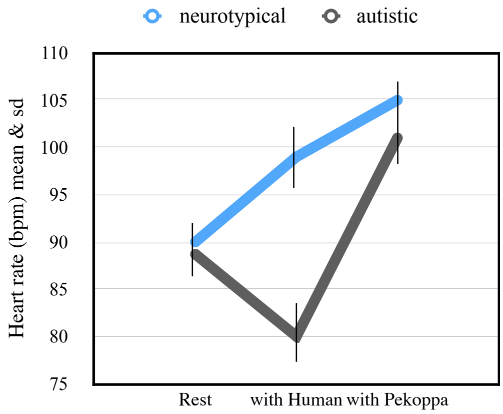

Figure 3. Mean Heart Rate

At the inter-individual level, the mean heart rate of neurotypical and autistic children was similar ($\chi2=2.06$, $p>0.10$) in the "rest condition". However, compared to the heart rate of neurotypical children, the mean heart rate of autistic children was lower when they interact with the human ($\chi2=8.68$, $p<0.005$). The mean heart rate of autistic children didn't differ from that of neurotypical children when the InterActor was the robot ($\chi2=2.85$, $p>0.05$).

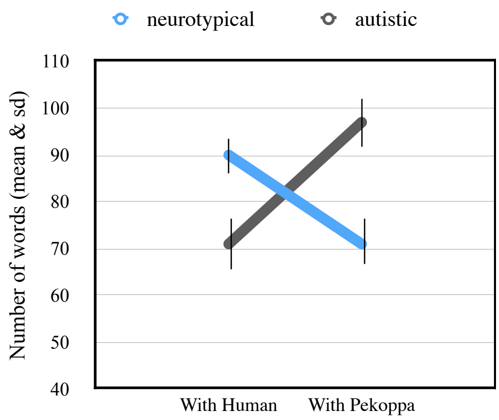

Figure 4. Number of words (nouns & verbs)

At the inter-individual level, as shown in figure 4, the mean number of words (nouns and verbs) was low in the "with human" condition for autistic children ($\chi^2=4.86$ $p<0.05$) and in the "with robot" condition for neurotypical children ($\chi^2=5.98$, $p<0.025$). The mean number of words expressed by autistic children in the "with robot" condition didn't differ from the mean number of words expressed by neurotypical children in the "with human" condition ($\chi^2=1.34$, $p>0.10$). At the intra-individual level, the mean number of words was higher when the autistic children had the robot as interlocutor than when the interlocutor was a human ($\chi^2=5.97$, $p<0.025$). The quasi opposite configuration was observed for the neurotypical children ($\chi^2=4.78$, $p<0.05$).

[1]Heart rate is measured in beat per minute (bpm) using a frequency counter ring placed on the index finger of each child. The experiment noted the HR of each child every 5 seconds. The physiological heart rate limits correspond to 95 bpm (±30) at the age of 6 to 7 years.

DISCUSSION

The present study aims at analyzing the embrainment of verbal and emotional expressions in neurotypical and autistic children aged 6 to 7 years. Our approach centered investigating the effects of a human or an InterActor robot in the context of a "speaker-listener" situation: the speaker was always the child; the listener was a human or an InterActor robot. To this end physiological data (i.e., heart rate), as well as behavioral data (i.e., number of nouns and verbs) were considered. The results showed that 1) the heart rate of autistic children is low when the listener was a human and increased nearer to levels of neurotypical children when the listener was the InterActor robot; 2) the number of words expressed by the autistic children was higher when the interlocutor was the robot.

Fundamentally, the results are consistent with our hypothesis according to which the predictability of the InterActor robot would facilitate the emotional and verbal expressions of autistic children. Our results showed significant differences of heart rate depending on whether the listener was a human or a robot. When the listener was a human, the children showed a low heart rate; when the listener was an InterActor robot, their heart rate increased. Such a result cannot be attributed to an order effect as the order of "human-human" and "human-robot" conditions have been counterbalanced. On the contrary, it can be understood as an effect of the InterActor robot on autistic children's mental state. This interpretation is also supported by the fact that when the autistic children had the InterActor robot as listener, their heart rate didn't differ from the heart rate of neurotypical children in the same condition. It is also interesting to note that the heart rate of the neurotypical children didn't differ when the listener was a human or a InterActor robot. Such difference reveals that an InterActor robot might improve autistic children behavior. This inference is reinforced by the fact that the physiological data we recorded reflects the modifications of orthosympathetic and parasympathetic autonomous nervous system which is dynamically (and bidirectionally) connected to the central nervous system [17]. Physiologically, the lower regulation of heart rate (in "with human" condition) reflects poorer action of the myelinated vagus nerve [17] which in turn would signify poor neural activity in temporal cortex (amygdala included), in cingulate cortex and in prefrontal cortex [18]. This neural architecture is hypo-activated in children with autism [9, 10], causing impairment in cognitive verbal, nonverbal and emotional behavior [5, 6, 7, 10]. Such hypo-activation might explain autistic children's behavior when the listener is the human. Contrary to research suggesting that autistic children show disruptions in autonomic responses to environmental (human) stressors [19], our findings indicate that not only are there no disruptions in autonomic responses but that these responses don't exceed the physiological limits. Apparently, when the listener is the InterActor robot, the heart rate of children with autism increases indicating a "mobilisation" of a given mental state. Such "mobilisation" provides support for the social engagement of autistic children. Namely, by making the autistic children available to engage emotionally (and verbally), the InterActor robot seems to modify their neural activity: the children enjoyed participating. It is noteworthy that they also verbalized such pleasurable sentiments at the end of the experiment. Essentially, the present results are consistant with our previous assumptions following which toy robots would improve autistic children brain functioning [12].

The above considerations could account for the number of words (nouns and verbs) expressed by the children. Even if the autistic children were verbal, the present finding indicated that when the listener was an InterActor robot, the number of words expressed by the autistic children was higher than the number of words they express when the listener was a human. Interestingly, such verbal behavior doesn't differ from that of neurotypical children when these latter had a human as listener. Once again, the use of the InterActor robot seems afford autistic children to express themselves as neurotypical children do with humans. This data is consistent with previous studies which have demonstrated that verbal expression can be facilitated by the active (but discreet) presence of a robot [12].

It can concluded that that minimalistic artificial environments could be considered as the root of neuronal organization and reorganization with the potential to improve brain activity in order to support the embrainment of cognitive verbal and emotional information processing.

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