

Report of the activities carried out by Daniele Panizza at the Linguistics Department, Macquarie University, Sydney.

During the year that I spent at the Linguistics department of Macquarie University (Sydney, NSW, Australia) I worked in collaboration with prof. Stephen Crain, prof. Rosalind Thornton and Anna Notley. My research goal was to investigate the children's understanding and acquisition of natural language quantifiers and number words, and the way they are affected by logical contexts.

The first months of my project were devoted to piloting. I developed together with my collaborators two experiments for exploring 3-5 years old children's interpretations of the indefinite quantifier "a" and numerals (*one, two, three* etc.). The experimental design included a puppet (Kermit the frog), three puppet-friends ("the boys"), some other toys (objects and animals) and a coin box that was given to the child who participated to our study. In both experiments the task performed by the participant was to reward the puppet-boys if they did the right thing, that is, if they brought the objects that were requested by Kermit. The command sentence uttered by the puppet could be a declarative statement "a boy has a train/two trains, give him a coin" or a conditional clause "if a boy has a train/two trains, give him a coin". Participants could be presented with either the first or the second kind of statement, thus the design was between-subjects. Our predictions were such that in the declarative conditions children should have employed more often the stronger meaning of both "a" and numerals (a = just one; two = exactly two) than in the conditionals. Remarkably, in the literature it has never been found that young children are able to adopt the weaker interpretation of numerals (two = at least two). Our main goal was to show that this interpretation is indeed available from the first stages of language development, as soon as the children master the meaning of number words.

After piloting around 20 children we only obtained "rejections" with numerals, in both declarative and conditionals, in the critical trials. Namely, when the puppet-boy had, e.g., three trains, and Kermit uttered the sentence "if a boy has two trains give him a coin" the children never rewarded the boy. On the other hand, we obtained some interesting differences with the indefinite, with respect to declarative vs. conditional conditions. However, after noticing a possible confound in the design (i.e. the indefinite *a* in "*a* boy has...." could interfere with both the object indefinite "a train" and the numeral "two trains"), we decided to modify the experiment and put the focus of our research on the numerals only.

In the new design Kermit asked the participant for each of the three boys, one at a time, whether they brought back the right thing. In the new version he uttered the following statement: "I think this boy brought back two trains, give him a coin if I'm right". In the conditional version the sentence was: "if this boy brought back two trains, give him a coin". To get an overall higher number of acceptance we constructed a "needing" context. Namely, before uttering the critical sentence

Kermit explicitly said that he needed two trains for the race he was organizing. Furthermore, after uttering the critical sentence containing the numeral *two*, Kermit asked the child to put "two of the trains" on the track, out of the three trains brought by one of the puppet-boys. By mean of this "acting out" we aimed to raise the saliency of the set/subset relation between the number of object that were requested (two) and the number of object brought by the boy (three). After piloting a few children we discovered that the new experimental design yielded some acceptance answers in the conditional version, and we proceeded with the full testing.

Around 40 children were tested in the two condition, and 24 were included in the final analysis (12 declarative, 12 conditionals, see below for the inclusion criteria). The final version of the experiment employed 10 stories. All the stories were about some animals and vehicles that Kermit needed in order to organize some races, as well as some prizes he needed to reward the contestants. Each story included three trials (one for each puppet-boy). One trial was a control where Kermit uttered a sentence containing an indefinite (e.g. "this boy brought a train..."). In this trials children were expected to reward the boy only in case he brought the right object vs. not reward him if he brought a wrong one (e.g. a boat instead of a train).

The other two trials employed numerals. In these trials Kermit always uttered a sentence like "I think this boy brought back two trains" (or "if this boy brought back two trains..." in the conditional version) and the puppet-boy had either three objects, two objects, or one object. When the boy had three objects the child could either accept (reward) or reject (not reward) the statement of Kermit. This constituted the critical trial. In contrast, when the boy had two objects the child was expected only to accept the statement and reward the boy, whereas when the boy had only one object the child had to reject the statement. The critical trial, thus, was the one in which the puppet-boy had three objects, but Kermit asked for two, with the other two kinds of trial serving as controls to make sure that the child knew the right meaning of the numeral. Indeed, if a child failed more one than the control trials he/she was excluded from the analysis. This could happen when the child rewarded the boy although he brought the wrong object, when he/she gave the reward when the boy brought a smaller number of objects (i.e. one when asked for two) or when he/she did not reward the boy in case he brought the exact number of objects (two when asked for two).

As predicted, we found that children rewarded the boy-with-three-objects, when Kermit asked for two objects, in about 40% of the times when the numeral occurred in the antecedent of a conditional, whereas they did so in 9% of the times in the declarative condition. This results, which were fully significant with a repeated measures ANOVA by subjects and by items, are consistent with what found in other study with adults (Panizza, Chierchia, Clifton 2009) and with children employing phrasal connectives (Guasti, Chierchia, Crain, Foppolo, Gualmini and Meroni, 2005), and demonstrate that childrens' interpretations of numerals, like adults' ones, are sensitive to the logical context where these items occur. In a declarative sentence

they employ more often the stronger interpretation of numerals (two = exactly two), which yields a more informative meaning, than when they are embedded under conditional, where the numeral interpretation yields a logically weaker meaning.

This results bring some important implications for the research on the acquisition of number words. First, they show that children, contrary to what previously found, are indeed able to adopt the weaker interpretation of numerals ('at least N'). Second, children are affected by the logical properties of the context in which these items occur just like adults. From this we can infer that they are likely to use the very same mechanisms to generate strong vs. weaker interpretations of such linguistic items. These mechanisms might be pragmatic inferences, such as scalar implicatures, which have been previously found to be sensitive to logical properties of the proposition. If this is right, then we must maintain that such pragmatic inferences are affected by the logical/semantic properties of the proposition even during the first stages of language acquisition.

Nowwithstanding this considerations, when we presented this experiment to adult controls (undergrad students at the Macquary University) we found that they were not affected by our experimental manipulation. That is, adults almost always rejected (i.e. did not reward) the boy-with-three-objects when Kermit asked for two objects in either experimental condition (declarative and conditionals). However, for in previous studies adults' interpretation and processing of numerals was found sensitive to the logical properties of the context (Panizza et al., 2009; Panizza, Huang, Snedeker, Chierchia, in prep.) we claim that the lack of this effect with adults in the current experiment must be due to reasons that are linked with our experimental design, which was developed to investigate this phenomenon within children.

One possible explanation is the following. The experiment was presented to adults in the very same version we employed with the children, and it did not contain any filler. Therefore the task was extremely simple and this could have caused the "rejection" pattern we detected. Alternatively, we might claim that adults strengthen the meaning of numerals more often than children (see Noveck, 2004 for a similar hypothesis) for other reasons (e.g. they compute more scalar implicatures, or more easily). Along with this explanation, this design was not able to capture the difference between declarative and conditionals with adults because of a ceiling effect (i.e. they never gave the reward in the conditional trials either).

Nevertheless, as this experimental study was design to investigate childrens' interpretation of numerals in different logical contexts, adults mainly constituted a control to make sure that the 'at least' reading was not too easy and trivial to employ, which in fact was not found.

During this fellowship I participated to a conference held in Rovereto ("Psycholinguistics across the borders") where I presented a work that I previously did in Rovereto, during my post-doc. Furthermore, I worked on a paper (experimental review) that has been accepted in a special issue of the Journal of

Neurolinguistics named "Formal Neurosemantics, Logic, Meaning and Composition in the Brain".

I thank my collaborators, Stephen, Rosalind and Anna for the tremendous help they gave me while developing and running this study. I'm writing down with them the paper related to this research, its results and their implication for the theory of language acquisition. I also thank the Marica De Vincenzi Foundatin for the support that was given to me in these months.

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