Language acquisition in Down Syndrome from embodied perspective: How body constrains language acquisition?

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Abstract

Parents of children with Down syndrome (DS) were asked to fill a questionnaire about how much their children understand and how well they use words. It was found that word acquisition is affected not only by word frequency, but also by whether a word is related to eventual misbalance of the body. The results are in favor of the hypothesis that the constraints of the human body may cause systematic variations of language acquisition as long as keeping the body balance is a typically difficult motor task for DS children. Additionally, we also found an asymmetry of the acquisition of the verbs and the nouns, depending on their frequency and relatedness to eventual misbalance of the body.

Introduction

Usually learning of a native language takes several years. During their first years of life children learn thousands of linguistic symbols and constructions used by people around them. How does this extensive learning happen? Glenberg, A.M., Havas, D., Becker, R., & Rinck, M. (2005) conclusively argue backed up with the Searl's Chinese room and the Harnad's symbolic marry-go-around argument, that language must be grounded outside the linguistic system. Language gets meaning from what is already meaningful for children, i.e. perceptions, actions and emotions. Many cognitive psychologists, however, would agree that the initial states of language acquisition are grounded in perception and action, since at least, the first symbols can be considered as gaining meaning from these modalities. The problem mainly concerns the mature language processing where the role of bodily states for language use is still debatable (Glenberg et al, 2005). Recently, however, a study on body-specificity hypothesis has shown that right-handers activate the left-premotor cortex during lexical decision on manual-action verbs, while left-handers activate the right premotor cortex (Willems, Hagoort, Casasanto, 2010). Hence, it seems reasonable to assume that different bodies lead to different representation of environmental categories and therefore, to predict that body differences are connected to specific differences in language usage.

The goal of this study is to provide preliminary evidence that specific body constraints correspond to specific patterns of language acquisition. The possibility that the human mind and body were evolutionary shaped by language in a way that allows language production and comprehension is largely recognized nowadays (for a review, Pinker, S., 2000), but the opposite direction is still fairly underestimated. In other words, there has been no attempt, at least to our knowledge, to investigate systematic variations in *language acquisition* due to particular body constraints.

We start from the consistent evidence for specific difficulties in the Down Syndrome population (Lauteslager, 2004; Winders, 1997) for problems with maintaining balance and posture (i.e., insufficient stability, lack of trunk rotation and delayed reaction speed) that according to Lauteslager (2004) leads to a peculiar compensatory symmetrical manner of moving, mainly characterized by lack of variability. Every move that threatens the balance seems to be problematic for children with Down Syndrome (DS). Thus almost every stage of the typical motor development is a hardship for a DS child, who usually is able to maintain head control, sitting, standing, climbing, walking, jumping etc. considerably late in his/her development. But importantly, the way DS child acquires the motor skills important for independent locomotion is different from the typically development trajectory and is characterized by preference toward symmetrical movements with a lot of external support. The main reason considered to be responsible for the specific motor development of DS children is the low muscle tone (i.e. hipotonia) that affects individiuals from this population in different degree but is present from birth and persist throughout life.

To summarize, the low muscle tone constraints motor development of DS children, causing problems with maintaining balance and posture, which in turn leads to development of specific symmetrical movements, movements with a lot of external support and static motor behaviour (Lauteslager, 2004). Thus we hypothesize that word for actions and objects that threaten body posture and balance will be represented differently from DS population compared to normally developing one.

Unfortunately, it is difficult to predict how these specific body constraints would change language acquisition. It is possible that children with DS will acquire the meaning of words that are problematic for their motor planing and behaiviour much later than other words which do not tread body posture and balance. In other words, because it is difficult for them to walk, run, climb, swing etc. they will avoid such behaviors and the respective situations that require these actions. If this hypothetical scenario really takes place, then the direct sequence should be a substantial underrepresentation of such nouns and verbs that in some respect threaten their balance and body posture.

But we may expect just the opposite result as well, namely that children with DS will know better the words, associated with maintenance of posture and balance than the other words. If children with DS are raised in a stimulating environment, which encouraged them to walk, to bring the ball, to jump, to ride etc. they will finally master these actions. Moreover, during this process of pure motor development child's attention necessarily should be focused on the accomplishment of movements that are difficult for them. Hence everything that happens at this moment of keen attention can be potentially encoded better, including the labels for the body movement, hopefully provided from people around them. Since, it was reported that they have substantial deficits in sustained attention (i.e. attention toward a given stimulus that allow its efficient processing) (Brown, Johnson, Paterson, Rick Gilmore, Longhi and Karmiloff-Smith, 2003), the attention toward a difficult action seems to provide a prolonged period of focused attention that may facilitate encoding at least of the label of the action and the associated with this action objects.

To sum up, we expect a substantial difference in both understanding and production of words, associated with body posture and balance in DS children. At this point, we don't have any strong theoretical reasons to narrow down our expectations. But, since we plan to study understanding and production of word in home-raised children with DS (i.e. hopefully, these children were stimulated to interact actively with the surrounding physical and social environment) we assume that the mere association of a given word with posture and balance maintaining will facilitate its knowledge.

Language acquisition in children with Down Syndrome

Overall, children with DS acquire language at slower rates than typically developing children on the same chronological age. They produce shorter sentences and tend to omit function words (i.e., articles, prepositions, pronouns, etc.) (Chapman, 1995). Language comprehension in DS is usually superior to language production, but still significantly behind their level of cognitive development (Miller, 1992), mental age (Vicari, Caselli, Gagliardi, Tonucci, & Volterra, 2002) or vocabulary size (Singer et al, as cited in Tomasello, 2006). Overall the linguistic abilities of children with DS are surprisingly behind the ones expected on the bases of their cognitive abilities.

But actually the picture is much more complicated. A few studies point to the possibility that language acquisition in DS has its own profile, which turned to be different from the one of typically developing children. When asked to repeat words and sentences children with DS omit a significantly higher number of articles, verbs, and prepositions than typically developing children and children with specific language impairment, matched on mental age (Caselli, Trasciani, & Vicari, 2008). The authors explain these differences with the specific repetition task administered to children that certainly relies on different cognitive abilities, including verbal short-term memory, executive control etc., that are usually reported to be poorer in DS than in mental age-matched children with typical development. However, general cognitive impairments can hardly explain why exactly verbs, articles and prepositions are preferentially omitted by children with DS rather than nouns and modifiers.

On other hand, another line of research points to the fact that verb acquisition poses specific difficulties to DS children, since verb understanding strongly relies on syntactic development (Tomasello, 2006), which is reported to be dramatically delayed in this specific population (Fowler, 1990 as cited in Tomasello, M, 2006). Naigles, Fowler, & Helm (1995) point out that verbs incorporate both semantic and syntactic knowledge and thus mastering of verb meaning should depend on both of these components: "specific lexical and syntactic information concerning each individual verb must be accrued in order to establish stable verb representations".

Overall, based on the Caselli et al (2008) and Naigles et al. (1995) findings we may expect that children with DS will underrepresent verbs compared with nouns. With respect to our hypothesis, also seems much easier to imagine how verbs are learned through out specific actions than nouns, for example. Hence, the expected effect of embodiment on language acquisition, if any, should be predominantly expected in the domain of verb learning.

Then, our question is what will happen with word learning in general and verb learning in particular, if some actions are more difficult for an individual than others.

Investigation

We asked parents of children with Down syndrome and parents of typically developing children, matched on age (control group) to judge on a 7-point scale how well their children understand and how well they use the respective words. We designed a list of 172 Bulgarian words, controlled for objective frequency, length, type (noun or verb), and balanced with respect to embodiment, i.e. the degree of association between a given word and maintenance of body posture and balance (see section Stimuli below).

Whereas, expectedly, the results for the control group reached a ceiling effect for all words, the data of DS group seems to follow an interesting trend.

Method

Design

The design of the study was 2(diagnoses of trisomy 21: yes/not) x 2(objective frequency: high/low) x 2(length of the word: long/short) x 2 (type of the word: noun or verb) x 2(embodiment: high/low) factorial design. The dependent measures were the ratings, given from the parents of the children, to the understanding and to the production of the respective words.

An additional independent factor – concreteness/abstractness was measured for control considerations (see the next section - Stimuli).

Stimuli

We achieved the objective frequency of 355 Bulgarian words from a corpus of 70 stories, included in the training program for public kindergartens in Bulgaria. The length of the words varied uniformly between 3 and 11 letters.

On the next step, we asked two native speakers to judge each of the word on a 7-point scale according to the instruction: "Please, rate on a 7-point scale how much each of the following concepts or actions disturbs body posture or balance". For example, both experts gave high ratings to verbs like rush toward, jump, and scramble. Both experts gave high ratings to nouns like fight, stroke, and ball. On the other pole, low ratings were given for verbs like rill, mistake, love; and nouns like sky, gold, sign… The highest disagreements between the expert's ratings were 3 (on a 7-point scale).

Finally, we chose 172 words from the whole list (100 verbs and 72 nouns) and formed 86 pairs of words with polar ratings according to their embodiment (relatedness to dis-balance of the body) and fixed objective frequency and length. More precisely, we ensured that for each verb (respectively noun) with a specific length, frequency, and low embodiment, there is another verb (respectively noun) in the list with same length and frequency but with high embodiment. The length of the words was distributed among 3 and 11 letters with a dominance of 4-8 letter words.

If the value of the words according to frequency and embodiment dimension are discretized onto "high frequent", "low frequent", and, respectively "high embodied" and "low embodied", the overall distribution of the stimuli would be the one shown in Table 1.

Table 1. Distribution of the stimuli – verbs on the top panel; nouns on the bottom panel.

VERBS		frequency		
		low	high	total
embodiment	low	31	16	47
	high	35	18	53
	total	66	34	100
NOUNS		frequency		
		low	high	total
embodiment	low	21	19	40
	high	17	15	32
	total	38	34	72

For an additional control, we asked 14 adults (10 women and 4 men) on mean age of 22.5, to rate the words according to their concreteness/abstractness. This was an additional ad-hock variable, used to control for: First, whether our measurement of embodiment wasn't actually a measurement of concreteness. Second, whether concreteness is the better predictor of understanding and usage of words then the other factors. Thus, for each of the 172 words we had also an average rating of its concreteness/abstractness on a 7-point scale (1- very concrete…7- very abstract).

Procedure and participants

Eight parents of children with DS (seven mothers and one father) were asked to evaluate each of the words according to two criteria:

First, how much they think that their child understand the respective word.

Second, how appropriate their children use the respective word.

The ratings were given on a 7-point scale. The order of the words was random for every participant. The parents worked at home. At the beginning of the questionnaire, they should fill the age of the child as well as additional health problems, if any. All parents were duly confident that the data are confidential and will be used for statistical purposes only.

The same procedure was used for a control group of the parents of ten children without DS.

The age the children with DS were between 4 years and 4 years and 7 months. Half of the children (4) were girls and the other half (4) – boys. Two of the children had corrected to normal vision, 2 had heart problems (one of them was diagnosed also with West Syndrome). All children with DS were with full trisomy 21and not mosaic. All parents of DS children in our study were recruited from Bulgarian Down Syndrome Association and were with university education.

The group of the typically developing children was matched in age and sex to the DS children in our study. None of them did not have heart or vision problems. All parents again were with university degree of education.

Results

First of all, we received a clear ceiling effect for the children from the control group. The mean rating for understanding was 6.662, st. dev. 0.623 for all words; the mean rating for usage was 0.659, st. dev. 0.708.

The respective mean ratings for the DS children, however, were:

For understanding: mean rating 3.887, st. dev. 1.883; for usage: mean rating 1.772, st. dev. 1.002

The rest of analyses were on the results from the DS children only and reflect the pattern of language understanding and production observed and reported from their parents. The data for all DS children were averaged by item (172 independent words) and we analyzed the impact of embodiment, frequency, length and type of the words two dependent variables – mean rating of understanding and mean rating of production.

For control (see below, at the end of the section Results), we aggregated the data by subject as well and repeated the analyses assuming within-subject design (each subject was an independent case).

Results for understanding*, depending on objective frequency, length of the words, type of the words* *(verbs/nouns) and embodiment (how much each concept or action disturbs body posture or balance)*

The Univariate ANOVA analysis on *understanding* detected main effect of the frequency (F (1, 164) = 12.031, p = 0.001) and of the embodiment (F (1, 164) = 8.730, p = 0.004). There was not significant main effect of the type of the word (verb or noun): (F (1, 164) = 1.465, p = 0.228). In other words, parents in our sample estimated words with high objective frequency as the words that their children understand better than the words with lower objective frequency. Interestingly, words with high embodiment were also rated as significantly more knowable for children with DS than words, associated with less posture disturbances and balance difficulties.

There were not significant interactions among pairs of the variables but it was a significant triple interaction among frequency, embodiment, and type of the word (F (1, 164) = 4.708, p = 0.031). Figure 1 illustrates this interaction:

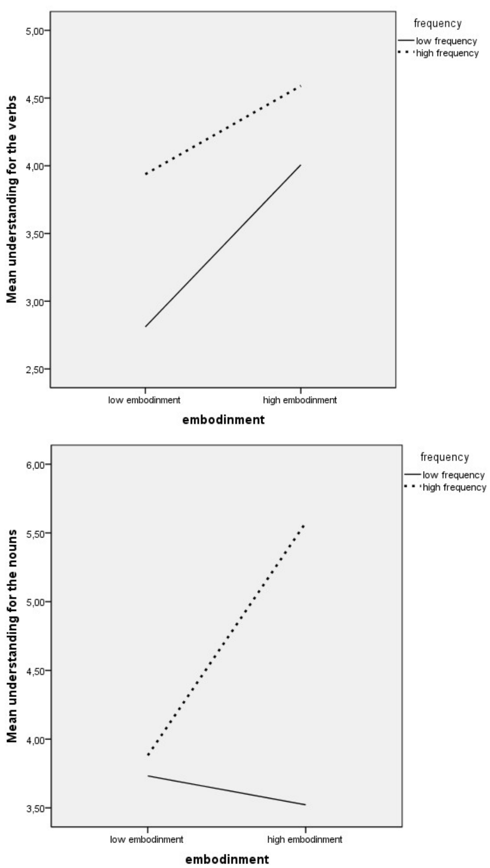

Figure1: The influence of the frequency and embodiment on the understanding of the words by the children with Down syndrome was different for the verbs (upper panel) and nouns (bottom panel)

Thus, the pattern of understanding of the words was found to be completely different. Whereas both high frequency and high embodiment support understanding (not much surprisingly), it happen that embodiment doesn't support understanding of low frequently nouns.

The length of the words influenced understanding of the verbs (F (1, 98) = 9.246, p = 0.003, obtained by a linear regression analysis): according to parents of DS children their children understand shorter verbs better than longer ones. However, the length doesn't influence significantly understanding of the nouns: (F (1, 70) = 0.125, p = 0.725). One may argue that this is due to the fact that children learn first the nouns, thus the influence of the length became slower. However, we didn't found a significant difference between the overall level of understanding of the verbs and the nouns. It should be mentioned, however, that it was a significant correlation between length and frequency (r = -0,279, p < 0.001).

The final control measurement – concreteness/abstractness of the words, correlated with embodiment (r = - 0.244, p = 0.001) and didn't correlated with the other independent variables.

Whereas it was a main effect of abstractness on understanding (F (1, 164) = 6.739, p = 0.010), there were no any interactions (neither paired, neither triple) with the other factors (i.e., embodiment, frequency, length and type of the word). Thus, our interpretation is that embodiment is different measurement from concreteness and that the interesting interaction on Figure 1 is due to the relatedness of the words to a possible disturbance on the balance of the body, instead of concreteness/abstractness.

Results for production*, depending on objective frequency, length of the words, type of the words (verbs/nouns) and embodiment (how much each concept or action disturbs body posture or balance)*

Although the ratings for the other dependent measure– correct usage of the words – were much lower, the results followed similar pattern according to all analyses:

It was main effect of the frequency (F (1, 164) = 11.885, p = 0.001) and of the embodiment (F (1, 164) = 4.582, p = 0.034). In contrast with the results for the understanding, it was a significant main effect of type of the word too: (F (1, 164) = 11.216, p = 0.001). The nouns received higher ratings.

There were not any pair interactions. The triple interaction between frequency, type of word, and embodiment was with a marginal significance only: (F (1, 164) = 3.046, p = 0.0083).

Length of the word influenced usage of the verbs (F (1, 98) = 14.126, p = 0.000) and doesn't influence the usage of the nouns (F (1, 70) = 0.055, p = 0.815).

It was main effect of abstractness (F (1, 164) = 4.137, p = 0.044) without any paired or triple interactions. For comparison with the marginal significance of the interaction between frequency, type, and embodiment, the results for the respective interaction between frequency, type, and abstractness was F (1, 164) = 0.194, p = 0.660.

Repetition of analyses*: analyses on the date averaged by subject*

The impact of embodiment, frequency, length and type of the word was measured with a Repeated Measures Analysis on data averaged by subject (i.e., eight DS children). The main effects of these factors were again estimated as significant. We obtained main effects of frequency ($F(1, 7) = 66.714$, $p = 0.000$), of embodiment ($F(1, 7) = 46.505$, $p = 0.000$), and also of type of the word ($F(1, 7) = 9.239$, $p = 0.019$).

The triple interaction was also significant: $F (1, 7) = 31.166$, $p = 0.001$. The only difference was that Repeated Measures Analysis estimated as significant the interaction between frequency and embodiment: $F (1, 7) = 12.071$, $p = 0.010$.

Discussion

According to their parents children with DS understand and use better words that involve difficult for them actions, namely the ones associated with greater posture disability and asymmetry. It seems that, while performing the difficult for them body movements, children learn better the words for these movements and the words for the objects that are typically connected to this movements. Having in mind that keeping the balance of their body is a typically difficult motor task for these children, the result is in favor of the hypothesis that the body constraints may cause systematic variations of language acquisition.

Interestingly, although both frequency and embodiment influence word understanding and production of DS children, the pattern for verbs and for nouns differs. The embodiment doesn't influence low frequent nouns. This was not due to a floor effect, as can be seen on Figure 1 and cannot be explained just by a complete misunderstanding of those words. This asymmetry raises new questions and requires further investigations.

The main effect of embodiment, however, points to an important trend in language acquisition in children with DS: the words that are related to eventual misbalance of the body were estimated as better understood and used from DS children.

The important question, however, is why this happens. We speculated at the beginning of this paper that children with DS may be recognize the situations that disturb their body posture or balance as more difficult and hence, requiring their attention. Then, their outperformance on words that are associated with such situations can be considered as a matter of attention, which is dedicated to the maintenance of body posture and balance. The extra attention dedicated to the movements that require maintaining of posture and balance may as a side effect improve the knowledge for the associated concepts. Attention, indeed, seems to be a problematic cognitive ability for DS population. Brown et al.(2003) conclusively argued that toddlers with DS has significant problems with maintaining attention to objects in the environment compared to a group of chronologically matched toddlers with Williams syndrome, a group of chronologically matched typically developing children and a group of mentally matched typically developing children. Possibly, the extra attention and effort toward the difficult actions may overcome the reported sustained attention deficits of DS children. Instead of training the sustained attention of children with DS we may compensate it with educational techniques that back on their posture and balance difficulties.

It could be, however, that DS children recognize actions that disturb their body posture and balance as threatening ones, since at least at the beginning of their motor development these actions usually end up with incidents, associated with physical pain. Possibly, in order to avoid successfully this actions, children with DS learned better everything, associated with situations that treat their body posture and balance.

Of course, both explanations could be rephrased in a way that appreciates the role of the parents in raising their children. It is quite possible, indeed probable that parents, rather than children recognize, which are the threatening and the difficult situations for their DS toddlers and pay more attention in teaching them how to master such situations. Again, the prediction will be that children finally will learn better the words associated with such situations than with others.

Unfortunately, our study could not disentangle between those possible explanations, but we find the compensatory account the most interesting one. If extra intentional resources can be allocated to particular movements and as a side effect this extra attention can improve conceptual knowledge, we may design techniques for both native and foreign language learning appropriate for the DS peculiarities.

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