

BRIEF RESEARCH REPORT

Overusing the pacifier during infancy sets a footprint on abstract words processing

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Abstract

Perturbations to the speech articulators induced by frequently using an interfering object during infancy (i.e., pacifier) might shape children's language experience and the building of conceptual representations. Seventy-one typically developing third graders performed a semantic categorization task with abstract, concrete and emotional words. Children who used the pacifier for a more extended period were slower than the others. Moreover, overusing the pacifier increased response time of abstract words, whereas emotional and (above all) concrete words were less affected. Results support the view that abstract words are grounded both in perception-action and in linguistic experience.

Keywords: pacifier; abstract concepts; phono-articulatory simulation; semantic categorization; embodied cognition

Introduction

The acquisition of language is a complex process that builds on the merging of many different dimensions, such as physiologic, motoric, sensory, and social dimensions, that co-evolve and constrain each other (Pezzulo, Barca & D'Ausilio, 2014). However, to what extent is the motor dimension important in language development? According to embodied theories, it plays a decisive role (Glenberg & Gallese, 2012). The integrity of speech-motor processes is crucial for typical development so that speech-motor dysfunctions such as developmental apraxia undermine the development of speech, language and socio-emotional interaction at large. Children with apraxia of speech (CAS) have difficulties coordinating speech articulators for the productions of spoken language. Retrospective studies indicate that infants with a later diagnosis of CAS might have a history of later onset of canonical babbling and low volubility (i.e., reduced vocalizations), leading to the suggestion that they might have fewer opportunities to map articulatory movements to their corresponding speech sounds (Overby, Belardy & Schreider, 2019; see also Terband, Maassen,

Guenther & Brumberg, 2009, 2014, for a simulation approach). In such conditions, the child greatly benefits from a multimodal approach that focuses on intense speech-motor and speech-sound therapy, coupled with the enhancement of communicative-linguistic skills through sign language (Tierney, Pitterle, Kurtz, Nakhla & Todorow, 2016).

In a non-clinical context, perturbations to the speech system induced by the transient use of an interfering object hamper the discrimination of linguistic sounds, and this occurs very early in life. Bruderer and colleagues (2015), indeed, have shown that auditory discrimination of a non-native speech sound contrast is selectively compromised when the infant holds in his mouth an object that interferes with tongue movements relevant for its production.

The tight bi-directional link between speech-motor acts and perceptual processes is also fueled by the study of sensorimotor influences on adults' language processing. Many studies on different languages have shown that phonological information has an impact on covert language processing (Barca, Benedetti & Pezzulo, 2015; Burani, Barca & Ellis, 2009; Barca, Pezzulo, Ouellet & Ferrand, 2017^o) as, at the cortical level, the activation of speech motor cortex in passive viewing of lexical stimuli (Barca, Cornelissen, Simpson, Urooj, Woods & Ellis, 2011).

Based on the evidence above, it can be hypothesized that limiting the motility of the speech articulators during language acquisition might interfere with language acquisition and processing. Recent evidence suggests that it might be the case. Using the pacifier for more than three years of age affects the conceptual features used by school-age children when providing oral definitions of abstract, concrete and emotional words (Barca, Mazzuca & Borghi, 2017). Conceptual features elicited in defining a concept might be of different sorts; for example, the code 'perceptual features' refers to perceptual properties of the presented object/entity, such as shape and colour. Thus, the early speech-motor perturbations exerted by using the pacifier beyond infancy appear to affect the processing of stimuli in which the recovery of linguistic information or on-line linguistic simulation is more relevant (e.g., abstract words), whereas this is less marked for stimuli more grounded in perception-action systems (e.g., words referring to actions, to concrete-manipulable objects and emotional domain). Concrete, emotional and action words re-enact previous experiences with their referents (Barsalou, 2008). By contrast, abstract words typically lack easily perceivable referents; they might refer to a broader range of contexts, to more complex situations and are more detached from sensorial experience (Barsalou, 2003; Barsalou & Wiemer-Hastings, 2005; Borghi & Binkofski, 2014; Hale, 1988; Pecher, Boot & van Danzig, 2011). They might be grounded in perception-action systems but to a lesser degree than concrete words; and the linguistic, emotional, interoceptive and social dimensions might be more relevant for them (for a review, Borghi, Binkofski, Cimatti, Scorolli & Tummolini, 2017; Borghi, Barca, Binkofski & Tummolini, 2018; Dove, 2016; Connell, Lynott & Banks, 2018; Ponari, Norbury & Vigliocco, 2018; Recchia & Jones, 2012). Words can be acquired either perceptually, interacting with their referent (e.g., for concrete words such as 'pen', perceptual, sensorimotor and linguistic information are merged) or mainly linguistically, when their meaning is verbally provided and gathered by the child during social interaction (e.g., for abstract words such as 'freedom') (Wauters, Tellings, Van Bon & Van Haaften, 2003; Della Rosa, Catricalà, Vigliocco & Cappa, 2010). The first words acquired by children typically refer to the child's environmental context, those that can be experienced through their senses, and the percentage of linguistically acquired words increases with age (Wauters, Tellings, Van Bon & Mak, 2007), consistently

with the fact that abstract words are typically acquired later than concrete ones (Kousta, Vigliocco, Vinson, Andrews & Del Campo, 2011; Rinaldi, Barca & Burani, 2004). The greater role that the linguistic/speech-motor system plays for abstract words' representation and processing is supported by studies mimicking the acquisition of novel concepts and words in adults, as well as experiments on word processing. For example, faster processing of abstract than concrete words has been reported when the task response is provided with the mouth, but not with the hand (Borghì, Flumini, Cimatti, Marocco & Scorolli, 2011; Granito, Scorolli & Borghì, 2015; Borghì & Zarcone, 2016; Mazzuca, Lugli, Benassi, Nicoletti & Borghì 2018).

We hypothesize that limiting the speech motor system by using the pacifier for a more extended period affects the way words are represented. By limiting the movement of speech articulators, the pacifier might interfere with speech motor acts and internal simulations taking place during language acquisition, resulting in sloppy motor representations. Affecting the integrity of words' speech-motor representation, we hypothesize the pacifier effect to be durable over time and observable even years after its withdrawal, when the child performs tasks requiring the re-enactment of speech-motor programs or internal linguistic simulation. Thus, the interference might be more pronounced for abstract words, given that the re-enactment of internal linguistic simulation is more relevant for abstract than other types of words (i.e., concrete and emotional ones).

Here, we asked third graders who have used the pacifier with different frequency (some rarely, others for many years) to perform a semantic categorization task. They were presented with 'animal' (i.e., elephant) and 'non-animal' words (i.e., helicopter). The non-animal category included abstract, concrete and emotional words.

Previous studies have shown that using the pacifier for more than three years of age affects the development of emotional competence (Niedenthal, Augustinova, Rychlowska, Droit-Volet, Zinner, Knafo & Brauer 2012; Rychlowska Korb, Brauer, Droit-Volet, Augustinova, Zinner & Niedenthal, 2014). Thus we included emotional words to test if pacifier use might influence the processing of words pertaining to the emotional domain. Moreover, it is currently debated whether emotional words can be seen as an intermediate case between concrete and abstract words (Barca *et al.*, 2017b; Della Rosa, Catricalà, Canini, Vigliocco & Cappa, 2018; Mazzuca, Barca & Borghì, 2017), and it has been proposed that emotional words can have a bootstrapping role for the acquisition of concrete ones (Ponari *et al.*, 2018).

Given the regularity of Italian orthography, children can develop an efficient reading system after just a few years of formal education (Barca, Ellis & Burani, 2007). Thus, we choose third graders because they are fluent in reading and, consequently, the visual processing of the stimuli was not an obstacle to the processing of the semantic features required by the task. Furthermore, it is likely that as the age of the children increases the effect of the pacifier (if any) might decrease, so eight years of age seemed a good compromise. We currently do not know how long the effect of the pacifier might last, and further studies are needed to cover this aspect.

An extended use of the pacifier may have two different (and possibly concomitant) effects: limiting the speech articulator it might reduce PHONO-ARTICULATORY SIMULATIONS (Topolinski & Strack, 2009), or it might affect FACIAL MIMICRY, reducing the ability to simulate and thus comprehend facial expressions (Niedenthal *et al.*, 2012). We hypothesize that early-prolonged perturbations to speech motor system affect the building of phono-articulatory representations of linguistic stimuli. Such perturbations should selectively hinder the processing of abstract words (e.g., slowing

down the time needed to their correct categorization), as their processing relies more heavily on linguistic dimension and phono-articulatory simulation (compared to concrete and emotional words). By contrast, if the perturbations induced by the pacifier affect facial mimicry, they might influence the grounding of emotional concepts. In such a case, children who used the pacifier for longer might process emotional words slower than the other type of stimuli.

Using the pacifier for a more extended period during social interaction might affect the child's linguistic experience at many different levels. For example, it might hinder proprioceptive information and speech-motor program (limiting the co-articulation of speech), auditory feedback (as the child receives an inaccurate input of his/her own speech) (Barca, 2019), and might also have a more distal effect on the child's linguistic environment.

Method

Ethics Statement. The procedure has been approved by the Institute of Cognitive Sciences and Technologies of the National Research Council, ISTC-CNR of Rome. Informed consent was obtained from participants' parents. Conflicts of interest: none.

Participants

Eighty-one typically developing children (32 males, aged seven-eight years) were recruited from two schools of Rome. Children's parents provided their Informed Consent filling out a questionnaire asking information about family composition, socioeconomic status and other health-related issues (i.e., familiarity with other languages, children's cognitive, auditory or linguistic impairments). Parents also specified if their child used a pacifier (a) during the day at home, (b) at night, and (c) during the day outside the home, including school (Barca *et al.*, 2017b; Niedenthal *et al.*, 2012). The children provided verbal assent at the time of testing. All children with approved Consent participated in the study. We subsequently analyzed the data of participants with normal or corrected to normal vision and no history of developmental disorders or reported special educational needs (demographic information are reported in Supplementary Materials).

A small group of children (11%) was not included in the analysis either because the enrollment questionnaire was not fully compiled or because the children were left-handed (five). Overall, the majority of children (71%) used the pacifier as previously reported (Barca *et al.*, 2017b). Specifically, 25 participants never used it, 24 participants used it for two years, 11 participants stopped using it between two-three years of age, and 12 children continued to use it during nursery school thus beyond three years of age. Twenty-six percent of children had been exposed to other languages (see Supplementary Materials).

Materials and procedure

A list of 90 lexical stimuli was used. Forty-five target stimuli referred to abstract, concrete and emotional concepts. The other 45 were fillers referring to animals. Target stimuli were Italian lexical nouns (15 abstract, 15 concrete, and 15 emotional), taken from Barca *et al.* (2017b). Stimuli are listed in Appendix 1, where selection criteria and groups psycholinguistic characteristics have been reported.

Children were tested at school, in a quiet room dedicated to data acquisition. They were asked to sit at the table with the experimenter, and a laptop computer was put in front of them. In the SEMANTIC CATEGORIZATION TASK, children were asked to press (as fast and accurately as possible) a key on the computer keyboard if the presented word referred to an animal (e.g., '0' if you see 'cat') and another one if it referred to something else (e.g., '1' if you see 'bottle'). To avoid a bias in the response just focusing on the animal category, and in order to induce a deeper processing of the non-animal category (the one interesting for us), another group of children performed a 'go no-go' version of the task. In this version, the button-press response was required only if the word refers to something other than an animal (e.g., '0' if you see 'bottle'). Thirty-six children (13 males) performed the semantic categorization task, and 35 children (19 males) performed the go no-go categorization task. The response key was balanced between participants. Categorization errors and reaction times were automatically recorded by E-Prime software. Each trial began with a central fixation cross, replaced by an experimental stimulus after 500ms. Stimuli remained on the screen until participants' responses (and for a maximum of 3000ms) and were followed by 1000ms blank screen. Stimuli were presented in ARIAL font (size 18), upper case black print on a white background. Children performed a practice session with 10 non-experimental items (5 animals and 5 non-animal stimuli). The experimental stimuli were presented in two blocks of 45 items each. The order of stimuli within blocks and the order of block presentation were randomized. The session lasted about 15 minutes.

Data analysis

A generalized linear mixed-effects model (GLMM) was used to assess the impact of Concept type and Pacifier use on ACCURACY data (Baayen, 2008, Bolker, Brooks, Clark, Geange, Poulsen, Stevens & White, 2009). GLMM fit by maximum likelihood (Laplace Approximation) was implemented in R with the 'lme4' package, with parameter family 'binomial' to account for categorical data (Bates & Maechler, 2009; Jaeger, 2008). The logit mixed-effects model included a random intercept for Subjects and Items, with maximal by-subject random structure as a baseline model (Barr, Levy, Scheepers & Tily, 2013). The following fixed effects were included: Task (Categorization, Go no-go), Concept type (Abstract, Concrete, and Emotional concepts), time of Pacifier use (number of months) and their interaction. A Likelihood ratio test has been used to compare different models varied for the complexity of the random and the fixed effects structures.

Linear mixed-effects model (LMM) was used to analyzed correct RESPONSE TIME data, with the 'lmerTest' package (Kuznetsova, Brockhoff & Christensen, 2016). Backward elimination of non-significant effects was performed with the step function (backward elimination of the random part is performed first, followed by backward elimination of the fixed part. Finally, least-squares means and their differences for the fixed part of the model were calculated. The p-values for the fixed effects were calculated from an F test and t-test based on Statterthwaite's approximation). The model included a random intercept for Subjects and Items (with maximal by-subject random structure as a baseline model), and Task, Concept type and Pacifier as fixed effects. A Likelihood ratio test was used to compare different models varied for the complexity of the random and the fixed effects structures.

Results

Data of right-handed participants (71 subjects) were considered. Data trimming of response time considered 2sd below and above the overall distribution means, resulting in the removal of 138 data points.

Overall, 8% of trial were errors (specifically 6.4% of trials in the semantic categorization task, and 10% of trials in go no-go categorization task), the majority of which were made with concrete words (i.e., 16% of concrete trials), and a similar percentage among abstract and emotional words (7.8% and 6.7%, respectively). A summary of the GLM analysis is reported in Table 1. No significant effects emerged from the analysis of accuracy data.

Moving to response time, correct response times as a function of years of pacifier use are displayed via raincloud plots in Figure 1. Raincloud plots combine a split-half violin, raw jittered data points, and a standard visualization of central tendency with boxplot (Allen, Poggiali, Whitaker, Marshall & Kievit, 2019).

The plot (panel A) shows that children who used the pacifier for longer (i.e., three years of age and more) tend to be slower in providing their correct responses. Panel B displays response time for the different type of concepts. The time needed to respond to emotional words was shorter ($1425\text{ms} \pm 518$ sd) than that required to respond to abstract ($1496\text{ms} \pm 541$ sd) and concrete words ($1529\text{ms} \pm 535$ sd).

LMMs were used to analyze response time data. In the analysis, we considered pacifier use as a continuous variable, considering the number of months of pacifier use (ranging from zero to 72 months of use in the current sample)¹. A Likelihood ratio test was used to compare different models, ending up with a model comprising Pacifier in the by-subject random slope, and the Concept by Pacifier interaction as fixed factor (the model output is reported in Table 2). Results indicate a significant interaction between Concept Type and Pacifier use, specifically in the difference between abstract and concrete concepts. The application of backward elimination function reduced the significance of the interaction ($F(2, 2442.2) = 2.67$, p -value .069), testifying the close relationship between the predictors.

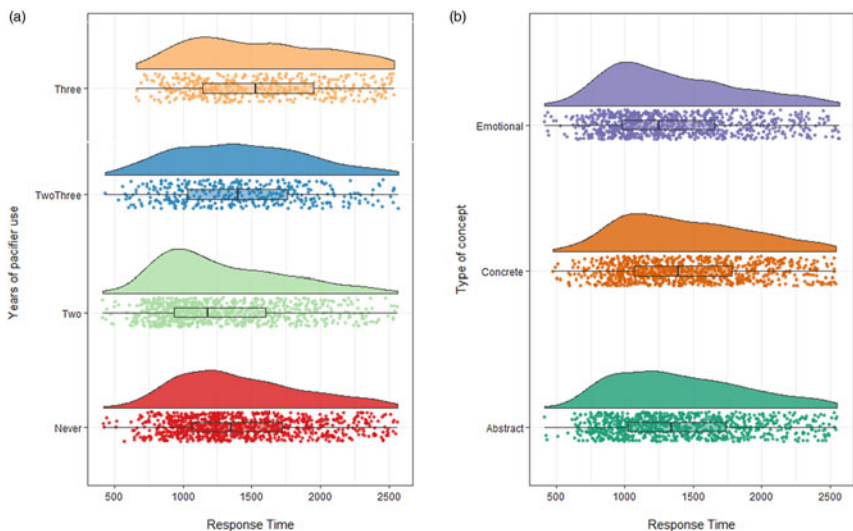
The *sjPlot* package (Ludecke, 2018) has been used to display marginal effects for the Concept Type by Pacifier interaction term of the LMM model (Figure 2).

The plot shows that the response time increases with the increasing number of months of pacifier use. This trend stands for the three types of concepts but is more marked in the case of the abstract ones. The slope (i.e., the proportional relation between the type of concept and the months of pacifier use) is greater for abstract concepts, whereas the difference is smaller for the other two types of stimuli. A progressive slowing is also observed for emotional concepts, but the slope of the predictive values suggests that using the pacifier for many months influences more abstract concepts than emotional ones. Response times for concrete concepts are the least influenced by the time of pacifier use, as indicated by their flat slope. The *phia* package (Martínez, 2015) was used to perform a posthoc analysis of the Concept Type by Pacifier interaction. Such R package computes a ChiSquare test with

¹The MuMIn R package (Barton, 2017) was used to compute a PseudoR2 (see also Nakagawa & Schielzeth, 2013), which indicates that our statistical model explained 41% of the variance with a large effect size ($f^2 = .70$) according to Cohen's conceptualization (1992). To verify the adequacy of the sample size we performed a post-hoc power calculation test with the *pwr.f2.test* function in R. The calculation indicates that a sample of 36 participants would have been sufficient to have a statistical power of .8, thus we believe that our sample (of 71 participants) is adequate.

Table 1. Generalized Linear Mixed model statistics on Accuracy data

Predictors	B	SE	z	P
Intercept	-3.61	.42	-8.61	<2e-16
Concept Concrete	.38	.27	1.41	.16
Concept Emotional	.24	.28	.88	.38
Pacifier	.02	.01	1.45	.14
Concept Concrete : Pacifier	.001	.01	.08	.93
Concept Emotional : Pacifier	-.02	.01	-1.46	.12

**Figure 1.** Raincloud plots showing response time for groups of pacifier use (A) and type of concept (B)

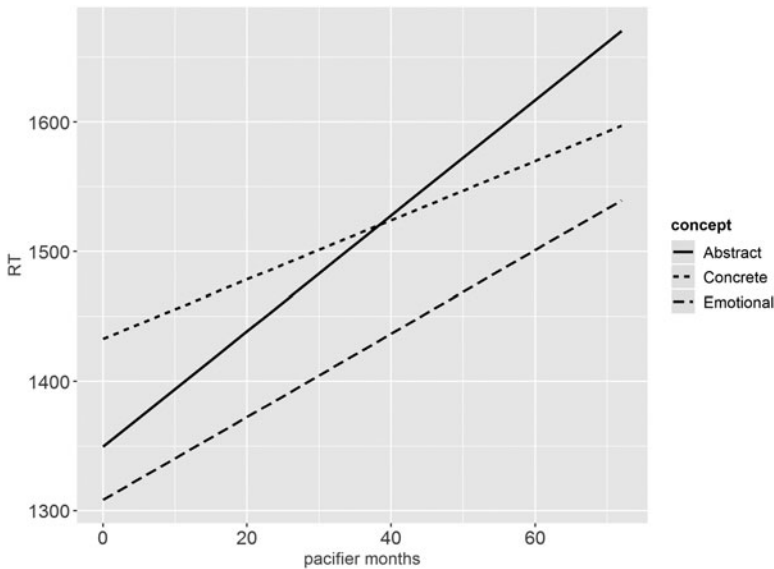
pairwise comparisons of the three levels of the Concept type factor, adjusting the slope to the pacifier values (results are reported in Table 3). The test shows a marginally significant difference between abstract and concrete concepts (Chi-Square = 5.29, p -value = .064), probably because children who have not used the pacifier are faster with abstract than concrete words, while the reversed pattern occurs for those who used it for longer (see Figure 2). However, given its marginality, we do not think this difference is reliable enough to give it further attention. Additional data and experiments are needed to confirm its significance (see also Martínez (2015) for an explanation of the issues related to the calculation of p -value within mixed-models).

Discussion

The type of language and corresponding motor acts we use to communicate (speech articulators for spoken language vs hands and upper limbs movements for signed language) affect our language processes at large, influencing, for example, the way we

Table 2. Linear Mixed Model statistics on Response Time data (significant effect are marked in bold)

Predictors	B	SE	Df	T value	Pr(> t)
Intercept	1369.86	70.85	67.52	19.33	<2e-16
Concept Concrete	83.46	54.76	53.91	1.52	.13
Concept Emotional	41.11	54.66	53.51	-.75	.46
Pacifier	3.75	2.21	52.85	1.69	.09
Concept Concrete : Pacifier	-2.18	.94	2442.44	-2.3	.02
Concept Emotional : Pacifier	-1.25	.93	2441.93	-1.34	.18

**Figure 2.** Plot of the interaction effect of the Linear Mixed Model on Response time

recognize visually presented words (Barca, Pezzulo, Castrataro, Rinaldi & Caselli, 2013; Barca, Napolitano, Castrataro, Rinaldi, Cannatà & Caselli, 2019; Napolitano, Andellini, Cannatà, Randisi, Bernardi, Castrataro, Pezzulo, Rinaldi, Caselli & Barca, 2019). The purpose of this study was to investigate if recurrent perturbations to speech articulators occurring during language acquisition set a footprint on linguistic representations, exerting an effect in language-related tasks later in life. Our study showed that children who used the pacifier for a more extended period (in our sample 72 months of age) were slower in the semantic categorization of visually presented words. As expected, the effect of the speech-articulators' perturbations grows with the increasing role of linguistic information in characterizing the stimulus to be processed: the speed of processing of abstract words was more associated with late pacifier withdrawal, with respect to the processing of emotional and concrete

Table 3. Post-hoc analysis of the Concept by Pacifier interaction

Pairwise comparison	Value	df	ChiSquare	Pr(>Chisq)
Abstract-Concrete	2.18	1	5.29	.064
Abstract-Emotional	1.25	1	1.81	.356
Concrete-Emotional	-.93	1	.99	.365

concepts. Limiting the movements of speech articulators during word acquisition likely impeded children's ability to benefit from phono-articulatory movements. Such restrictions might also affect the simulations of speech motor programs (related to words' pronunciation and their meanings), internally reproducing their sounds at an age critical for language acquisition. This slowed down response times for abstract words, i.e., those for which the linguistic input (and sensorimotor linguistic simulation) is more crucial. Accordingly, response times to concrete concepts are less sensitive to the increase of months of pacifier use. The perturbations induced by the pacifier are likely the same, but their resonance for concrete concepts is reduced given their stronger grounding in perception-action system; that is sensorimotor experience with the objects is more relevant than speech-motor information (see also Wellsby & Pexman, 2014, for relevant data on Body Object Interaction measure and naming speed). Our results also suggest that emotional words differ from both concrete and abstract ones. The weaker association between pacifier use and emotional words' response time suggests that it affects peripheral feedback from speech motor system rather than facial mimicry.

Using the pacifier during social interaction might have a broader impact on the child's development, affecting social aspects of linguistic interaction. Social interaction (and primarily contingent social feedback) plays a decisive role in shaping infants' vocalization, boosting their transition to the production of more complex structure (Goldstein, King & West, 2003). This evidence concerns the structure of the first vocalizations of the child, but this same mechanism of social reinforcement might affect linguistic development at large and therefore also the acquisition of words and concepts. Adults might be less inclined to linguistically interact with the children when he/she is using the pacifier, as their emotional resonance with the child is reduced (Rychlowska *et al.*, 2014). This might result in using a different kind of child-directed speech, in which, for example, the adults might refer more extensively to the current context, reducing the use of abstract words and concepts. This case would be an 'indirect' effect of the pacifier, not specific to the speech-motor program and internal simulation but concerning linguistic communication at large. This account is compatible with the previous one since children might be less inclined to performing linguistic simulation due to the reduced exposure to linguistic stimuli. Experiments are currently underway to further explore this hypothesis.

At present, we have not observed a detrimental effect of prolonged pacifier use. Children's accuracy in linguistics tasks such as those employed here (semantic categorization) and our previous study (word definition in Barca *et al.*, 2017b) is not affected by the age of pacifier withdrawal, and the variables influenced by it (such as response speed) remain in a typical range. Nevertheless, we cannot exclude the possibility that the use of standardized assessment tools might detect some deviations from a typical performance.

Our results have important theoretical implications for the proposal of embodied and grounded cognition (Pexman, 2017). Overall, they are in line with the recently emerged multiple representation views, according to which not only perception-action but also linguistic, emotional, and social experience plays a prominent role in abstract concepts representation. Within these views, some authors emphasize the role of the emotional dimension (e.g., Kousta *et al.*, 2011; Vigliocco *et al.*, 2014; Newcombe, Campbell, Siakaluk & Pexman, 2012), while others highlight more the role of the (social and) linguistic experience for abstract concepts representation (Borghi, Barca, Binkofski, Castelfranchi, Pezzulo & Tummolini, 2019; Dove, 2019). Our experiment does not directly test theories that put the accent on emotionality for abstract concepts. Our results suggest that an extended use of the pacifier might influence abstract concepts acquisition not because it impacts facial mimicry, but because it limits phono-articulatory simulations. However, the difference in processing times between emotional and abstract concepts is broadly consistent with the proposal according to which emotional concepts may provide a bootstrapping mechanism for the acquisition of abstract concepts (Ponari *et al.*, 2018; Lund, Sidhu & Pexman, 2019). More crucially, our results are consistent with embodied theories claiming that abstract words are not only grounded in perception-action systems but also evoke linguistically conveyed information (Dove, 2014, 2019; Borghi & Binkofski, 2014; Moffat, Siakaluk, Sidhu & Pexman, 2015). Specifically, the Words As social Tools proposal (Borghi *et al.*, 2018; 2019) predicts that activating linguistic information also involves its embodied counterpart, the speech motor system; and here we have shown that limiting speech articulators during infancy and beyond (up to 72 months of age) might have a lasting association with subsequent language processes.

Limitations and future directions

Some aspects of our study might limit its conclusions. First, the study focused on pacifier use but did not consider other variables that might be related to the use of pacifier for a more extended period, and which might account for the present findings. For example, LOWER LEVELS OF MATERNAL EDUCATION (e.g., elementary schooling) have been associated with prolonged pacifier use (e.g., Korlahalli, Shivaprakash & Noorani, 2014). Parental education (coupled with their occupation and family income) defined the SOCIO-ECONOMIC STATUS (or SES) of the family, which has been critically associated with the child's linguistic development (Schwab & Lew-Williams, 2007). Both the quantity of words directed to the child and their quality appeared to be affected by socioeconomic disparities so that highly educated parents use more rare words and decontextualised utterances than those with low education (Rowe, 2012).

Additionally, it reflects also in differences in adult/children conversational turns frequencies, which have an impact on the development of language-related cortical structures (Merz, Maskus, Melvin, He & Noble, 2019). Thus, the effect of pacifier use on abstract word processing might be due to reduced linguistic skills resulting from an impoverished linguistic environment associated with low SES. Unfortunately, we lack the information necessary for the computation of the SES of our sample. Although this explanation might be plausible, we believe it is unlikely that it affects the results because participants of the current study were enrolled at school, and they live in the same urban area. Thus they likely have similar cultural and social backgrounds.

Furthermore, in our sample, there were only two children with a low level of maternal education (see Appendix), and these were not included in the analysis because the questionnaires had not been correctly completed. The same applies to the socio-economic status of the family. However, further studies need to carefully address the relation between SES and age of pacifier withdrawal, and their long-term effects on child linguistic processes.

Moreover, the current measure of pacifier use also has some flaws. The measure we consider is not an 'objective measure' of pacifier use, in that we asked parents to provide retrospective information on the habit of pacifier use by their children. Although the use of questionnaires and ratings is widespread in psycholinguistics, and a correlation between objective and subjective measures has been reported (see, for example, Bates, Burani, D'Amico & Barca, 2001), it is possible that the information provided by parents was not entirely accurate. A possible way to solve this issue might be to study more directly the relationship between pacifier use and linguistic performance: for example, testing younger children who are still using the pacifier. This might allow establishing a causal relationship between the sensorimotor limitations induced by the pacifier and linguistic processing, providing further support for the present findings that at such are correlational.

Despite these flaws, the study of pacifier use opens up new perspectives for exploring the socio-emotional nature of speech development.

Conclusion

Sensorimotor-articulatory information is decisive during language development. Perturbations to the phono-articulatory system during child development might interfere with the processing of abstract words later in life. This suggests that sensorimotor-linguistic information is central for abstract words' representation and that abstract words are grounded both in perception-action and in language.

Supplementary Material. For supplementary material accompanying this paper, visit <https://doi.org/10.1017/S0305000920000070>

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Appendix

The first criterion for items selection was that the words were known in written form by the children (i.e., that they had a frequency in the Child Written Lexicon different from zero (Marconi *et al.*, 1993)¹), and that they were familiar words. Subsequently we control other psycholinguistic variables. Words can be characterized in a multidimensional space, which includes for example their meaning, the age at which they were acquired and their mode of acquisition. Given the high multicollinearity between these (and other) dimensions, trying to separate them to create a list of stimuli in which they are perfectly controlled might lead to the selection of rather awkward stimuli. As for written frequency, the only significant difference is between concrete and abstract words with an advantage for the latter (higher frequencies), whereas they do not differ in familiarity. Considering the other variables abstract words of this sample are acquired later in life, and have lower values of Imageability and Context Availability than concrete words, and have higher values of Modality of Acquisition (MoA). Concrete words are acquired earlier in life and have lower values of Abstractness and MoA than emotional words, but higher values of Imageability and Context Availability ($ps < .05$, paired t-test computed in Excel). Animal stimuli were used as fillers, and were matched with the non-animal stimuli as to length in letters.

¹Marconi, L., Ott, M., Pesenti, E., Ratti, D., and Tavella, M. (1993). *Lessico Elementare. Dati Statistici Sull'italiano Letto e Scritto dai Bambini delle Elementari* [Elementary Lexicon: Statistical Data on Italian as Written and Read by Elementary School Children]. Bologna: Zanichelli.

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Table A1. Psycholinguistic characteristics of the stimuli

	FREQ	FAM	CONC	IMA	AOA	CA	ABS	MOA	LET	EMO
Abstract	83.3 (..)	530.4 (73)	311.0 (103)	398.0 (146)	323.7 (75)	463.3 (102)	435.9 (92)	477.7 (107)	7.3 (2)	2.8 (1)
Concrete	37.7 (..)	563.2 (92)	669.8 (40)	664.3 (34)	251.8 (59)	614.3 (53)	130.9 (42)	237.1 (79)	7.4 (2)	2.1 (1)
Emotional	84.7 (..)	571.1 (79)	373.9 (147)	431.5 (120)	307.0 (84)	504.6 (92)	379.2 (128)	394.4 (103)	6.8 (2)	5.5 (.3)

Note. ABS: abstractness; CONC: concreteness; EMO: words emotionality; FREQ: written word frequency; IMA: imageability; FAM: familiarity; AOA: word age of acquisition; MOA: concept mode of acquisition; LET: word length in letters. Mean values and standard deviation are provided (in bracket).

Table A2. Experimental stimuli

Word (English translation)		
Abstract	Concrete	Emotional
accordo (agreement)	bandiera (flag)	alba (sunrise)
area (area)	bottiglia (bottle)	amore (love)
bellezza (beauty)	campeggio (camping site)	bacio (kiss)
crescita (growth)	casco (helmet)	cuore (heart)
cultura (culture)	cipolla (onion)	curiosità (curiosity)
descrizione (description)	corona (crown)	dolore (pain)
fantasma (ghost)	crystallo (crystal)	felicita` (happiness)
incantesimo (spell)	elicottero (helicopter)	infanzia (childhood)
inizio (beginning)	labirinto (labirinth)	odio (hate)
mistero (mystery)	lago (lake)	paura (fear)
motivo (reason)	libreria (library)	soddisfazione (satisfaction)
numero (number)	noce (walnut)	sorpresa (surprise)
scoperta (discovery)	orologio (clock)	veleno (poison)
stella (star)	pennello (brush)	vendetta (vengeance)
vittoria (victory)	scatola (box)	vergogna (shame)