

Do early meanings of negation map onto a fully-fledged negation concept in infancy?

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ABSTRACT

Young children acquire an amazing knowledge base, rapidly learning from, and even going beyond the observable evidence. They arrive at forming abstract concepts and generalizations and recruit logical operations. The question whether young infants can already rely on abstract logical operations, such as disjunction or negation, or whether these operations emerge gradually over development has recently become a central topic of interest. Here we target this question by focusing on infants' early understanding of negation. According to one view, negation comprehension is initially restricted to a narrow range of meanings (such as rejection or non-existence) and only much later infants develop a broader understanding that maps onto a fully-fledged negation concept. Alternatively, however, infants may rely on a fully-fledged negation concept from early on, but some forms of negation may pose more mapping and processing difficulties than others.

Here we tested infants' understanding of two syntactically and semantically different forms of negation, existential negation and propositional denial in a language (Hungarian) that has a separate negative particle for each, and thus the two negation forms can be directly compared. We engaged 15- and 18-month-old infants in a search task where they had to find a toy in one out of two locations based on verbal utterances referring to the object at one of the locations involving existential negation (*Nincsen* - not.be.3SG) or propositional denial (*Nem itt van* - not here be.3SG). In Experiments 1–3 we found a parallel development for these two kinds of negation. 18-month-olds successfully comprehended both, while 15-month-olds were at chance for both. In Experiment 4 we excluded the possibility that 15-month-olds' chance performance is explained by task-related difficulties, as they succeeded in a similar, but nonverbal task. Thus, 15-month-olds likely still have not solved the mapping for the two negation forms. The parallel performance of the two age groups with the two negation types (failing or succeeding on both) is consistent with the hypothesis that different forms of negation rely on similar conceptual underpinnings already in early development.

1. Introduction

Humans, as well as other animals were adapted to perceive and learn about the entities that surround them. We quickly learn how to distinguish objects and agents from their surroundings, remember their locations and extract rules that will allow us to predict future events. Crucially, besides encoding what is around us, we also benefit from information about absent and non-existent entities. While concepts related to the absence of objects tend to be extraordinary (like nothing, zero or no ghosts), most of the time we do not realize how special they are when verbally expressing them via negation in our everyday life, for instance, when we utter the sentence “There are no more cookies in the box”.

Negation is rather prevalent in our everyday communication, yet we have only scarce knowledge about the nature and the development of the representations through which we acquire and comprehend the meaning of negative sentences.

Adults' understanding of negation has been the subject of intense research, yielding to the typical finding that the comprehension of sentences containing negation is more effortful than the comprehension of affirmative sentences (for a review see: [Horn, 2001](#); [Kaup, Lüdtke, & Zwaan, 2007](#)). These processing difficulties are usually discussed in relation to two factors. The first concerns the way in which we may make sense of negative sentences. A sentence like “A is not above B” might be processed by negating an affirmative proposition i.e., “false (A is above

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B)” (Clark & Chase, 1972; Singer, 2006) or, alternatively, by transforming the negative sentence into a possible affirmative form i.e. “A is below B” (Kaup, Lüdtke, & Zwaan, 2007; Wason, 1961). Either process (applying the truth-functional operator on a proposition vs. making a transformation from a negative to an affirmative sentence) may explain the processing delay.

The second factor relates to the possible function of negation in communication, which reflects a violation of our underlying expectations (Vandamme, 1972; Wason, 1965). For instance, starting a story with “My train was not late” might sound awkward, unless the audience knows that this particular train is always late. The slow processing of negative sentences may be explained by the lack of a contextual background in experimental tasks (Wason, 1965; Vandamme, 1972; De Villiers and Flusberg, 1975; Glenberg, Robertson, Jansen, & Johnson-Glenberg, 1999).

With respect to young learners, besides the challenge of grasping the abstract meaning of truth-functional negation (that changes the truth value of a proposition, via combining with other linguistic units), there might be further aspects that render negative statements difficult for a child at an early stage of language acquisition. Utterances involving words related to negation (e.g., negative markers, such as ‘no’ or ‘not’) are also characterized by greater referential ambiguity and they convey more abstract meanings compared to affirmative statements. While concrete words (e.g., “apple”) are most often used in the presence of their referent, this is not the case for abstract words; furthermore, the referents of the latter are also more diverse (Gogate, Bahrlick, & Watson, 2000). For instance, the statement “This is not a cat” can be mapped to a variety of things, that can range from dogs to chairs. Studies suggest that the concreteness of the word is an important factor in word learning: abstract words are acquired later compared to concrete ones (Bergelson & Swingley, 2013; Swingley & Humphrey, 2018). Thus, the question emerges: if statements involving negation rely on an abstract meaning and often do not have a clear referent, how and when do they obtain their meaning in the developing mind, and what kind of conceptual representations may underpin them? Of course, negation may come with certain representational requirements that will likely affect infants’ ability to capture negation. For instance, to comprehend the meaning of negation expressing non-existence, infants must be able to conceive of absent entities in the first place. Thus, one would not expect infants to understand “There are no more peas” if they are not able to encode the absence of expected objects. The first signs of object permanence are documented rather early, around the age of 4 months (Baillargeon, 1987) and by 12 months infants already point to absent referents in communicative contexts (Liszkowski, Carpenter, & Tomasello, 2007). Beyond the minimum requirements, however, mapping words expressing negation to the underlying concepts might be yet a further challenge for infants.

Not surprisingly, in line with the processing difficulties of adult language users and the potential issues language learners might face when processing negative statements, young children seem to understand negative sentences later than affirmative ones (Nordmeyer & Frank, 2014; Reuter, Feiman, & Snedeker, 2018; Feiman, Mody, Sanborn, & Carey, 2017; Grigoroglou, Chan, & Ganea, 2019; but see Austin, Theakston, Lieven, & Tomasello, 2014). While from about 20 months of age infants comprehend sentences like “It is in the bucket” when faced with two possible hiding locations (a bucket and a truck), they seem to understand its negative correspondent “It is not in the truck” only around 24–27 months (Feiman et al., 2017).

On the other hand, however, observations targeting negation production suggest that infants start to use negation already from around their first birthday (Bloom, 1970; Choi, 1988; Pea, 1980). Different taxonomies have been proposed to explain the negation forms articulated by infants and toddlers at the early stage of their language development. Bloom (1970) has targeted multi-word speech production and described three categories emerging in the following order: non-existence, rejection, denial/truth functional negation. The study

performed by Pea (1980) included gestural expressions and single words as well. Based on these observations, rejection emerged first, then self-prohibition, followed by disappearance, unfulfilled expectation, and finally by truth functional negation. Choi (1988) has investigated the first negative verbal utterances of children exposed to one of three different languages (Korean, French or English) and argued that in all these languages the first negation functions emerged in the following order: non-existence, prohibition, rejection, and failure and denial. While there are some differences in the order in which different forms of negation seem to emerge in these studies, they are consistent in finding that rejection and non-existence emerge earlier than denial/truth-functional negation.

Impressively, these studies report a relatively early capacity to use verbal negation. For instance, infants were found to express rejection from the ages of 10 to 13 months, non-existence from 13 to 19 months and truth functional negation from 19 to 23 months on (Pea, 1980).

However, in comprehension, toddlers were found to understand proposition denial in two alternative choice tasks only at 24–27 months (Feiman et al., 2017) and the youngest age at which infants show evidence for understanding some forms of verbal negation is at 18 months (negative noun and verb phrases: de Carvalho et al., 2021).

While there are obvious differences between research methods and the complexity of investigated linguistic units, one may wonder how to explain this apparent lag between the early production of negation in naturalistic speech and the relatively late comprehension of propositional denial (e.g. “It is not in the bucket”, Feiman et al., 2017) demonstrated in experimental settings. There may be two different possibilities: infants may possess negation concepts early on, but in tasks targeting comprehension they may be limited by their general language proficiency, or alternatively, their early production may not reflect fully fledged negation concepts, and they may undergo a conceptual change after the second year of life, when they also pass the comprehension tasks.

According to the first account, infants may have the conceptual prerequisites to represent negation (including denial) but they may face language processing difficulties in comprehension tasks, which may mask their abilities. One challenge may be mapping the abstract concept of negation to the respective words. Indeed, concrete words seem to be mapped earlier by infants than abstract words (Bergelson & Swingley, 2013; Parise & Csibra, 2012). Another difficulty may be understanding the rest of the proposition in which negation occurs, and successfully combining multiple words to decipher the meaning of a complex sentence. For instance, to comprehend “It’s not in the bucket” – besides understanding negation – infants also have to process a complex proposition to which negation can be applied and its elements, which may mask their conceptual competence in specific experimental tasks. Note that infants’ negation production usually involves relatively simple sentences. Such difficulties with processing complex sentences involving negation are not that surprising considering that 24-month-olds often show a fragile, chance-level performance even for comprehending affirmation, e.g., “It is in the bucket” – although it should be both conceptually and syntactically easier than negation (Austin et al., 2014; Reuter et al., 2018). In line with this, studies suggest that affirmative trials can boost 24-month-olds’ performance on consequent trials involving negation, pointing to the importance of establishing the crucial structures the conveyed information involves, and suggesting that the observed difficulties may be independent of negation (Reuter et al., 2018).

Importantly, this account pre-supposes the presence of negation related concepts from very early on. Recent studies have targeted whether nonverbal negation-like concepts and specific logical operations are available for infants well before they acquire the related linguistic forms (Cesana-Arlotti et al., 2018; Cesana-Arlotti, Kovács, & Téglás, 2020; Dudley, Kovács, & Téglás, 2023). These studies suggest that 10- and 12-month-olds seem to use reasoning by exclusion, possibly relying on negation (A or B, not A, therefore B) to identify ambiguous

objects or speech sources (Cesana-Arlotti et al., 2018; Ekramnia, Mehler, & Dehaene-Lambertz, 2021). Furthermore, data from verbal referent identification at the age of 12 months also seems to corroborate such findings (Pomieczowska, Bródy, Csibra, & Gliga, 2021).

According to the second account targeting the puzzling discrepancy between the production and comprehension data, infants early on may have an immature understanding of negation, and the early production evidence may not reflect a fully-fledged negation concept. Such accounts have advanced the conceptual-gap hypothesis, proposing that infants start from a narrow, non-propositional meaning of negation and they arrive to an adult-like understanding only later in development (Bloom, 1970; Pea, 1980; Feiman et al., 2017, but see Gomes et al., 2023). For instance, Pea (1980) has suggested that negation originates from the comprehension of prohibition and that this understanding gradually develops into a more mature concept, as children's thoughts become more and more complex. Thus, the first meanings of negation might be limited in the propositions these can target or may not involve propositions at all. Feiman et al. (2017) have suggested that certain domain specific cognitive tools might be available for infants (e.g., to represent absence) and they may initially map some of these representations to linguistic negation (e.g., expressing non-existence "All gone"). Fully fledged negation may emerge later on, and one factor that is argued to play a crucial role in this is language, often conceptualized as augmenting abstract concepts and abstract thought (Grigoroglou & Ganea, 2022). For instance, Mody and Carey (2016) suggested that logical operators emerge only around the third year tightly together with (or related to) linguistic competencies. A similar proposal was developed to explain how children acquire the concept of natural numbers (Carey, 2009). In line with such views, infants' early capacity to produce only some, but not other linguistic forms of negation, alongside with their poor performance in comprehension tasks reveal the limited nature of their negation concept.

Furthermore, given that the meaning of negation can be obtained only by combining it with other linguistic units, answering the question whether infants understand different forms of negation early on (including truth functional proposition denial) may also speak to broader theories of language acquisition. Indeed, if infants are able to correctly interpret utterances involving negation early on, it would also provide support to an early emerging compositional thought, that may not be heavily relying on rich linguistic knowledge (see recent evidence in this direction: Pomieczowska, Bródy, Téglás, & Kovács, 2024). However, according to influential theories, extensive experience with natural language may be necessary to support compositional processes (Shukla & de Villiers, 2021; Spelke, 2017; Spelke, 2022). For instance, it is argued that when children start producing multi-word utterances, those are initially learned and used in an item-based manner (as fixed phrases), and only much later they productively produced in novel combinations, and are used in an abstract manner as a result of a conceptual change (Tomasello, 2000).

However, it is currently unclear whether language processing difficulties or a conceptual gap can better explain the observed discrepancy between negation production and negation comprehension. In particular, it is still a question which types of negation are available to young infants and whether the first forms of negation observed in production (i.e. expressing non-existence) should be characterized with processes not related to propositional negation. One could argue that early utterances like "All gone" or "No cookies" that look like existential negation, may in fact be similar to verb islands (Tomasello, 1992) and rely on concepts that do not involve negation (but rather relate to absence or empty space representations, Feiman et al., 2017). This argument, in contrast, cannot be advanced for linguistic forms like Not x that emerge later in development and involve negation that can be applied flexibly to any content (proposition).

Importantly, however, in many languages there is a special negation particle –different from standard negation– that is used to negate a wide range of existential predications (Dahl, 2010; Veselinova, 2013), which

may allow for comparing how different forms of negation emerge, an initiative we aim to undertake in the present study. Such are, for instance, the suppletive negative existential verbs, like *yok* in Turkish, or *net* in Russian. Similarly, while in Hungarian the main negative particle is *nem*, the particle *nincsen* is specifically used to express the absence of entities. In the present study we will compare infants' comprehension of these two types of negation, and in the following section we briefly describe how these are expressed in Hungarian (for a detailed description of Hungarian negation see Kiss, 2011).

Nem (not) is the Hungarian negation word, which is used to express the denial of propositions in indicative clauses. In sentences with no structural focus the negative particle precedes the verb (1a), while in predications with preverbal structural focus *nem* is followed by either the focus (1b) or in case of background negation the negative particle precedes the verb (1c).

1. a) *Nem teszi bele a pohárba.*
Not place.3SG into the cup.ILL.
"She doesn't place it into the cup."
- b) *Nem a POHÁRBA teszi bele.*
Not [the cup.ILL]FOCUS place.3SG into.
"It is not into the cup that she puts it."
- c) *A POHÁRBA nem teszi bele.*
[The cup.ILL]FOCUS not place.3SG into.
"It is into the cup that she doesn't put it."

Nincsen is the Hungarian negative existential and it has three specific uses: it can negate existential predications (2a), possessive predications (2b) and locative predications (2c). It is used in present tense and with the copula defined in 3rd person (singular *nincs* or *nincsen* or plural *nincsen-ek*). In future and past tenses, the standard negation *nem* is used to express these meanings.

2. a) *Unikornisok nincsen-ek.*
Unicorns not.be.PL.
"Unicorns do not exist".
- b) *Nincsen pénzem.*
Not.be.SG money.1SG.
"I have no money".
- c) *Nincsen (itt).*
Not.be.SG (here);
"(She/he/it) is not (here)".

Directly comparing how infants comprehend negative particles involving different syntactic forms and semantic functions (e.g., existential negation and proposition denial) would advance our understanding regarding how the developing human mind manages to make use of negation at this early stage. In particular, it would answer the question whether infants arrive to understand different functions of negation at the same time, or in a specific order when the two forms are each used in more than one context and thus their mapping demands may be more comparable (though note that the propositional negator is used more widely).

In the present study we aim to investigate this specific question by asking how infants comprehend two different forms of negation referring to the location of an object in a two-alternative-choice task (object invisibly hidden in one out of two identical cups). In Hungarian such locative predications can be conveyed in two different ways - either using negative existential or propositional negation. For both sentences we aimed to use the most minimal forms possible that are still grammatical, however note that the negative existential sentence we have used, i.e., *Nincsen* ((It) is not/ not.be.3SG) is composed of a single word, while for the proposition denial i.e., *Nem itt van* (It is not here/ not here be.3SG) the minimal form is composed of 3 words, as less would be ungrammatical. We decided to use the adverb "here" (instead of e.g. "in the cup") as we thought it would be more simple in terms of processing

demands. In Experiments 1 and 2 we targeted 18-month-olds. Although earlier studies investigating similar questions and using a similar task found positive evidence only around the age of 25–27 months (Austin et al., 2014; Feiman et al., 2017), we have chosen a younger age group, because understanding negation expressing non-existence might be an easier achievement, and indeed it appears in production already around 16 months. Furthermore, given that, in comparable two-alternative choice tasks not involving language infants were successful from a similar age (17–20 months in Feiman et al., 2017, Feiman, Mody, & Carey, 2022), we assumed that 18-month-olds possess the general cognitive skills to cope with the general task requirements. Next, to probe the early limits of infants' abilities, in Experiment 3, we assessed the comprehension of these two forms of negation in 15-month-olds in a within participant design. In Experiment 4, 15-month-olds' performance was measured in a nonverbal version of the two-alternative choice task used in Experiments 1–3.

Finding earlier evidence for comprehending the negative existential compared to propositional denial (consistently with the pattern found in production) would support the idea of infants' limited conceptual understanding and a gradual acquisition of negation. In contrast, if infants understand the two types of negation at the same time, it would favor the hypothesis that from an early on a rather sophisticated negation concept may be acquired, which supports understanding different functions of linguistic negation.

2. Experiment 1

In Experiment 1 we investigated 18-month-olds' comprehension of a negative existential, which is expressed in Hungarian via the utterance *Nincsen*¹. In our task *Nincsen* was used to negate a locative predication regarding the presence of a target object at a specific location (i.e., a toy invisibly hidden in one of two locations). Infants' ability to correctly choose the location containing the target object would indicate whether they understand that the negation conveys the absence of the object at the other location.

3. Method

3.1. Participants

Thirty 18-month-old infants participated in the study (20 girls, mean age was 18 months 0 days, range: 17 months, 19 days to 18 months, 18 days). Fifteen additional infants were tested but excluded from the analyses due to experimental error (2); not completing at least 4/6 experimental trials (10); not choosing any of the two containers; or removing both lids and grasping both containers simultaneously (3). Parents were informed about the procedure and the aim of the study and gave written consent. All the experiments reported here were approved by the United Ethical Committee for Psychological research in Hungary (EPKEB).

3.2. Stimuli

Infants participated in a task where the experimenter hid a target object in one of two opaque containers (Fig. 1). The target object was a colorful round silicone toy (diameter = 5 cm) with face like features (e.g.

¹ Negative locative predications can be expressed with the single word sentence (i.e. *nincsen* ((she/he/it) is not (here)) or by adding of an adverb of place (i.e. *Nincsen itt* ((she/he/it) is not here)). We chose *nincsen* because it is the simplest linguistic structure possible in this context, and we aimed to give infants the best chances to succeed. Furthermore, its meaning is closer to verbal phrases in other languages expressing absence or non-existence (i.e. “all gone”), and based on the production studies from English this should be an easy form of negation for infants to map.

eyes). The containers were two white plastic cups, 14 cm high, which could be covered with white lids. The cups were placed on a plastic tray that was in front of the experimenter during the hiding and then pushed towards the participant during the choice phase. In test trials the experimenter occluded herself and the hiding event with a 100 cm × 150 cm cardboard screen.

3.3. Procedure

Infants were sitting on their caregiver's lap at a table in front of the experimenter. The study consisted of 2 warm up, 2 familiarization and 6 test trials.

3.3.1. Warm up trials

In the warm up trials only one cup was used, once without a lid, and once with the lid. In these trials, the experimenter visibly placed the target (introduced as “This is Bobó. Bobó likes to hide very much” – (*Ő itt Bobó. Bobó nagyon szeret elbújni.*) into the cup and pushed it towards the participant saying, “Where is Bobó? Can you find it?” – (*Hol van Bobó? Megkeresed?*) If the infant was too shy to touch the cup and retrieve the object, the experimenter or the parent (if she was asked by the experimenter) encouraged the child to find the object.

3.3.2. Familiarization trials

At the beginning of the familiarization trials, the experimenter introduced another identical cup, and arranged the two cups on the tray approximately 20 cm away from each other. Then, she directed the participant's attention to the target object saying, “Look! Bobó is hiding” – (*Nézd! Bobó elbújik.*) Afterwards, the experimenter placed the object into one of the cups in the full view of the infant. After the placement, the cups were covered with the lids and then the experimenter asked, “Where is Bobó? Can you find it?” (*Hol van Bobó? Megkeresed?*) The tray with the cups was pushed towards the infant and she could search. There were two familiarization trials, in which the target was hidden once in each cup (order counterbalanced). If the infant choose incorrectly in either of the two familiarization trials, a third, extra familiarization trial was presented afterwards.

3.3.3. Test trials

There were six test trials using a similar procedure as described in the familiarization phase. Crucially, however, in test, the placement was not visible to the participant. To cover the hiding event from the infant's view, the experimenter placed an occluder screen on the table covering the cups and herself. At the beginning of each trial, the experimenter raised the object above the screen in the middle and said, “Look! Bobó is hiding” (*Nézd, Bobó elbújik.*) After hiding the object, the experimenter removed the screen and turned to the infant saying “Where is Bobó?” (*Hol van Bobó?*) Afterwards, the experimenter lifted one cup, looked into it and said, “Maybe this? (It) is not (here)” (*Vajon ez? Nincsen.*) To equalize the participant's attention to the two cups, the experimenter lifted the other cup without looking into it and provided neutral information – “Maybe this?” (*Vajon ez?*) – about the other cup as well (order counterbalanced). To prevent recency effects, infants' gaze was directed away from the cups towards the experimenter's face before the choice via addressing them with the question “Where is Bobó? Can you find it?” (*Hol van Bobó? Megkeresed?*) or if it was necessary, calling them by their name. Afterwards, the cups were pushed within the infants' reach, and they could search for the object.

We measured infants' first choice, which was defined as the first cup the infant touched (which was coded as a correct choice if the cup was the one that contained the object, and incorrect if it was the empty cup). Occasionally participants reached with two hands and removed simultaneously the lids of both cups but then grasped or looked into one of the cups. As removing the lids did not provide information about the content of the containers (due to the position of the cups on the table the infants could not see inside the cups), these trials were also coded as valid trials

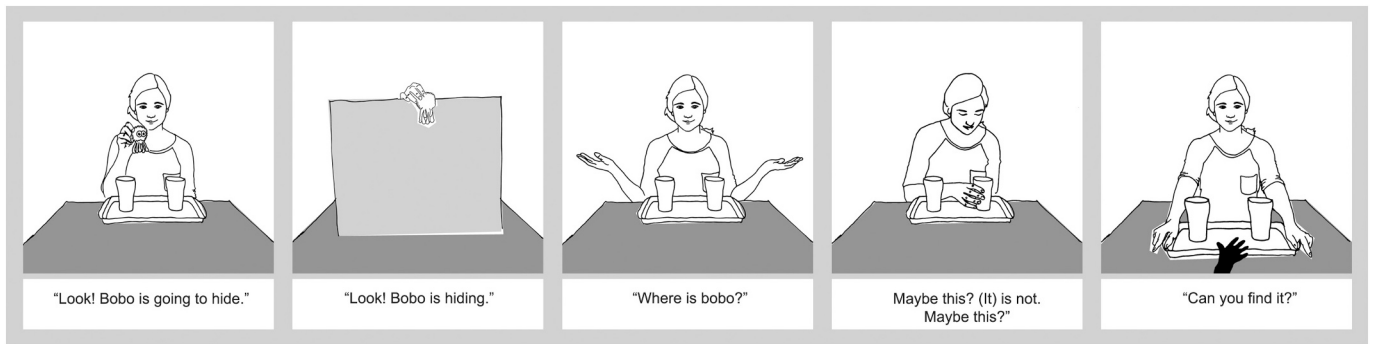


Fig. 1. Schematic depiction of the two-alternative choice task. After the invisible hiding of the target object, the experimenter provided information about where the object is not present, by looking into one cup and saying “Maybe this? (It) is not (here)””; in addition, she also lifted the other cup and said “Maybe this?” (Experiment 1). Afterwards, infants could choose between the two possible locations.

and the grasped cup or the cup into which the infant first looked was considered as first choice. If infants grasped and lifted the two cups simultaneously, this was coded as invalid trial for two reasons. First, it was not possible to decide which one was their first choice; second, the weight of the cups carried information about their content. If the infant chose the incorrect location first, although the trial was coded as an incorrect choice, they were allowed to search and find the object in the other cup.

3.4. Counterbalancing

The location of the target (left or right side) was counterbalanced within the six test trials using an ABBAAB order. The order of the cup that was manipulated first by the experimenter (the cup with the object or the empty cup) was counterbalanced within participants – for half of the trials the cup with the object was touched first and for the other half of the trials the empty cup was touched first (using an ABABAB order). Additionally, we also varied between participants whether the location of the target (left/right) in the first test trial corresponded or not to the preceding familiar trial (left/right).

3.5. Results

Responses were coded in relation to the actual location of the object, and a choice was scored as correct (coded as 1) if the infant first chose the cup with the object and incorrect (coded as 0) if the infant first chose the empty cup. The criterion for inclusion in the data analyses was to provide at least four valid test trials out of 6, via expressing a clear choice of one of the cups. Out of 30 participants, 26 contributed with 6 trials, 3 infants with 4 and 1 infant with 5 trials to the final data set. We calculated the proportion of correct choices for each participant and averaged the proportions across infants. The averaged values were compared to chance (50%). A one-sample Wilcoxon Signed-Rank test indicated that the average proportion of correct choices was significantly higher than chance ($M = 0.663, SD = 0.039, Z = 465, p < 0.001$), suggesting that infants were more likely to choose the correct cup than the empty one based on the provided verbal negation.

Analyzing infants' performance separately on the very first test trial, we found that their performance was significantly above chance level (25 out of 30, binomial test, $p < 0.001$). Thus, infants predominantly chose the correct cup even in the very first trial ($M = 0.833$), which suggests that at 18 months their comprehension of existential negation is likely already well-established. This pattern, together with a trial-by-

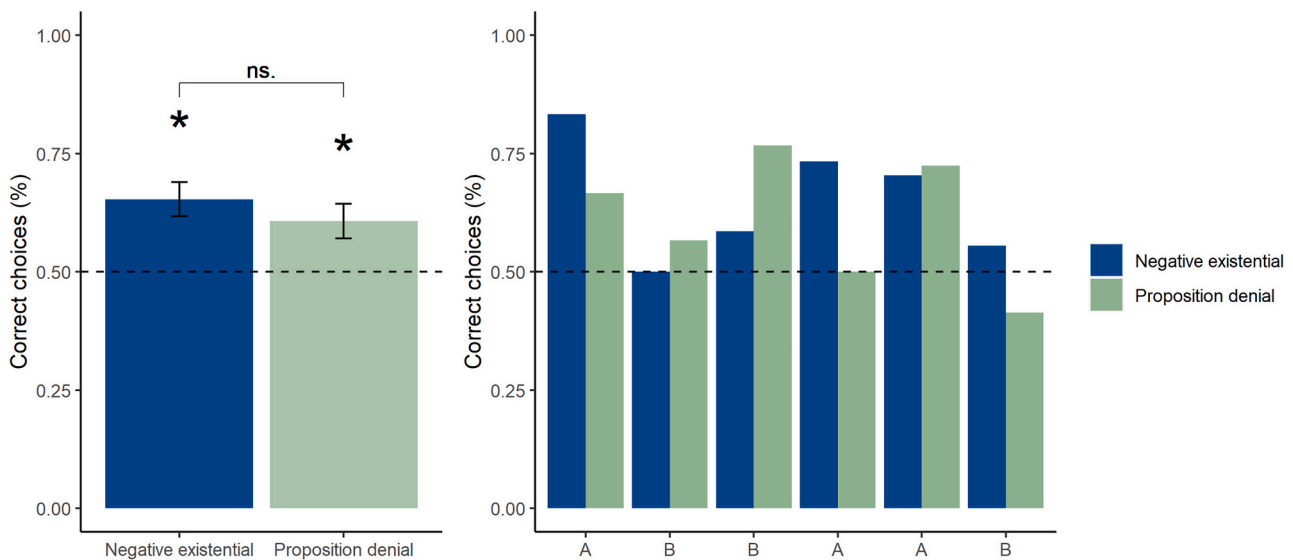


Fig. 2. The results of Experiment 1 (Negative existential) and 2 (Proposition denial)-18-month-olds. A) Mean percentage of correct choices across all trials in Experiments 1 and 2 compared to chance level (50%). Error bars represent standard error. B) Percentage of participants choosing the correct location trial by trial. Capital letters on the x axis represent the counterbalancing of the location of the target (left/ right: for half of the infants A stands for right and B left, and the opposite was the case for the other half of the infants).

trial inspection of correct performance (Fig. 2.) excludes the possibility that they do not understand negation, but have instead developed some alternative heuristic over the course of the experiment (e.g. to always avoid the cup about which an additional comment was made).

Additionally, we asked whether infants' understanding of negation is modulated by other factors, such as a possible perseveration to the location where the object was found in the previous trial (as it is found sometimes in other studies not targeting negation, e.g. Kovács, Téglás, & Csibra, 2021, Exp. 3). Thus, we compared infants' performance on test trials in which the location of the object has changed compared to the preceding trial (location-change: trials 2, 4 and 6) and in trials in which the location of the object has not changed (no-location-change: trials 3 and 5). We included in this analysis only those participants' data who completed all the 6 test trials ($n = 26$). We found no significant difference between the performance in the no location-change trials ($M = 0.635$, $SD = 0.333$) and the location-change trials ($M = 0.59$, $SD = 0.053$), (Wilcoxon Signed-Rank Test, $Z = 104.5$, $p = 0.467$). Thus, infants' comprehension of existential negation seems robust enough not to be affected by their memory from the preceding trial (regarding where the object was hidden previously).

3.6. Discussion

18-month-olds in Experiment 1 correctly comprehended the utterance containing a negative existential *Nincsen* (It's not (here)) and they were able to use this information to find the target object. Comparing present data to findings from other studies, our participants seem to understand the negative existential at least six months earlier compared to when children were found to understand denial in a similar task (e.g. "It's not in the bucket" Austin et al., 2014; Feiman et al., 2017; Reuter et al., 2018), and 1.5 years earlier compared to when they show signs of understanding negation expressing non-existence in more complex sentences (e.g., "Look at the boy with no apples", Nordmeyer & Frank, 2014). Such an early success of infants in our task may be explained with the specific form of negation we have used, or it may suggest that earlier tasks might have been too demanding for infants, masking their abilities.

To test our main research question, specifically whether infants comprehend only this special form of negation or, alternatively, infants at this age may have a broader conceptual understanding of negation, we run a further experiment. In Experiment 2, we used standard proposition denial: "(It) is not here" – *Nem itt van* ((It) is not here/ not here be.3SG) in Hungarian to express where the object was not. This form is structurally and semantically more similar to the expressions used in previous experiments (e.g. "It's not in this bucket" in Austin et al., 2014), which have found successful performance only around the age of 24 months. Note, however, that in the present study in order to keep the utterance as simple as possible, we have chosen to avoid mentioning the label of the container. If 18-month-olds fail in Experiment 2, it would support the view that the acquisition of the negative existential and that of proposition denial may follow different developmental paths. In contrast, a similar performance in the two experiments would suggest that the comprehension of the two negation types develops in parallel. This latter pattern would be in line with the proposal advocating an early presence of a common, more general conceptual apparatus supporting both negative existentials and proposition denial.

4. Experiment 2

4.1. Method

The materials and the procedure were the same as in Experiment 1, with the only difference being the negation type used to express the absence of the object. Instead of the negative existential, the experimenter used proposition denial saying "(It) is not here" – *Nem itt van* ((It) is not here/ not here be.3SG) in Hungarian.

4.2. Participants

Thirty 18-month-old infants participated in the Experiment 2 (18 girls, mean age = 18 months, 1 day, range: 17 months, 16 days to 18 months, 15 days). Five additional infants were tested but excluded from the analyses due to not completing at least 4 test trials out of 6 (2), or not choosing a cup (3). Parents were informed about the procedure and the aim of the study and gave written consent.

4.3. Results

Out of 30 participants, 29 infants contributed with 6 trials and 1 infant contributed with 4 trials to the final data set. We calculated the average proportion of correct choices across all trials, and we compared this value to chance level (50%) (Fig. 2). Participants chose the correct cup significantly more often than chance ($M = 0.608$, $SD = 0.179$, $Z = 465$, $p < 0.001$). Analyzing only the first trials, the majority of infants chose the correct cup (20 out of 30), the comparison to chance tending towards significance (Binomial test, two-tailed $p = 0.09$). When comparing infants' performance in the two experiments we did not find a significant difference between the mean percentages of correct choices (Mann-Whitney test, $U = 381.5$, $p = 0.298$) in Experiment 1 ($M = 0.663$, $SD = 0.039$) and 2 ($M = 0.608$, $SD = 0.179$), nor in performance on the first trials (Fisher's Exact Test, two-tailed $p = 0.233$).

To test for a possible effect of perseveration to the location where the object was found on the previous trial, as in Experiment 1, we compared the performance in no location-change trials and location-change trials. We included in this analysis only those participants' data who completed all the 6 test trials ($n = 29$). Noticeably, there was a significant difference in participants' performance on these trials (Wilcoxon Signed-Rank Test, $Z = 53$, $p = 0.002$). Specifically, infants performed significantly better in the unchanged-location ($M = 0.759$, $SD = 0.290$) than in the changed-location trials ($M = 0.483$, $SD = 0.297$). Note, however, that perseveration cannot explain children's successful performance in this experiment, as it would predict an overall chance performance (specifically, below chance performance on the changed-location trials and an above chance performance on the unchanged-location trials which should average to chance level) which is not what we find. Therefore, while there seems to be some effect of perseveration, children's performance was crucially driven by the information expressed in the proposition denial.

Next, to compare the two experiments we calculated a difference score for perseveration-sensitivity by subtracting the location-change from the no location-change values. This comparison revealed a significant difference (Mann-Whitney test, $U = 304.5$, $p = 0.030$) in perseveration-sensitivity across the two experiments. Infants' performance was more affected by perseveration in Experiment 2 ($M_{\text{difference score}} = 0.267$, $SD = 0.072$) than in Experiment 1 ($M_{\text{difference score}} = 0.038$, $SD = 0.056$). These results suggest that when infants are exposed to proposition denial, in contrast to the negative existential in Experiment 1, their behavior might be more prone to interference from a memory trace about where the object was in the preceding trial.

4.4. Discussion

Overall, 18-month-olds performed above chance to a similar degree in Experiments 1 and 2, suggesting that they have comprehended both the sentences containing the negative existential, as well as the ones containing the proposition denial at this young age. This pattern is divergent from what is found in studies targeting negation production (Bloom, 1970; Pea, 1980; Choi, 1988; Cameron-Faulkner, Lieven and Theakston, 2007) that suggest that non-existence is expressed earlier in production than denial. In our studies that targeted negation comprehension, we did not find evidence for a conceptual gap in the sense that infants' comprehension would be initially limited to specific meanings (i. e. non-existence). In contrast, infants showed evidence for the capacity

to comprehend different types of negation at the same age, which points to the possibility that these may have a common, more general conceptual underpinnings. The similar performance of infants in Experiments 1 and 2 is especially remarkable if we consider the semantic and syntactic differences between the two kinds of negation, two aspects that could potentially make proposition denial more difficult than negative existential. Regarding their semantics, the negative particle in Experiment 2 (proposition denial) is used in a broader context than existential negation. ‘Not X’ can express the negation of literally any possible proposition, while existential negation expresses the absence of entities, and it can negate existential, possessive or locative predications. Syntactically, decomposing the negative particle *nem* (‘not’) and the statement *itt van* (‘it is here’, here be.3SG) in Experiment 2 is likely more complex than processing a single word in Experiment 1 (i.e. *Nincsen* (It) is not/ not.be.3SG). 18-month-old infants’ competence in comprehending the negative existential (Experiment 1) and proposition denial (Experiment 2) expressing the absence of an object points to rich and early competencies related to interpreting utterances containing negation.

The only difference we could observe between the two kinds of negations was infants’ sensitivity to perseveration effects. While perseveration influenced performance in the proposition denial condition, we did not observe such effects in the negative existential condition. This sensitivity to interference may indicate greater processing demands in propositional denial condition. Proposition denial used in a two alternative choice task might involve inhibitory demands that may make the task more difficult for infants (de Carvalho et al., 2021). For instance, uttering the word “bucket” in a sentence like “It is not in the bucket” used by Feiman et al. (2017) may initially drive participants’ attention towards the incorrect container. To succeed, infants first need to disengage from the mentioned container and then to switch to the correct location. Similarly, in Experiment 2 of the present study the sentence *Nem itt van* ((It) is not here) could have been more challenging because it might first draw attention to the to be excluded location by involving the word “here”, or the utterance may be first interpreted as an affirmation based on the last two words *itt van* (it is here). However, no such interpretation would be elicited with the negative existential *Nincsen*. Thus, as a result of the possibly higher cognitive demands in the proposition denial condition, infants could have been more susceptible to perseverations towards where they have found the object earlier.

However, although overall we did not find differences between the comprehension of these two types of negation in 18-month-olds, we cannot exclude the possibility that such a divergence might be present at a younger age. To address this question, next we aimed to investigate an earlier stage of negation comprehension and targeted 15-month-olds (Experiment 3). Testing a younger age group might help us shed more light on the developmental path of the two types of negation used in Experiments 1 and 2.

5. Experiment 3

5.1. Method

In Experiment 3 we tested the comprehension of the negative existential and the proposition denial from Experiments 1 and 2. As in Experiment 3 we focused on the possible differences in the trajectory of the acquisition of the two types of negation, we tested the same 15-month-olds infants in two separate sessions. The order of conditions was counterbalanced within the experimental group and the testing took place on average 7 days apart (minimum 5 days and maximum 11 days). Otherwise, the procedure was identical to the one described in Experiments 1 and 2.

5.2. Participants

Thirty 15-month-old infants participated in Experiment 3. The mean

age at the first session was 15 months 18 days (15 girls; range: 15 months, 1 days and 16 months, 4 days). At the second session the mean age was 15 months 25 days (range: 15 months 10 days and 16 months 12 days). Seventeen additional infants were tested but excluded from the analyses due to not choosing any of the two containers (1), not completing at least 4 trials out of 6 per either session, or not completing both sessions (12), or technical and experimental error (4). Parents were informed about the procedure and the aim of the study and they all gave written consent.

5.3. Results

First, we analyzed infants’ performance in the negative existential condition (Fig. 3). Out of 30 participants, 24 infants contributed with 6 trials, 4 infants contributed with 5 and 2 infants contributed with 4 trials to the final data set. As in the earlier experiments, we calculated the average proportion of correct choices among all valid test trials and compared it to chance level (50%). Participants’ choice was not different from chance level ($M = 0.511$, $SD = 0.034$; $Z = 105$, $p = 0.682$). Analyzing only the first trials, 15 infants out of 30 chose correctly in the first trial in the existential negation condition, (binomial test, two-tailed value $p = 1.00$). In addition, we have also calculated binomial Bayes Factors (BF) contrasting the null hypothesis (equal probability of searching at the two locations) to the alternative hypothesis of higher probability for the not negated location (using the default hyperparameters in JASP). The Bayes Factor favored the null hypothesis ($BF = 4.48$).

Thus, 15-month-olds do not seem to comprehend the negative existential in our task. As in Experiments 1 and 2, we then tested the possible effect of perseveration to the location where the object was found in the previous trial. Comparing the performance in no location-change trials ($M = 0.52$, $SD = 0.33$) and location-change trials ($M = 0.51$, $SD = 0.26$), we did not find a difference indicating interference from perseveration (Wilcoxon Signed Ranks test, $Z = 140$, $p = 0.77$).

Next, we analyzed infants’ performance in the proposition denial condition. Twenty-five infants contributed with 6 trials, 3 infants with 5 and 2 infants with four trials to the final data set. A one-sample Wilcoxon Signed-Rank test indicated that the average proportion of correct choices ($M = 0.49$, $SD = 0.16$) was not different from chance ($Z = 38$, $p = 0.594$). Analyzing the first trials only revealed a similar pattern (15 correct out of 30, binomial test, two-tailed value $p = 1.00$). The Bayes Factor favored the null hypothesis ($BF = 4.48$).

This pattern suggests that 15-month-olds do not seem to comprehend proposition denial either in our task. However, in this condition, similarly to the data obtained from 18-month-olds in Experiment 2, we found a significant difference between no location-change trials ($M = 0.62$, $SD = 0.26$) and location-change trials ($M = 0.41$, $SD = 0.240$) (Wilcoxon Signed Ranks test $Z = 68.5$, $p = 0.016$) indicating an effect of perseveration.

Further, we compared infants’ performance in the two conditions. When comparing the mean proportions of correct choices in the negative existential and proposition denial condition, we found no differences (Wilcoxon Signed-Rank Test, $Z = -0.637$, $p = 0.524$). Next, we sorted infants in different categories based on their performance on the two tasks, asking whether they were more likely to pass one condition compared to the other. If a participant’s mean proportion of correct choices was higher than 50% in a specific condition, they were considered as passing, coded with (1), while proportions at 50% or below were coded as failing (0). Seventeen infants failed in both conditions, 8 infants passed in the negative existential condition but failed in the proposition denial condition, 2 infants succeeded in the proposition denial condition but failed in the negative existential condition, and 3 infants succeeded in both conditions. A McNemar’s test performed on a 2 by 2 contingency table revealed no significant difference between performance in the two conditions ($p = 0.23$). While numerically more infants passed the negative existential and failed the propositional denial condition ($n =$

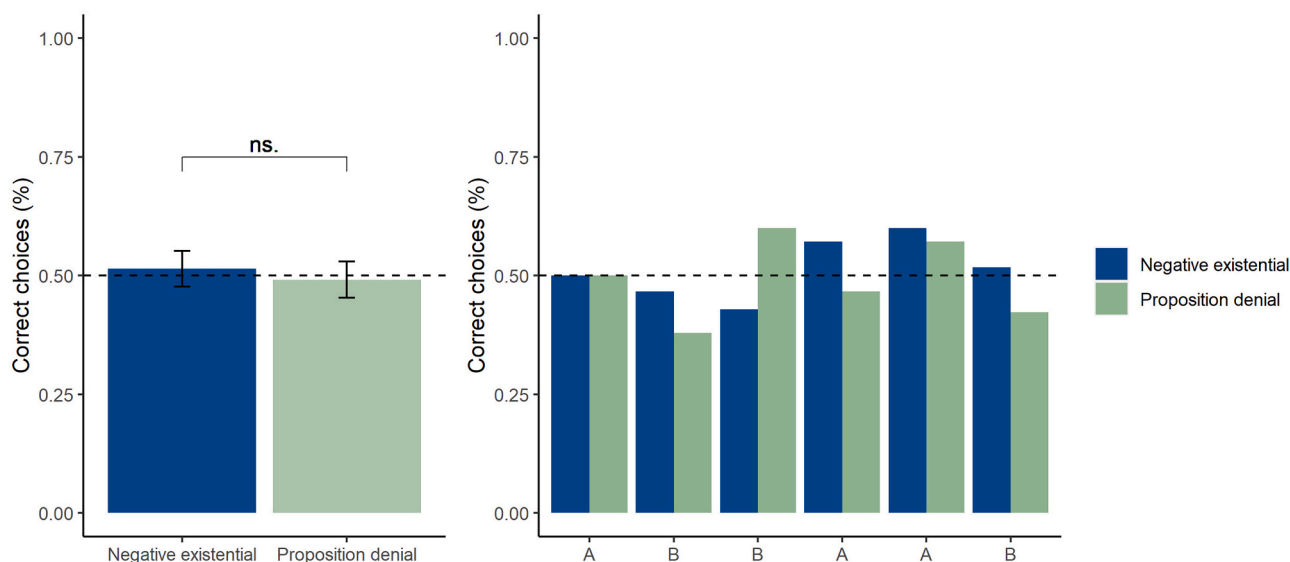


Fig. 3. The results of Experiment 3 (Negative existential and Proposition denial) - 15-month-olds. A) Mean percentage of correct choices across all trials in Experiment 3 compared to chance level (50%). Error bars represent standard error. B) Percentage of participants choosing the correct location trial by trial. Capital letters on the x axis represent the counterbalancing of the location of the target (left/ right: for half of the infants A stands for right and B left, and the opposite was the case for the other half of the infants).

8), compared to infants showing the opposite pattern ($n = 2$), most infants in fact failed both (59%). Although² the majority of infants tended to behave consistently in the two conditions (20 out of 30 either failed both or succeeded in both, $p = 0.09$, binomial) we found no significant correlation between the mean proportions in the two conditions ($r = 0.077$, $n = 30$, $p = 0.688$).

5.4. Discussion

In Experiment 3, 15-month-olds did not show evidence for comprehending and using information conveyed by two types of negation, specifically negative existential and proposition denial.

However, one could argue that infants' failure in Experiment 3 may reflect some task-specific (and negation-unrelated) difficulties. To exclude this possibility, we performed Experiment 4. Besides the linguistic demands (i.e. the comprehension of negation), the two-alternative choice task we have used also involves other complex mental processes. Specifically, solving this type of task likely requires the participant to represent the two possible locations interrelated with each other (e.g. A OR B) and after excluding one possibility by representing the absence of the target at that location (e.g. NOT A), to infer that the object is in the other location (e.g. NOT A, THEREFORE B). Earlier studies found success only at around the age of 17–20 months (Feiman et al., 2017; Feiman et al., 2022) on similar choice tasks not involving language, and around 14 months in implicit tasks measuring infants' looking times in a goal attribution paradigm (Cesana-Arlotti et al., 2020). Thus, it is unclear whether 15-month-olds are able to successfully recruit all the necessary mental operations in such a two-alternative choice task that does not involve language and verbal negation.

To this end, in Experiment 4 we measured 15-month-olds' performance in a modified version of the two-alternative choice task: instead of verbal cues, the experimenter provided only non-verbal evidence about the absence of the object, by showing the content of the empty cup to the participant. If 15-month-olds pass the non-verbal version of the

task, such a pattern of behavior would suggest that all other necessary capacities to solve the task (aside of reliable verbal negation comprehension) are available at this age. In this case, one could argue that 15-month-olds' failure in Experiment 3 would indicate their difficulty to correctly map verbal negation. In contrast, 15-month-olds' failure in the non-verbal version would indicate that the task exceeds some more general abilities of this age group.

6. Experiment 4

6.1. Method

In Experiment 4, we modified the two-alternative choice task used in Experiments 1–3. Instead of providing information about the absence of target object verbally, the experimenter slowly turned the target cup upside down – showing the infant the inside of the cup, specifically that it did not contain the object. Then she turned the cup back to its original orientation and put it back to its initial position. To equalize the participant's attention to the two cups, the experimenter also touched and lifted the other (baited) cup, and then she put it back to its initial location. Besides these differences, the procedure and the materials of Experiment 4 were the same one used in Experiments 1 and 2.

6.2. Participants

Thirty 15-month-old infants participated in Experiment 4. The mean age was 15 months 18 days (range: 15 months, 0 days and 16 months, 4 days; 16 girls). Five additional infants were tested but excluded from the analyses due to not completing at least 4 trials out of 6 (2), or due to technical/experimental error (3). Parents were informed about the procedure and the aim of the study and they all gave written consent.

6.3. Results

We calculated the average proportion of correct choices among all valid test trials and compared it to chance level (50%) (Fig. 4). Twenty-five infants contributed with 6 trials, 4 infants with 5 and 1 infant with 4 trials to the final data set. Participants chose the correct cup significantly more often than chance ($M = 0.703$, $SD = 0.195$; $Z = 328$, $p < 0.001$). Analyzing only the first trials, we found that subjects chose correctly

² Infants showed a similar performance on the two conditions independently whether they were exposed to negative existential or propositional denial in the 1st session.

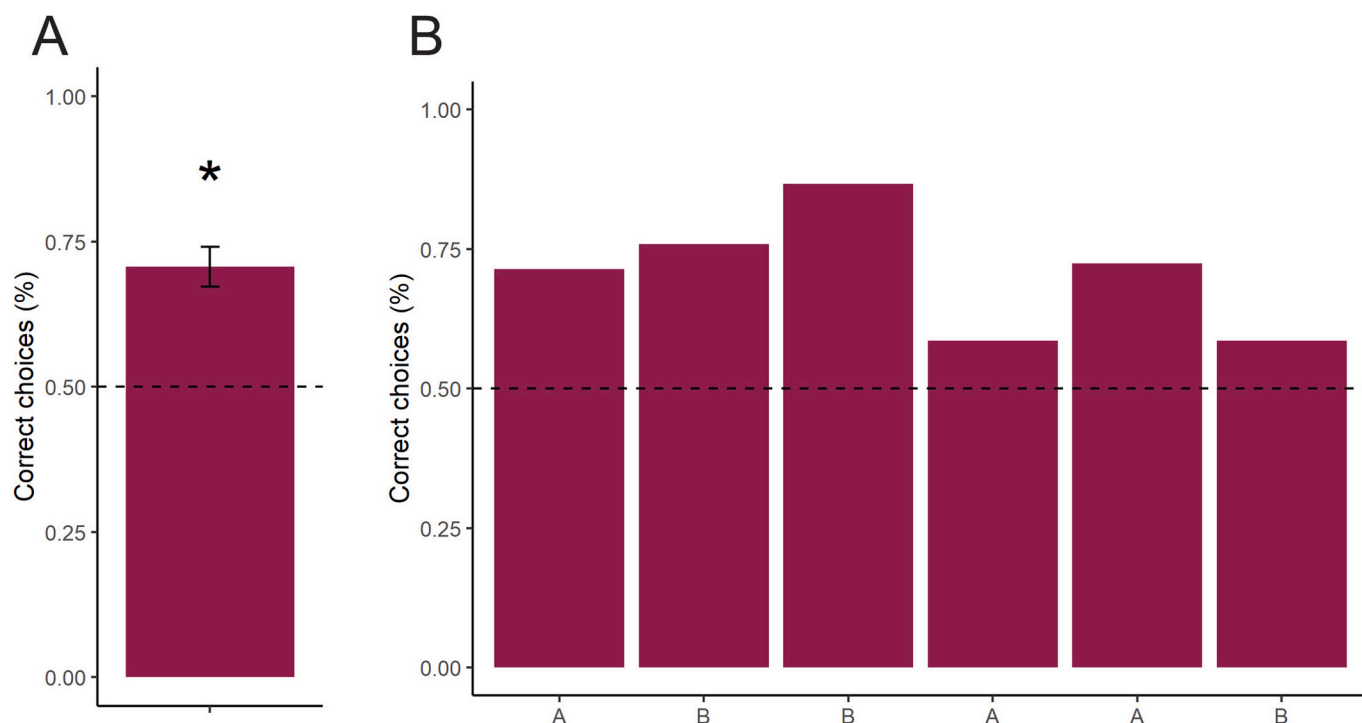


Fig. 4. The results of Experiment 4, Nonverbal task – 15-month-olds. A) Mean percentage of correct choices across all trials in Experiment 4 compared to chance level (50%). Error bars represent standard error. B) Percentage of participants choosing the correct location trial by trial. Capital letters on the x axis represent the counterbalancing of the location of the target (left/right: for half of the infants A stands for right and B left, and the opposite was the case for the other half of the infants).

significantly more than chance (20 out of 28; binomial test two-tailed, $p = 0.036$). This suggests that 15-month-olds have a stable capacity to solve the inferential problem posed by the task. Specifically, they encoded the empty content of the cup and used this information to exclude one location to find the target object at the other possible location. Peculiarly, comparing the performance in no location-change trials and location-change trials, we found a significant difference in participants' performance (Wilcoxon Signed-Ranks test, $Z = 59.5$, $p = 0.027$). Infants performed significantly better in the no location-change trials ($M = 0.80$, $SD = 0.25$) than in the location-change trials ($M = 0.653$, $SD = 0.225$). Similarly to the performance in Experiment 2 and 3 investigating the comprehension of proposition denial, 15-month-olds' behavior in a non-verbal two-alternative choice task was affected by a possible perseveration arising from their memory about the presence of the target at a location in the preceding trial (i.e. where the object was found in the previous trial).

6.4. Discussion

In Experiment 4, we found evidence for 15-month-olds' ability to find the target object based on visual evidence about which cup does not contain the object. This result reveals 15-month-olds' capacity to encode the content of the empty cup and to use this information to find the target object at the other alternative hiding location. The pattern of results from Experiments 3 and 4 seems consistent with previous studies showing that similar non-verbal versions of the two alternative choice task are passed by infants who do not yet pass the corresponding verbal negation versions of the respective task, albeit these infants were older (20-month-old) compared to our 15-month-olds (Feiman et al., 2017). Also, data from Experiment 4 is in line with other results involving looking time and pupil dilation measurements demonstrating 12-month-olds' ability to use reasoning by exclusion in a different task (Bohus, Cesana-Arlotti, Martín-Salguero, & Bonatti, 2023; Cesana-Arlotti et al.,

2018).

Importantly for the current study, 15-month-old infants' failure in Experiment 3 testing the comprehension of verbal negation, and the successful performance in the non-verbal version of the same task (Experiment 4) suggest that infants' difficulties at this age are indeed related to the comprehension of verbal negation.

6.5. General discussion

The aim of the present study was to investigate the possible conceptual underpinnings of linguistic negation at an early stage of language learning. Specifically, we have focused on how the comprehension of different types of negative sentences (existential negation and denial) emerges, targeting two age groups: 18- and 15-month-olds. Earlier research investigating the production of negative sentences has suggested a developmental path where non-existence emerges earlier than propositional denial (Bloom, 1970; Choi, 1988; Pea, 1980) and it was suggested that early negation might have restricted meanings (Pea, 1980). However, here we have found that these two types of negation seem to emerge at the same time in comprehension. 18-month-old infants understood both negative existentials and proposition denials in the used searching task. In contrast, 15-month-olds did not perform above chance for either kind of verbal negation, though they could solve the non-verbal version of the task.

As discussed earlier, two different accounts can be proposed to explain the difficulties infants may encounter while acquiring the meaning of the first negative words. One suggests a change in conceptual development, while the other highlights the possible difficulties in linguistic processing. According to the conceptual change account, a fully-fledged negation concept is not present early on (infants first only entertain a narrow range of meanings for linguistic negation), rather it is a slowly constructed concept that in the end will result in an adult-like truth-functional negation (Feiman et al., 2017; Mody & Carey, 2016).

How this conceptual change is accomplished is a puzzling question, and Mody and Carey (2016) have suggested that it may tightly relate to developing richer linguistic competencies. This account seems to imply that there is no negation before/without language and therefore it should not be present in prelinguistic or nonlinguistic creatures.

The second account, having at its core possible language processing difficulties, suggests that infants may possess the required conceptual underpinnings for representing negation early on, but correctly mapping them to linguistic labels and correctly interpreting complex syntactic structures may require certain time and experience. This second account would allow for a negation concept before, or without a fully-fledged language.

In the present work, we have proposed that one potential way to study the conceptual underpinnings of early negation is to investigate the comprehension of semantically different kinds of negation words in a language which contains negative particles for both existential negation and denial. Across four experiments, we did not find evidence for an early, but limited understanding of a specific type of negation (i.e. non-existence) that precedes the understanding of the more abstract negation, which can be applied to any proposition (i.e. denial). It seems that at 18 months infants have already mapped both kinds of negation to the respective concepts, as well as managed to correctly process the respective syntactic constructions used in our task. In contrast, 15-month-olds still struggle with mapping negation words (even the single word *nincsen*) to the relevant concepts.

We have also found indications for some potentially extra processing difficulties that infants might face while comprehending proposition denial i.e. performance in this condition seemed more susceptible to perseveration that may parallel adults' difficulties (Carpenter & Just, 1975; Clark & Chase, 1972) and is in line with former studies highlighting the importance of being able to process complex syntactic structures in toddlers' negation comprehension (Reuter, Feiman, and Snedeker, 2018).

Importantly, our data show that infants seem to understand the two semantically and syntactically different negations around the same time. These results are consistent with the hypothesis that infants may start with a general concept of negation that supports the comprehension of different linguistic forms already in 18-month-olds. Thus, proposals arguing for language processing difficulties seem to align more with our results than accounts of conceptual limitation. Note that even under a linguistic processing limitation account one may argue that it is still possible that although infants may possess fully fledged negation from early on, the earliest negation words may be still mapped to simpler negation concepts (nonexistence). However, this would have predicted a faster mapping of existential negation.

Still, one could raise the question whether 18-month-olds' success with the two types of negation could be explained with a limited understanding of negation that is not, in fact, propositional negation. As discussed earlier, it is widely accepted that at least some primitive negative concepts – e.g., rejection – might be available for infants already from 13 months on (Pea, 1980). One could argue that infants in our tasks mistakenly mapped utterances that involved existential negation or proposition denial to these meanings, while giving a false impression of a more advanced ability. However, we think this interpretation of our results is unlikely because rejection is available from 13 months on, and if infants use alternative strategies to solve the task and rely on such mistaken mappings, we should have observed success in 15-month-olds as well.

Furthermore, one might wonder whether our data can be explained by mapping negative utterances to concepts of non-existence, after all this is a task where the utterances they have to interpret negate the presence of the toy at a location. While it may be difficult to fully exclude the possibility that various populations (e.g., infants, children or adults for that matter) do not rely on non-existence concepts in such tasks that involve reasoning based on the absence of an object at a location, we think such concepts alone cannot explain our data for three

reasons. First, in our task infants successfully interpreted both forms of verbal negation (existential *Nincsen* and proposition denial *Nem itt van*) to solve the task, at 18, but not at 15 months of age. Second, relatedly, in our task already 15-month-olds succeeded in the nonverbal version in which they were shown that the object was not present at a location, however they failed to map negative utterances to such concepts in the verbal versions of the task (see for a similar argument, for excluding reasoning based on non-existence concepts in 24-month-olds in Feiman et al., 2017). While one might argue that 15-month-olds may have the concept of nonexistence, but have not yet managed to map it to language, if infants in our study rely solely on non-existence concepts, we should expect that they succeed earlier with a negation form, that is regularly used to express non-existence, compared to proposition denial, however this is not what we find.

Third, although we lack data from Hungarian, production data from English learning infants suggest that they already use negation forms expressing non-existence in production from the age of 16 months (Choi, 1988; Pea, 1980), however they do not seem to map such meanings to propositions similar to what we have used in Experiment 2, and fail such tasks till about 24 months of age (e.g. "It is not in the bucket", or "Is it in the bucket? No."); Feiman et al., 2017). Finally, if infants use "simpler" negative concepts, like non-existence, to help scaffold their early learning of negative words, it is unclear how the exclusive mapping of proposition denial to non-existence, and the initial erroneous interpretations will be later corrected and re-mapped onto full propositional negation.

Thus, while future studies are needed to elucidate this issue, we believe that it is unlikely that reliance on non-existence can explain our data, and the data may be more congruent with a more domain general concept of negation used for interpreting various propositions involving negation, corroborating other studies using different methodologies and a different language (French) and finding evidence for negation comprehension at 18 months of age (de Carvalho et al., 2021).

Regarding the findings obtained on the nonverbal task, while 15-month-olds failed to exploit the information provided via linguistic negation in Experiment 3, interestingly, in Experiment 4 they readily demonstrated their capacity to encode the absence of objects. One might wonder how infants may have represented the absence of objects to solve the task: did they rely on nonverbal negation, or some other processes? Indeed, representing absence without language may not be a trivial issue. In fact, non- and pre-linguistic creatures have been shown to struggle with encoding the absence of an entity. Preverbal infants fail to form expectations based on the absence of objects (Kaufman, Csibra, & Johnson, 2003; Wynn & Chiang, 1998) and pigeons have difficulties in recognizing the absence of stimuli as a rule of reinforcement (Hearst, 1984; Newman, Wolff, & Hearst, 1980). Nonetheless, representing the absence of food or predators seems a necessary ability for an animal to survive, therefore one may wonder how this could be achieved without negation. Indeed, various species show success in two alternative choice tasks based on evidence that one location is empty (for a review see Voelter & Call, 2017).

While it is a matter of debate how animals may represent absence, Bermúdez (2003) has suggested that a pre-linguistic, pre-logical negation may be available for a limited set of concepts, for instance for encoding absence. According to this proposal, contrary concepts (e.g. presence/absence) may be available for non-human animals, and they navigate within these structures using a special form of negation, protonegation. Protonegation is limited to eliminating the appropriate pair of the contrary concepts (e.g. the gazelle is either present or absent from the waterhole). Supporting evidence that non-human animals can use information about absence comes from studies of Merten and Nieder (2012) showing that rhesus monkeys are able to form absence representation via categorical encoding, and from studies suggesting that a couple of days old chicks can encode the absence of an imprinting object in the absence of extensive training experience (Szabó et al., 2022).

Moreover, recent studies suggest that primates may go beyond the

representation of absence and are able to learn visual cues symbolizing 'not' (Dautriche, Buccola, Berthet, Fagot, & Chemla, 2022). Baboons were trained to avoid visual cues (i.e. not blue) in a match-to-sample task and importantly to combine "not" signs with other visual elements. However, the question of non- and pre-linguistic representations of absence involving or not involving negation goes beyond the scope of the present paper. Further investigations should determine whether 15-month-olds may rely on non-linguistic representations that involve negation or protonegation, and how the non-linguistic and the linguistic encoding of absence may be related in early childhood.

In any case, it should be noted that in the present study we have found success at an earlier age compared to other similar studies (e.g. Austin et al., 2014; Feiman et al., 2017). While we can only speculate about the relevant factors that may lead to a better performance in the nonverbal and in the verbal tasks, we would like to point out two potential reasons. The first one is related to the specific task we have used, while the second one is related to the population we have tested. First, it is possible that participants in our task had to maintain the relevant information in mind (the negative evidence or the inference made based on that) for a shorter time compared to other similar studies. We do not have exact data available from other studies for this comparison, but reaching for a container at a table in our case should require much shorter time compared to walking to the container after receiving the critical information (e.g. in Feiman et al., 2017). Indeed, even short differences in the time (3 vs. 12 s) required to maintain a piece of information in mind (i.e. the location of a toy) seem to crucially affect 18-month-olds' performance in a two-location search task (Goupil, Romand-Monnier, & Kouider, 2016). Furthermore, regarding the verbal task, in other studies (Austin et al., 2014; Feiman et al., 2017) the negative statement was uttered after checking a specific container, and returning to the middle, while in the present study it was communicated while the experimenter was still touching and looking into the container. The latter situation might have supported infants to find easier the location referent mentioned in the sentence and maintain focus on it, possibly leaving more resources to interpret the negation.

Second, one may wonder whether population differences might have contributed to the differences in the results between our study and earlier ones. We have no reasons to presume that our population had better task relevant skills (e.g. inhibition, for instance related to higher SES), as families visiting scientific centers are likely from middle/middle upper class in various countries. However, relatedly one may argue that specificities of the Hungarian language might play some role. For instance, the existence of a separate negation word for expressing existential negation may bootstrap infants' learning of negation words. If so, it may be easier to acquire different functions of negation in languages where there is a specific form for each of them. While this may be a theoretical possibility, the limited crosslinguistic production data available from other languages does not seem to support such an account.

For instance, crosslinguistic data including Korean language that has a special negation word for non-existence (*epse/epta*) points to a similar pattern of early negation production as it is observed in languages without such linguistic forms (i.e. in English) (Choi, 1988). Other studies targeting children learning languages with various negative markers for different functions (e.g. Cantonese: Tam & Stokes, 2001; Tamil: Vaidyanathan, 1991) seem to also suggest a similar developmental path as described earlier for English children - i.e. rejection and non-existence preceding denial in language production. Furthermore, these studies do not seem to report earlier ages for expressing non-existence compared to studies targeting English speaking children (for instance, in Tamil, the word *illa* is used to express negative existentials and it is first produced only after the second year, Vaidyanathan, 1991). Based on these studies we believe it is unlikely that Hungarian infants' early performance in our experiments is explained by the fact that Hungarian has separate words for non-existence and denial. However, it is a task for future carefully designed cross-linguistic studies to elucidate how this or further

potential language related factors contribute to infants' performance.

Importantly, data from the present set of experiments point to a similar developmental path for comprehending two types of verbal negation (non-existence and denial), which have been claimed to rely on different concepts, and to emerge at different times. In contrast to such proposals suggesting that infants start with limited abilities to produce and comprehend only specific negation forms, here we argue that the similar performance of the infants in the two conditions involving different types of negation observed in the present studies is likely to reflect a sophisticated conceptual understanding of propositional negation from early on.

CRediT authorship contribution statement

Eszter Szabó: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Ágnes-Melinda Kovács:** Writing – review & editing, Writing – original draft, Supervision, Resources, Funding acquisition, Conceptualization.

Declaration of competing interest

None.

Data availability

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