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The emergence of indexicality in an artificial language

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Abstract

We investigated the emergence of register-like indexical associations, whereby linguistic forms that are associated with groups of speakers acquire novel associations with contextual features of those groups. We employed an artificial-language paradigm in which participants were exposed to an “alien” language spoken by two alien species wearing two different ceremonial outfits. The language varied with respect to plural suffixes, such that one suffix was associated reliably with one species and outfit in training. We then tested participants on what associations they had acquired. In two experiments we manipulated which aliens wore which outfits in the test phase. Regardless of condition or length of training, participants associated suffixes strongly with aliens rather than clothing. In a third experiment we introduced a new alien species in the test phase. For these aliens, which participants had not seen during training, participants made a clear association based on outfit. These results show clearly ranked indexical (or proto-indexical) associations on the part of participants and lay clear groundwork for the experimental investigation of the emergence of indexical social meaning in language.

Keywords: artificial-language learning; social meaning; indexicality; sociolinguistics

Language conveys not only semantic meaning but also social meaning. For instance, the sentence “I had a can of pop with my tea” not only conveys what the speaker drank with their meal, but also (via the words *pop* and *tea* as opposed to, e.g., *soda* and *dinner*) carries implications about the their background (Dyer, 2007). But language also varies according to circumstance and situation. A lawyer, for example, is likely to talk rather differently when addressing a court from how they talk in conversation with a client, or a colleague, or a family member. Such differences in *register* or *style* are different from the “pop” and “dinner” examples above to the extent that the latter reflect interindividual rather than intraindividual variation. However, the two kinds of social variation are very closely related, and language users might well vary in what they call their drink or their evening meal according to situation and audience, depending on what social inferences are likely to be drawn based on different choices. Indeed, distinctions of register may arise from observed variation between speakers. The association in English of words of French origin with particular registers, for instance, reflects to a great extent historical perceptions (following the Norman Conquest) of relationships between French and power.

These phenomena can be thought of in terms of *indexicality*, that is, the indexing of non-linguistic features by linguistic ones (Silverstein, 2003). Almost any linguistic feature can

acquire indexical social meaning although, even in a given region and context, sociolinguistic meaning is not necessarily simple, unitary, or fixed. Rather, linguistic features occupy a “field” or “constellation” of related social meanings (Eckert, 2008). For instance, Canadian raising (often represented in spellings of *about* as *aboot*) might not only carry stereotypical associations with Canada but might also index such features as “niceness”, based on stereotypes about the personality of Canadians. Similarly, the speech patterns of people who happen to have social prestige, or who are associated with (e.g.) particular fashion styles, or particular professional contexts, might acquire associations with these things. This kind of indirectly acquired social meaning is known as *higher-order indexicality* (Silverstein, 2003; Eckert, 2008). First-order indexicality involves the association of a linguistic feature with a group whose members use it. Second-order indexicality occurs when a feature becomes associated with some quality or behavior associated with the social group in question (e.g., niceness, a particular way of dressing, or a particular professional context). Third-order indexicality would involve association with a quality associated with that quality (e.g., gullibility as a consequence of niceness), and so on. We consider register a special case of higher-order indexicality.

Theoretical work on indexicality has inspired a large body of empirical work involving naturalistic data, which has shed light on the ways in which people use language to shape and convey their identity and how they acquire existing indexical associations (e.g. Jaffe, 2009; Meyerhoff & Schlee, 2012; Pharo, Maegaard, Møller, & Kristiansen, 2014). A key question concerns *enregisterment*, the process by which forms acquire indexical meaning (Agha, 2006; Johnstone, 2016). But how does enregisterment occur? How do linguistic forms acquire new associations with contextual or other features? The process must rely partly on the perceived juxtaposition of linguistic forms with particular groups of speakers co-occurring with particular contexts. It may be that this is sufficient, given enough exposure, to create novel associations. However, this cannot be the whole story. The transferal of associations from a group to a feature or context associated with that group must rely to some extent on breaking the reliability of that association, such that it can be extended to new individuals. The associations forms are also likely to be modulated by the perceived social importance of the features in question (Johnstone, 2016; Rącz, Hay, & Pierrehumbert, 2017). In the

study presented here we investigate whether (a) the simple association of a linguistic form with both a group of language users and a situational non-linguistic feature (attire) and (b) the breaking of the association between language users and the non-linguistic feature leads to a novel association between the linguistic and non-linguistic features.

Empirical work based on observations of natural-language data is typically hampered by a lack of control over such factors. Artificial-language experiments, which we employed here, are an empirical approach that allows greater control. Sneller and Roberts (2018), for instance, investigated the influence of indexicality on the *adoption* of linguistic variants, finding that features with higher-order indexicality spread more readily (though only when the indexed trait had practical social relevance). A related strand of work concerns the acquisition of grammatically unpredictable variation in artificial languages, which suggests that learners will tend to condition such variation on available linguistic or social cues (Smith & Wonnacott, 2010; Hudson Kam & Newport, 2005; Vihman, Nelson, & Kirby, 2018; Samara, Smith, Brown, & Wonnacott, 2017). Little work, however, has shed direct light on the emergence of higher-order indexicality, though Rácz, Hay, and Pierrehumbert (2020) investigated differential sensitivity to different kinds of indexical meaning, relevant to Sneller and Roberts’s (2018) finding concerning the practical relevance of cues. Along similar line, Lai, Rácz, and Roberts (2020) found the salience and learnability of indexical associations was influenced by the unexpectedness of the linguistic variant.

To our knowledge no such work has directly investigated the emergence of higher-order indexical meaning. Here we present an exploratory artificial-language-learning study intended to lay groundwork for this question. The study involves exposing participants to an artificial language in which grammatically unpredictable variation co-occurred reliably with two different non-linguistic features: alien species and clothing. We then measured the extent what associations participants had acquired between these features. In a first experiment we investigated whether participants would acquire associations primarily between a group of speakers or with their clothing (predicting that, given the likely greater social salience of speaker group over clothing, it would be the former; cf. Rácz et al., 2017). In a second experiment we replicated the first experiment with longer training. In a third experiment we introduced a new species of alien in the test phase, wearing the same clothing as the other aliens, and tested whether this broke the established association between alien species and clothing and allowed the linguistic feature to be transferred to the new alien species based on attire.

Experiment 1

Experiment overview

The goal of Experiment 1 was to establish what associations participants would make when exposed to a reliable three-way relationship between a linguistic form, a speaker group,

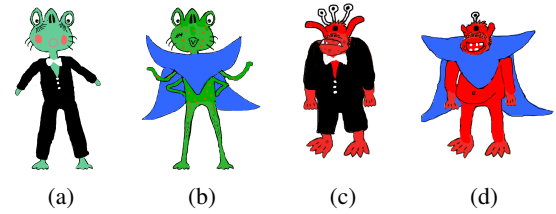


Figure 1: Nulus (a, b) and Gilis (c, d) in different outfits.

and a cultural trait. We trained participants on an “alien” language exhibiting variation in plural endings. The language was used by two alien species, who wore different outfits and used different plural endings. We tested participants on which aliens were most likely to use which plural ending, manipulating whether aliens in the test phase wore the same outfits as in the training phase. We then measured what associations participants formed with the plural endings.

Method

Participants 61 participants, recruited through Prolific, took part for \$6. After excluding four participants whose duration was below the 2.5% quantile or above the 97.5% quantile of all participants, data from the remaining 57 participants (24 female, 33 male; aged 18–54, median = 22) were analyzed. There were 28 participants in the Flipped condition and 29 participants in the Nonflipped condition.

Alien language The language contained ten noun stems (Table 1). There were also two plural endings, *-dem* and *-gok*, each of which could be affixed to any noun stem; their distribution was entirely determined by the alien speakers and not by any feature of the noun itself.

Table 1: Noun stems in the Alien language

kabuq, bupod, hasot, wejun, kenig, tulimur, petilet, ropuko, luragur, gunawul
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Aliens and outfits Two alien species were presented as users of the language: the *Nulus* and the *Gilis*. The aliens were presented as wearing two different ceremonial outfits: a black suit-like outfit and a blue cloak-like outfit (Fig. 1).

Procedure The experiment consisted of four phases: (1) Familiarization (to familiarize participants with the aliens and the outfits); (2) Training (to expose participants to the language); (3) Memory test (to check to what extent participants attended to the aliens and outfits); (4) Association test (to test what associations participants learned between aliens, outfits, and linguistic forms).

The **familiarization phase** introduced the two alien species and their ceremonial outfits and ensured that participants were fully aware of both. First, participants saw a screen with four images of aliens: a Nulu wearing the black outfit, the same Nulu wearing the blue outfit, a Gili wearing

the black outfit, and the same Gili wearing the blue outfit. Each image was labeled with the words “Nulu/Gili wearing outfit one/two”. To ensure participants understood the difference between the species and outfits, this was followed by a grouping exercise. First, participants saw images of one alien wearing both outfits; then they saw a screen of 16 aliens (four different Nulus + four different Gilis $\times$ two outfits) and were asked to select all the aliens from the species they had just seen. Then they were given the same task for the other species and for each of the two outfits separately.

After becoming acquainted with the aliens and outfits, participants entered the **training phase** in which they were asked to “try to learn what the alien words are for the different objects and how the language works.” This phase involved two kinds of trials: *passive exposure trials* and *forced-choice trials*. In passive exposure trials a singular or plural word was presented paired with an image of the object(s) it referred to. In each case, the word was depicted as being spoken by an alien wearing one of the two outfits (Fig. 2a). Each outfit and plural suffix was paired 100% reliably with one of the two alien species; that is, while participants had seen both species wearing both outfits in the Familiarization phase, one outfit was now only seen on Gilis while the other was seen only on Nulus. (The assignment of outfits and suffixes to alien species was counterbalanced between participants.) Passive exposure trials were not timed and participants could proceed to the next trial by clicking a button marked “Next”. In forced-choice trials participants were asked to choose the right word to go with an image (Fig. 2b). In every case the correct word was presented along with a foil word generated by swapping two segments of the correct word (e.g., kabuq vs. kaqub). For plurals, the swapped segments were always in the suffix (e.g., kabuqgok vs. kabuqkog). This was to ensure that participants would attend to the suffixes as well as the stems. In forced-choice trials, participants had to choose correctly in order to proceed. If the wrong word was chosen, they were told so and asked to try again. Participants were trained on 20 alien words (10 singular and 10 plural) in total. Every four passive exposure trials were followed by four forced choice trials on the same four words the participants had just been exposed to. The order of trials in each such block was randomized. In total, participants went through $10 \text{ words} \times 2 \text{ forms (singular and plural)} \times 2 \text{ alien species} \times 2 \text{ trial types (exposure and forced choice)} \times 2 \text{ repetitions} = 160 \text{ trials}$.

After the training phase, participants were presented with a total of 12 **memory test** trials, with three trials each on isolated words, objects, aliens (without outfits) and outfits (not on aliens). Some of the words, aliens, and outfits had been encountered during the training phase; others had not. Participants were instructed to answer yes or no on each screen to indicate whether or not they recalled seeing the word or image before. The purpose of this phase was to check that participants had been attending to both the words and the images in the training phase and to reinforce the importance of the aliens and outfits in the training.

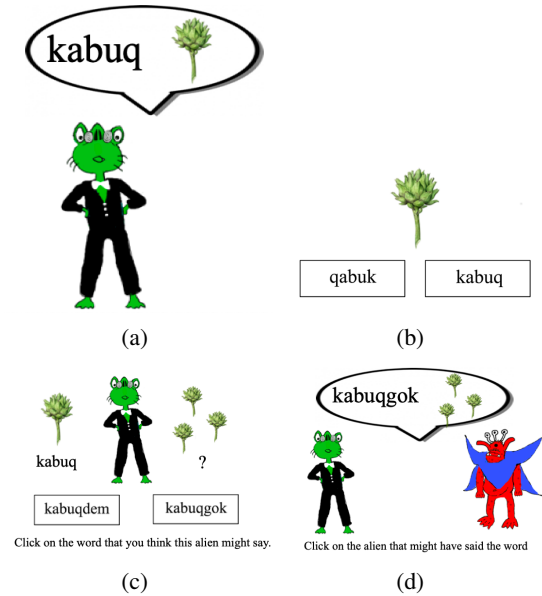


Figure 2: Example trials: (a) passive learning trial; (b) forced-choice trial; (c) suffix selection trial; (d) alien selection trial

After completing the memory test, participants began the **association test**, which was also the final phase of the experiment. This phase consisted of two kinds of trials. In *suffix-selection trials* participants were presented with an alien wearing one of the two outfits along with an image of a group of objects and two plural word forms (Fig. 2c). The participant’s task was to choose the word form they thought the alien was most likely to use. In *alien-selection trials*, by contrast, participants saw one alien from each species (each wearing a different outfit) and one object paired with a word form (always plural). In this case participants had to choose which alien they thought most likely to use that form (Fig. 2d). There were 80 trials in total in this phase ($10 \text{ suffixed words} \times 2 \text{ species} \times 2 \text{ repetitions} \times 2 \text{ tasks}$). Due to the different set-ups of the two tasks, participants saw each plural form twice during suffix selection and once during alien selection. The left/right location of the each word form in the suffix-selection task and of each alien in the alien-selection task was counterbalanced throughout.

Experimental conditions. There were two conditions, which differed with respect to which outfits were worn by which species in the association test phase. In the training phase, as stated above, each outfit was paired 100% reliably with one of the two alien species. In the *unflipped condition* this pairing was continued in the test phase. In the *flipped condition* the pairing was reversed, such that the alien species that had worn outfit 1 in the training phase now wore only outfit 2, and vice versa (Fig. 3).

Predictions. Assuming that participants formed associations with the two plural forms, there were three main possibilities. First, participants might overwhelmingly associate

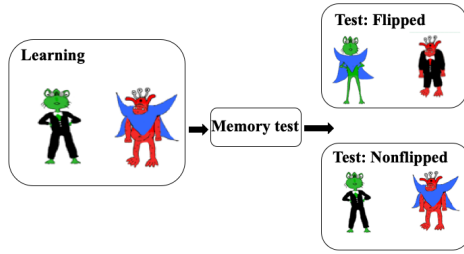


Figure 3: Conditions of Experiment 1

plural forms with alien species, not outfits. If so, participants in both conditions would associate the plural forms with the aliens they had seen produce those forms in training (but the association with outfit would be reversed). The second possibility was that participants would overwhelmingly associate plural forms with outfits as opposed to aliens. In this case, the association of outfit with plural form would be the same in the two conditions (but the association with aliens would be reversed). The third possibility was that participants would form a mixed association, which would be indicated by results in the flipped condition that were neither identical to nor the reverse of the unflipped results for either aliens or outfit; rather, the results in the flipped condition would be closer to chance selection.

Based on earlier literature (e.g., Rácz et al., 2020), we predicted that the second possibility was unlikely. It would be surprising if participants overwhelmingly associated the forms with the clothing rather than the aliens. Second-order indices, after all, are considered to emerge as secondary associations for linguistic features already associated with a speaker group (Eckert, 2008; Sneller & Roberts, 2018). However, even if (as expected) participants formed a strong primary association between linguistic forms and alien species, they might then develop a strong secondary association with the outfits, consistent with possibility three.

Results for Experiment 1

Analyses were conducted using the R Statistical environment (R Core Team, 2017); generalized mixed-effects logistic regression was conducted using the `glmer` function from the `lme4` package (Bates, Mächler, Bolker, & Walker, 2014). Plots were created using `ggplot2` (Wickham, 2016).

On average, it took participants (outliers excluded) 23 minutes ($sd = 12$) to complete the experiment. Fig. 4 shows the aggregate results of suffix selection and alien selection in Experiment 1. Across conditions, in both suffix- and alien selection, participants strongly associated suffixes with alien species, consistent with the first possibility described above.

Mixed-effects logistic regression models were fit separately for the two tasks, with Response as the dependent variable, Condition (Nonflipped as the intercept), Stimulus (Gili and the Gili Outfit as the intercept in suffix selection, and the Gili suffix as the intercept in alien selection) and their interactions as independent variables, and Participant and Word as

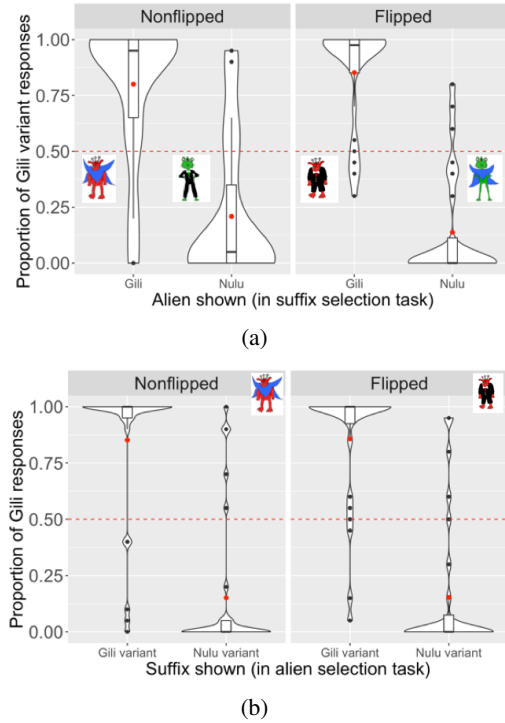


Figure 4: Results for Experiment 1 (red dots indicate means and black dots indicate outliers): (a): suffix selection task; (b): alien selection task

random effects. Model results suggested that for the SUFFIX SELECTION, the Stimulus effect was significant ($\beta = -2.71$, $p < .001$ for alien stimulus and $\beta = -2.71$, $p < .001$ for outfit stimulus). There was a significant effect of Condition ($\beta = 0.36$, $p = .02$ for alien stimulus and $\beta = -3.22$, $p < .001$ for outfit stimulus). The interaction between Stimulus and Condition was also significant ($\beta = -0.86$, $p < .01$ for alien stimulus and $\beta = 6.30$, $p < .001$ for outfit stimulus). For ALIEN SELECTION, there was a significant effect of (suffix) Stimulus ($\beta = -3.47$, $p < .001$ for alien responses and $\beta = -3.47$, $p < .001$ for outfit responses). The Condition effect was found only for outfit responses ($\beta = -3.53$, $p < .001$), not for alien responses ($\beta = 0.04$, *n.s.*). The interaction between Stimulus and Condition was significant only for outfit responses ($\beta = 6.97$, $p < .001$) but not for alien responses ($\beta = -0.03$, *n.s.*).

Discussion of Experiment 1

Participants across conditions strongly associated suffixes with the aliens who used them, regardless of outfit. However, the interaction effect suggested a slight tendency to also make a secondary association with outfits. One possibility is that participants would have formed a stronger secondary association with the outfits given a longer training period. To test this we performed a follow-up to Experiment 1 in which we extended the training period.

Experiment 1b: Extended training

Experiment 1b was designed as a replication of Experiment 1 with a longer training phase.

Method

The method for Experiment 1b was identical to that of Experiment 1 except that it included an extra training phase and an extra memory test, so that it had the following structure: (Familiarization → Training 1 → Memory test → Training 2 → Memory test 2 → Association test). Training phase 2 was identical to Training phase 1 except that it had no forced choice trials. Memory test 2 was of the same length as Memory test 1 but included a different subset of words and objects..

60 participants, recruited through Prolific, took part in return for \$6. After excluding participants ($N = 4$) whose duration was below the 2.5% quantile or above the 97.5% quantile, data from the remaining 56 participants were analyzed. Of these, 23 were female and 33 male, aged 18–52 (*median* = 23). There were 30 participants in the *Flipped condition* and 26 participants in the *Nonflipped condition*.

Results for Experiment 1b

On average, it took participants (outliers excluded) 24 min ($sd = 9.04$) to complete the experiment. The same model configuration from Experiment 1 was adopted and similar results were obtained: significant Stimulus effect ($\beta = -4.55$, $p < .001$ for alien stimulus and $\beta = -4.56$, $p < .001$ for outfit stimulus), Condition effect ($\beta = -0.91$, $p < .001$ for alien stimulus and $\beta = -3.64$, $p < .001$ for outfit stimulus) and their interaction ($\beta = 1.82$, $p < .001$ for alien stimulus and $\beta = 7.29$, $p < .001$ for outfit stimulus) in SUFFIX SELECTION. In ALIEN SELECTION, there was a significant Stimulus effect ($\beta = -4.91$, $p < .001$ for both alien and outfit responses), Condition effect ($\beta = -0.48$, $p < .01$ for alien responses and $\beta = -3.59$, $p < .001$ for outfit responses) and their interaction was also significant ($\beta = 1.25$, $p < .001$ for alien and $\beta = 7.14$, $p < .001$ for outfit responses). In addition, randomization tests, in which the data were shuffled 100,000 times and compared with the true result to generate a p-value (Edgington & Onghena, 2007), were conducted to compare Experiments 1 and 1b and identify if length of training had an effect. No effect was found for either suffix selection or alien selection (all $p > 0.6$).

Discussion of Experiment 1b

Experiment 1b replicated Experiment 1 with a longer training phase, and the results of the two experiments were highly consistent: Participants strongly associated the plural endings with the alien species and not with the outfits. This establishes a clear base expectation for further experimentation. It could have been that participants would exhibit flexibility or uncertainty in what they associated the variation with. This was not the case. However, our experiment did not (and was not designed to) exclude the possibility that some kind of higher-order indexical associations were indeed formed by

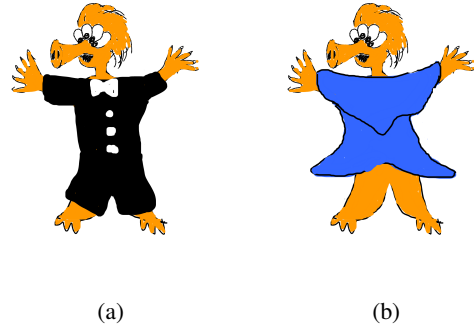


Figure 5: (a) the new alien wearing the black outfit; (b) the new alien wearing the blue outfit

participants. Our results show only that, forced to choose between aliens and outfits, participants would overwhelmingly choose the former. A key question is how participants might extend what they have learned to new language users. Investigating this was the purpose of Experiment 2.

Experiment 2: Encountering new aliens

Experiment overview

Experiment 2 resembled Experiment 1b except that we introduced a new alien species in the test phase. We then examined whether participants would associate plural endings with the new species based on outfits.

Method

Participants 59 participants were recruited through Prolific in return for \$6 dollars. After excluding participants ($N = 4$) whose duration was below the 2.5% quantile or above the 97.5% quantile of all participants, data from the remaining 55 participants were further analyzed. There were 26 female and 28 male participants (one participant self-identified as ‘Other’), aged 18–54 (*mean* = 25.7, *median* = 23).

Procedure Experiment 2 worked like Experiment 1b except that a new alien species, who had not been previously seen by participants, was gradually introduced during the testing phase (Fig. 5). There were 64 trials in the test phase. Participants did not encounter new aliens in the first 16 trials but saw only Nulus and Gilis as in the other experiments. However, the following 14 trials includes two trials with new aliens (randomly ordered), and the proportion with new aliens increased from then on, with four in the following 12 trials and 14 in the final 22 trials. Suffix-selection and alien-selection trials occurred equally often for each alien. Trials with Nulus or Gilis participants were the same as in earlier experiments. Trials with new aliens were similar except that, for the alien-selection task, the two aliens were of the same species and differed with respect to outfit only.

Results

On average, it took participants 25 minutes to complete the experiment ($sd = 13$). Fig. 6 shows results for new aliens only. (The pattern of results for Nulus and Gilis was the same as in Experiments 1 and 1b.) In suffix selection, participants tended to select variants based on the outfits associated with them in training, though—as can be seen in Fig. 6a—there was more variation than in results for earlier experiments. The pattern was similar for alien selection (Fig. 6b).

Similar to Experiment 1a and 1b, mixed-effects logistic regression models were configured separately for suffix selection and outfit selection for new alien species, with Response as the dependent variable, Condition (Version 1 as the intercept), Stimulus (Gili Outfit as the intercept in suffix selection and Gili suffix as the intercept in outfit selection) and their interactions as independent variables and Participant and Word as random effects. Model results suggested that when encountering the new aliens, there was a significant Stimulus effect ($\beta = -0.98$, $p < .01$ in SUFFIX SELECTION and $\beta = -0.146$, $p < .001$ in OUTFIT SELECTION), suggesting that participants were significantly less likely to choose the Gili variant or Gili outfit for the new alien species when it is wearing a Nulu outfit or using a Nulu variant. No significant Condition effect was found ($\beta = 0.44$, $p = 0.12$), suggesting which version participants were exposed to was not statistically important. There was a significant interaction effect between Condition and Stimulus ($\beta = -1.05$, $p = 0.01$ in OUTFIT SELECTION and $\beta = -1.68$, $p < 0.001$ in ALIEN SELECTION).

Discussion of Experiment 2

Results suggest that, while participants acquired very strong first-order associations between suffixes and alien species in all experiments, they extended these associations via clothing to previously unencountered aliens in Experiment 2, implying that they had established an at least latent secondary association with clothing that revealed itself when presented with new aliens.

General Discussion

We investigated the emergence of higher-order sociolinguistic indexicality in a laboratory setting using an artificial language-learning paradigm. The first experiment investigated whether participants exposed to linguistic variation that covaried reliably with both a group of individuals (the alien species) and a cultural trait (their clothing) would learn to associate the variation primarily with the group or with both the group and the trait. We found that participants tended to overwhelmingly associate the variable plural endings with alien species rather than their outfits. A follow-up experiment indicated that this effect was not influenced by length of training. In our next experiment, we introduced a new alien species exhibiting the same variation in cultural traits (i.e., wearing the same outfits) to investigate whether participants would extend established associations to the new aliens via clothing.

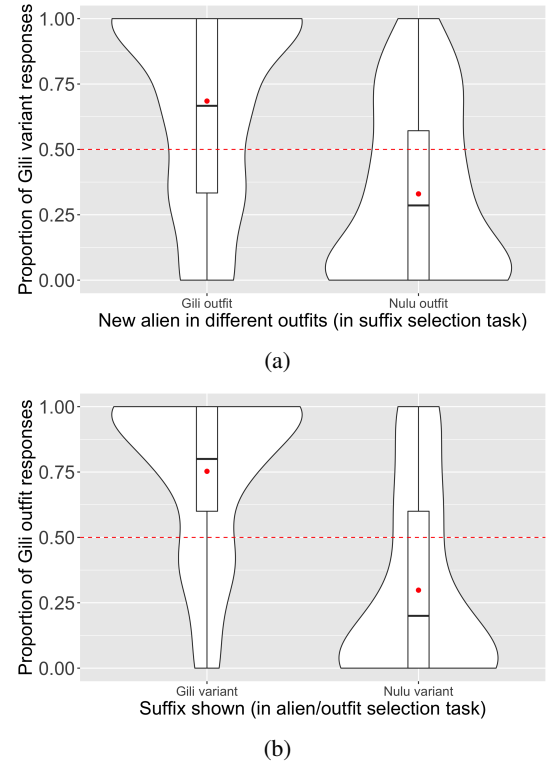


Figure 6: Results for Experiment 2 (red dots indicate means)

We found that this occurred. Taken together, these results are consistent with an account of indexicality whereby the emergence of second-order indexical associations with contextual or situational features depends in part on extension to novel individuals.

There are limitations and prospects for future research, for which this study was designed to establish a base. Our association test leaves an open question, for instance. Our results make clear that participants formed at least a latent secondary association between suffixes and clothing that revealed itself in a forced-choice task, but this is not necessarily the same as full higher-order indexicality or enregisterment. The question remains: What makes some such associations, once formed, susceptible to taking on a full indexical role, where they become used as markers of social identity? The role of practical social importance (Eckert, 2008; Johnstone, 2016; Sneller & Roberts, 2018) and salience (Lai et al., 2020) are important avenues to consider.

It is also important to note that in our experiment a three-way association between aliens, outfits, and suffixes was established simultaneously. While this occurs in the real world, the different associations are perhaps more often established independently. This represents another clear research direction. However, we consider that this experiment lays important groundwork for the future experimental investigation of sociolinguistic meaning.

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References

- Agha, A. (2006). *Language and social relations* (Vol. 24). Cambridge University Press.
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *arXiv preprint arXiv:1406.5823*.
- Dyer, J. (2007). Language and identity. In C. Llamas, L. Mullany, & P. Stockwell (Eds.), (pp. 101–108). Routledge.
- Eckert, P. (2008). Variation and the indexical field. *Journal of Sociolinguistics*, 12(4), 453–476.
- Edgington, E., & Onghena, P. (2007). *Randomization tests*. CRC press.
- Hudson Kam, C. L., & Newport, E. L. (2005). Regularizing unpredictable variation: The roles of adult and child learners in language formation and change. *Language Learning and Development*, 1(2), 151–195.
- Jaffe, A. (Ed.). (2009). *Stance: Sociolinguistic perspectives*. Oxford: Oxford University Press.
- Johnstone, B. (2016). Enregisterment: How linguistic items become linked with ways of speaking. *Language and Linguistics Compass*, 10(11), 632–643.
- Lai, W., Rácz, P., & Roberts, G. (2020). Experience with a linguistic variant affects the acquisition of its sociolinguistic meaning: An alien-language-learning experiment. *Cognitive science*, 44(4), e12832.
- Meyerhoff, M., & Schleef, E. (2012). Variation, contact and social indexicality in the acquisition of (ing) by teenage migrants. *Journal of Sociolinguistics*, 16(3), 398–416.
- Pharao, N., Maegaard, M., Møller, J. S., & Kristiansen, T. (2014). Indexical meanings of [s+] among copenhagen youth: Social perception of a phonetic variant in different prosodic contexts. *Language in Society*, 1–31.
- R Core Team. (2017). *R: A language and environment for statistical computing* [Computer software manual]. Vienna, Austria. Retrieved from <https://www.R-project.org/>
- Rácz, P., Hay, J. B., & Pierrehumbert, J. B. (2017). Social salience discriminates learnability of contextual cues in an artificial language. *Frontiers in psychology*, 8, 51.
- Rácz, P., Hay, J. B., & Pierrehumbert, J. B. (2020). Not all indexical cues are equal: Differential sensitivity to dimensions of indexical meaning in an artificial language. *Language Learning*, 70(3), 848–885.
- Samara, A., Smith, K., Brown, H., & Wonnacott, E. (2017). Acquiring variation in an artificial language: Children and adults are sensitive to socially conditioned linguistic variation. *Cognitive psychology*, 94, 85–114.
- Silverstein, M. (2003). Indexical order and the dialectics of sociolinguistic life. *Language & communication*, 23(3-4), 193–229.
- Smith, K., & Wonnacott, E. (2010). Eliminating unpredictable variation through iterated learning. *Cognition*, 116(3), 444–449.
- Sneller, B., & Roberts, G. (2018). Why some behaviors spread while others don't: A laboratory simulation of dialect contact. *Cognition*, 170, 298–311.
- Vihman, V.-A., Nelson, D., & Kirby, S. (2018). Animacy distinctions arise from iterated learning. *Open Linguistics*, 4(1), 552–565.
- Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer.