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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 44(44)

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Publication Date
2022

Peer reviewed

An experimental study of semantic extension in a novel communication system

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Abstract

Semantic extension plays a key role in language change and grammaticalisation. Here we use a dyadic interaction paradigm to study semantic extension of novel labels in controlled circumstances. We ask whether participants will be able to (i) use highly accessible associations in the perceptual environment (colour-shape associations) to converge on a meaning for the novel labels, and (ii) extend these meanings to apply to both concrete targets (objects) and abstract targets (emotions). Further, given the argument that both metonymy and metaphor are important drivers of language change, we investigate whether participants will be able to draw on relations of contiguity ('metonymic' associations, e.g. colour-shape or object-colour) and relations of similarity ('metaphorical' associations, e.g. emotion-colour) to extend the meaning of labels.

Keywords: language change; semantic extension; experimental semiotics

Introduction

Semantic extension involves applying a word to something that falls outside of the word's linguistically-specified denotation, on the basis of a principled relationship between the literal and the extended denotation, e.g. "rabbit" meaning animal is extended to mean the meat of that animal, "mouth" meaning the oral cavity is extended to mean the opening of a cave, based on its resemblance to a mouth. In the historical linguistics literature, semantic extension is widely acknowledged as playing a key role in semantic change and *grammaticalisation*, a word's journey from a lexical, concept-encoding word to a functional item with a more abstract grammatical meaning (see e.g. Givón, 1979; Bybee, Perkins, & Pagliuca, 1994; Heine, Claudi, & Hünnemeyer, 1991; Heine, 1997; Haspelmath, 1998; Traugott & Dasher, 2001). Here we adapt experimental techniques from evolutionary linguistics, based around communicative interaction using novel signalling channels (e.g. Galantucci, 2009; Scott-Phillips, Kirby, & Ritchie, 2009; Fehér, Ritt, & Smith, 2019) to study semantic extension in controlled circumstances, testing the ability of interlocutors to ground semantic extensions in co-occurrence/contiguity and resemblance.

Ad-hoc semantic extensions are made on-the-fly by speakers in a particular interaction as a short-term means to achieve their communicative goals. If a given extension recurs to the point of becoming highly frequent and familiar, it is plausible that the pragmatic interpretation process may routinise, eventually resulting in the extended meaning becoming encoded as an additional conventional sense of the word. This cycle of increasing frequency and familiarity, leading to routinisation of pragmatic processing and the eventual encoding of the originally pragmatically-derived interpretation, is a driving force behind diachronic developments of the meaning of words (e.g. Höfler & Smith, 2009; Hopper & Traugott, 2003; Kuteva, 2008; Traugott & Dasher, 2001).

Two of the primary motivations for semantic extensions are: (i) perceived *metonymic* connections between the literal and extended denotations, where the critical relation is contiguity between an entity and its distinctive/saliently associated properties (e.g. for the extension of "rabbit" from animal to meat, a distinctive property of a type of meat is the animal it comes from); and (ii) perceived *metaphorical* connections between the literal and the target denotation, where the critical relation is resemblance between the entities in question (e.g. as in the extension of "mouth") (e.g. Klepousniotou & Baum, 2007; Klepousniotou, Titone, & Romero, 2008; Klepousniotou et al., 2008). Our grasp of these associations is taken to be an accessible part of the common ground we share with interlocutors, derived from our shared experience of the world (Clark, 1996).

Both metonymically- and metaphorically-motivated extensions are involved in language complexification via grammaticalization (Traugott & Dasher, 2001; Hopper & Traugott, 2003; Heine et al., 1991; Heine, 2003; Lakoff & Johnson, 2003; Lakoff, 1987; Smith & Höfler, 2015). To illustrate a case of metonymic extension: in several languages including English, an abstract causal meaning has developed from a more concrete temporal meaning: e.g. the present-day English conjunction "since", which is used causally as in "Since it's raining, we can't rollerblade in the park", has evolved from the Old English temporal expression siþþan meaning "from the time that", plausibly due to the metonymic (contiguity-based) association between temporally sequential/overlapping events and cause-effect relations, in that causes typically precede their effects, and effects may be distinguished by their distinctive causes (see Traugott & König, 1991; Panther & Thornburg, 2010). A clear illustration of metaphorically-motivated grammaticalisation comes from the development of movement verbs into markers of futurity (e.g. English "going to" meaning moving towards becomes "going to"/"gonna" meaning future): based on our physically embodied experience in which moving forward in space nec-

In J. Culbertson, A. Perfors, H. Rabagliati & V. Ramenzoni (Eds.), *Proceedings of the 44th Annual Conference of the Cognitive Science Society.*

essarily involves moving forward in time, we are able to understand the abstract domain of time in terms of movement in space. Motivated (metonymically/metaphorically grounded) semantic extensions may also be a key mechanism in the early evolution of linguistic systems, allowing speakers to make maximum use of even a limited set of symbols and therefore setting in train the emergence of more abstract grammatical categories (see e.g. Deutscher, 2005; Smith & Höfler, 2015).

Historical examples are of course irreplaceable in understanding processes of language change, but lack the experimental control necessary to identify and differentiate the mechanisms responsible for those patterns of change, for example disentangling the role of different kinds of shared perceptual experience and world knowledge in facilitating semantic extension; historical data also speaks only indirectly to the prehistory of linguistic systems. Here we present an experimental method which allows us to systematically manipulate the extent to which metonymic (shape-colour and object-colour) and metaphoric (emotion-colour) associations are present, and thus to test their role in semantic extension. Our participants play a pair-based game where they communicate about shapes, colours, objects and emotions using a limited repertoire of communicative labels (geometrical shapes); participants start by using those labels in an intuitive way (the "star" label refers to the star referent) but extend the meaning of those labels metonymically to encompass colours ("star" means red) and objects ("star" means volcano), and metaphorically to encompass emotions ("star" means anger). We experimentally manipulate the availability of salient and shared metonymic associations; we find that semantic extension is facilitated by such associations, but is robust to their absence, in which case it draws on more general common ground associations.

Methods

Participants

268 English-speaking adults were recruited through the online crowdsourcing platform Prolific. We obtained complete data from 107 pairs (214 participants), 54 pairs in the Fixed Associations condition and 53 in the Random Associations condition. Participants who completed the experiment (duration 35-40 minutes) were paid £7; partial payment was made to participants who were unable to complete the experiment (e.g. due to not being paired with a partner).

Materials

We selected a set of simple geometric shapes to serve as the labels in a graphical communication game, and in some phases of the experiment as the referents to which those labels referred (see below). Each pair of participants was allocated 4 shapes selected at random from a set of 7 options (square, circle, diamond, star, cross, pentagon, hexagon). We used shapes as labels (rather than e.g. novel words) because (i) we expected them to have relatively weak pre-existing associations with colours, objects and emotions (not entirely correctly, as it turns out), allowing us to better probe the availability of metonymic and metaphorical associations to processes of semantic extension, and (ii) we expected shapes to have iconic affordances in the first blocks of the experiment, allowing participants to quickly grasp the communicative task without additional training.

Some blocks of the experiment involve shapes or coloured splats appearing in one of four different colours: red, yellow, pink and grey. These colours have been shown to have strong, stable associations with specific emotions, both for native English speakers and across cultures: anger (red), happiness (yellow), love (pink) and sadness (grey) (Jonauskaite et al., 2019; Jonauskaite, Parraga, Quiblier, & Mohr, 2020). This led us to hypothesise that these colour-emotion mappings would be available to participants as a grounds for metaphorically-motivated semantic extensions in the Emotions block of the experiment (see below). Further, we selected a set simple black-and-white line drawings (from `https://thenounproject.com`) of four different objects that we judged to be associated with each of the four colours by virtue of (stereotypically) being those colours: volcano (red), banana (yellow), pig (pink), and city (grey). Lastly, we chose four photographs of people representing the emotions that Jonauskaite et al. (2019, 2020) argue to be associated with our chosen colours. These pictures were obtained by google image search on the relevant emotion terms.

Procedure

The experiment was coded in javascript using jsPsych (de Leeuw, 2015) and featured real-time interaction between crowdsourced participants, achieved via websockets and a python server coordinating pairs of participants (based on code from `https://kennysmithed.github.io/oels2021/`).

Participants were informed that they would be playing a communication game with a partner, which would involve sending and interpreting simple visual labels. After consent and instructions, participants entered a waiting room and were paired with another participant for the communication game proper. Paired participants worked through six blocks of increasing difficulty, taking turns as *Sender* and *Receiver* and switching roles after every trial. On any trial (see Figure 1 upper) the Sender saw a *selection array* of three pictures, the target picture highlighted with a green box. The Sender's task was to select a label (a geometric shape from their label inventory) to label the target picture for the Receiver. The Receiver then saw the Sender's selected label, plus the same array as seen by the Sender but with left-right order randomized and no highlighting of the target; the Receiver's task was to click on the picture being labelled by the Sender. Both Sender and Receiver were awarded a point for every correct Receiver choice, and both Sender and Receiver saw as feedback the Sender's target picture, the label used, and the Receiver's selection. Success on this communicative task reflects participants' ability to successfully extend label meanings and is our main dependent variable.

The *White Shapes* block (the first block of the experiment) was intended to familiarise participants with communicating using shapes as labels: all the pictures in the Sender and Receiver's arrays were of white shapes (see Figure 1 lower), meaning that the sender could trivially encode the target picture by using the corresponding shape as the label. This block featured 8 trials (each participant acting as Sender for each shape once). In the *Shapes* block (block 2) the target pictures (but not the labels) appeared in colour (grey, red, pink or yellow); however, all pictures in the array also differed in shape, meaning that encoding the shape of the target picture was again trivial and sufficient. We used the Shapes block to establish two conditions. In the *Fixed Associations* condition, each shape was assigned a colour (each pair received a random shape-colour assignment) and always appeared in the Sender or Receiver's selection array in that colour (e.g. the hexagon was always pink), establishing a shared grounds for metonymic extension in later blocks. In the *Random Associations* condition, the colour in which a shape appeared in the selection array was randomly generated on each trial. The Shapes block featured 64 trials, each participant acting as Sender for each target shape 8 times.

In the *Coloured Splats* block (block 3), the selection array on each trial featured three splats differing in colour. Participants therefore needed to establish shared mappings between the target colours and the shape labels. We expected that the colour-shape associations provided during the Shapes block would make this straightforward in the Fixed Associations condition, allowing the participants to extend the meaning of those labels to the associated colour (e.g. using the hexagon label to convey the colour pink); we expected this would be substantially harder for participants in the Random Associations condition given the lack of such prominent associations (i.e. communicative success would be lower). In the *Coloured Shapes* block (block 4), the selection array featured three of the same shape (e.g. three crosses) in different colours. To communicate the target shape (e.g. the pink cross), participants again had to draw on shape-colour mappings to signal the target in terms of its colour, but in this case also over-riding the label's inherent and established meaning (e.g. using a hexagon label to refer to a cross). The Coloured Splats and Coloured Shapes blocks each consisted of 32 trials (each participant acting as Sender for each colour 4 times).

The Coloured Splats and Coloured Shapes blocks provided a first test of whether participants could extend the meaning of a label (e.g. "star" means star) to encompass colour (e.g. "star" also means red). The final 2 blocks tested whether participants were able to make further extensions drawing on pre-existing associations of that extended meaning. In the *Objects* block (block 5), the selection array consisted of three black-and-white line drawings of objects. Participants had to select a shape label to communicate the target to their partner by drawing on metonymic (contiguity-based) associations between an object and its (stereotypical) colour, and using the shape-colour mappings established in the preceding blocks,

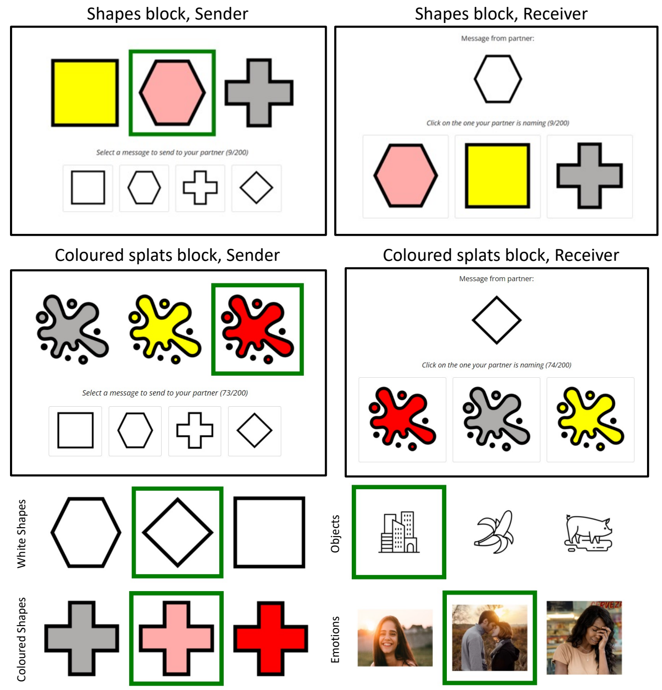

Figure 1: Upper: Example Sender and Receiver screens from the Shapes and Coloured Splats blocks; the Sender selects a label (a geometric shape) to convey the target picture (highlighted with a green box) to the Receiver, who selects a picture based on that label. Lower: example selection arrays in the other blocks.

e.g. "star" means star and/or red, a volcano is red, therefore the meaning of "star" can be extended to cover volcano. Finally, in the *Emotions* block (block 6), the selection array consisted of three photographs representing different emotions. Here the crucial associations were metaphorical in nature, e.g. anger is red, therefore the meaning of "star" can be extended to cover anger. These blocks were 32 trials long (each participant acting as Sender for each object/emotion 4 times).

Results

Communicative success

Communicative success (the proportion of trials where the Receiver clicked on the correct response) in the first two blocks of the experiment (White Shapes, Shapes) was uniformly high, with average accuracy of over 99% in both conditions. Figure 2 (left) shows communicative success on the subsequent blocks of the experiment. Participants were quite successful in the task in both conditions, and many pairs were able to reach high levels of accuracy in using shapes to communicate about colour (in the Coloured Splats and Coloured Shapes blocks), could decouple the basic and extended meaning of the signals (i.e. using "star" to refer to a red square because "star" means red) in the Coloured Shapes block, and were able to further extend those colour-shape associations to communicate about objects and emotions.

We used logistic mixed effects models to analyse the binary outcome of communicative success on each trial (success/failure), with condition, block, and their interaction as fixed effects.[1] A model with block treatment-coded (with Coloured Splats as the reference level) and condition (Fixed or Random Associations) sum-coded shows that the conditions differed at the Coloured Splats block (b=0.32, SE=0.12, p=.009), with participants in the Fixed Associations condition communicating more successfully. A model with block coded using successive differences shows that performance on the Coloured Shapes block was higher than in the Coloured Splats block (b=0.26, SE=0.09, p=.004) and was higher in the Objects block than the Coloured Shapes block (b=0.56, SE=0.13, p$<$.001), but there was no increase in performance from Objects to Emotions blocks (b=0.16, SE=0.12, p=.182). While the difference between conditions is numerically largest in the Coloured Splats block and declines across subsequent blocks, neither model showed a significant interaction between block and condition (e.g. in the treatment-coded model, lowest p=.188). These results therefore suggest that the presence of statistical associations between colour and shape established in the Shapes block in the Fixed Associations condition gives pairs in that condition an advantage in initially extending the meaning of those labels, and that advantage persists in subsequent extensions.

Figure 2 (right) shows the timecourse of performance (i.e. success by trial number) in each block. Performance rapidly increases in each block, and drops at the start of each new block as participants are required to extend their established label meanings to convey a new distinction (although this drop in performance is quite modest at the transition from Coloured Splats to Coloured Shapes). A model with fixed effects of condition, block and trial number as well as their interactions suggests a marginal three-way interaction between condition, block and trial number ($\chi^2(3) = 6.66$, p=.084). Posthoc analyses considering each block in turn show a marginal condition x trial number interaction in the Coloured Splats block (b=0.29, SE=0.15, p=.055), visible in the graph as the short period spent near chance performance at the start of this block in the Random Associations condition. While this result should be treated with caution, it is consistent with our assumption that the difficulty of establishing a signalling convention for colour in the absence of salient shared colour-shape associations is particularly pronounced early on.

[1]Models were run in R (R Core Team, 2019) using lmer (Bates, Mächler, Bolker, & Walker, 2015); successive difference coding used the contr.sdif function from the MASS package (Venables, Ripley, & Venables, 2002); plots were produced in ggplot2 (Wickham, 2009). For all models reported here the random effects structure consist of by-pair (not by-participant) random intercepts and random slopes for fixed effects that varied within-pair (i.e. block, trial number). Including a by-participant random effect nested within pair produced substantial convergence issues and explained very small amounts of variance. Data and analysis code is available at `https://github.com/kennysmithed/SemanticExtension`.

Patterns of extension of meaning across blocks

In the Fixed Associations condition we expect participants to extend the meaning of a given label to include the colour associated with that shape (e.g. if stars were always red in the Shapes block, they should extend the meaning of "star" to encompass red in the Coloured Splats block). Participants in the Random Associations condition could do the same — due to the random colour-shape associations there will tend to be some shapes which occur more often in a particular colour — but since those associations are weaker we expect the extension behaviour in this condition to be more arbitrary (as is also suggested by the lower performance in the communicative task in the extension blocks). Beyond the initial extension in the Coloured Splats block, we expect that participants in both conditions will extend their newly-established labels for colour in predictable ways: e.g. in the Coloured Shapes block participants should continue to use the label established for red in the Coloured Splats block to signal red; in the Objects block that signal should be extended to convey the volcano concept, and in the Emotions block it should be extended to convey anger.

We evaluate this by calculating a measure of difference between concept-label co-occurrence counts across blocks, as illustrated in Figure 3 (upper). For each block and each pair we count the co-occurrence of each concept and signal and then calculate a normalised measure of difference between those matrices; if two matrices are identical this produces a difference score of 0, if two matrices are maximally different the difference score is 8. This metric suffers from the fact that random matrices tend to have relatively low difference scores; to resolve this we convert the raw difference scores to a z score by generating a random distribution of difference scores by permuting the columns of one of the two matrices and re-calculating the difference score, repeat this operation 1000 times to obtain a distribution of difference scores, then calculate the z-score (i.e. number of standard deviations from the mean) for the observed difference score. The resulting difference z-scores will be around 0 for two concept-signal co-occurrence matrices which are no more similar than expected by chance; negative z-scores indicate matrices which are quite similar (i.e. have lower differences) relative to chance, and z-scores below -1.96 indicate similarities which are unlikely to be generated by chance at p$<$.05.

Figure 3 (lower) plots these block-to-block difference measures. Difference scores in the Shapes-Coloured Splats transition are reliably lower in the Fixed Associations than Random Associations condition, as expected (t(88.3)=-4.72, p$<$.001): participants in the Fixed Associations condition generally exploit the associations between colour and shape provided in the Shapes block, leading to reliably negative difference z-scores (most pairs show difference z-scores smaller than -1.96); in contrast, the z-scores in the Random Association conditions are around 0, reflecting colour-label associations in the Coloured Splats block which are effectively arbitrary with respect to any colour-shape associations present

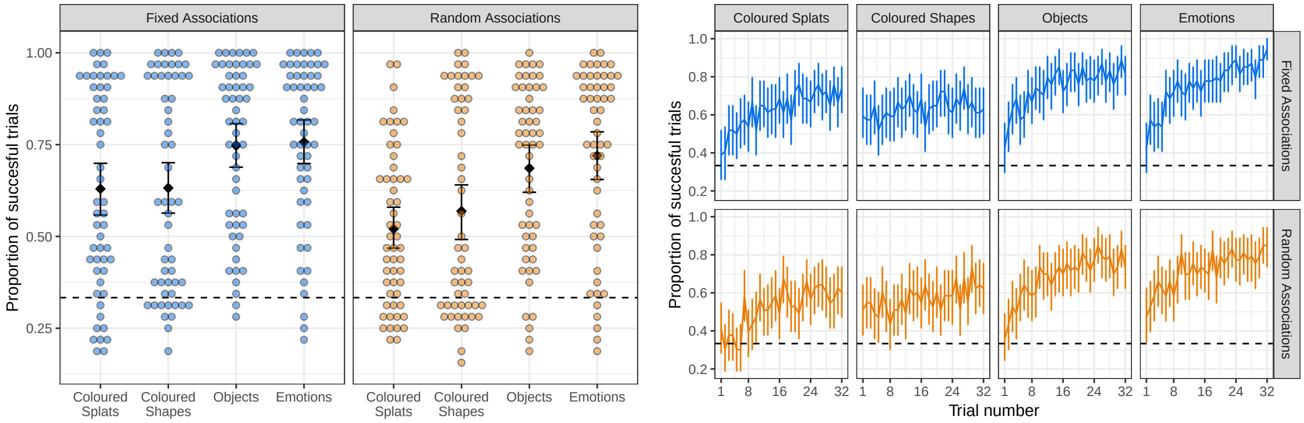

Figure 2: Left: Success in the communicative task against block. Coloured points give means for individual pairs, black diamonds plus error bars indicate means of pairs plus bootstrapped 95% CIs. Right: Success against trial number in each block; lines and error bars plot the mean and 95% CI across all pairs. Dashed lines gives chance performance.

Associations in Shapes

	□	☆	✚	⬡
Grey	32	0	0	0
Red	0	32	0	0
Pink	0	0	0	32
Yellow	0	0	32	0

Associations in Coloured Splats

	□	☆	✚	⬡
Grey	14	0	2	0
Red	2	12	1	1
Pink	0	0	0	16
Yellow	0	16	0	0

Absolute normalised difference

	□	☆	✚	⬡
Grey	$\frac{2}{16}$	0	$\frac{2}{16}$	0
Red	$\frac{2}{16}$	$\frac{4}{16}$	$\frac{1}{16}$	$\frac{1}{16}$
Pink	0	0	0	0
Yellow	0	1	1	0

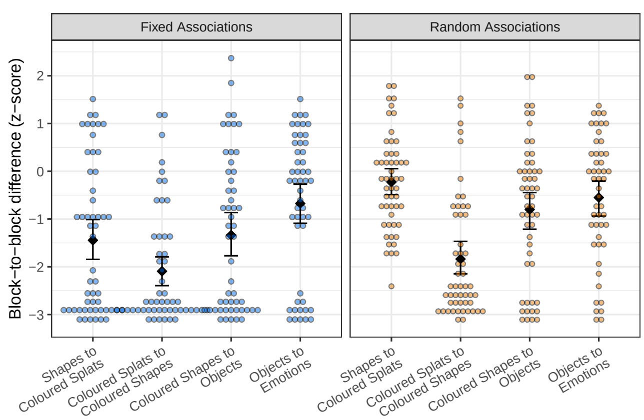

Figure 3: Upper: Calculating the difference between association matrices in the Shapes and Coloured Splats block. For each pair we tabulate meaning-label co-occurences, convert these to normalised values so that each row sums to one, then take the absolute difference between those normalised values; the summed normalised difference values are then converted to a z-score. Lower: Block-to-block differences calculated using this measure, where negative z-scores indicate matrices which are quite similar (i.e. have lower differences) relative to chance. Plotting conventions as in Figure 2.

in the Shapes block. In subsequent blocks the two conditions look more similar: difference scores for the Coloured Splats-Coloured Shapes transition do not differ between conditions (b=0.25, SE=0.28, p=.300, obtained from a model where block transition is treatment coded), and in both conditions participants continue the colour-signal associations established in the Coloured Splats block to the Coloured Shapes bock (as indicated by reliably negative z scores). Those associations are often extended in the predicted way to the Objects block, although we see a progressive weakening of the correspondence there (the block-to-block difference scores increase, i.e. move towards 0, at successive comparisons: Coloured Shapes-Objects difference scores are higher than Coloured Splats-Coloured Shapes differences, b=0.88, SE=0.15, p<.001; Objects-Emotions difference scores are higher than Coloured Shapes-Objects differences, b=0.46, SE=0.15, p=.003, obtained from a model with block transition coded using successive differences). In the Emotions block many pairs have z-scores around 0, indicating labelling conventions for emotion which do not extend labels in the predicted direction, although 13 pairs in the Fixed Associations and 8 in the Random Associations condition do have high negative z-scores at this transition, indicating the conventions are extended in the predicted way in some pairs.

In summary, this analysis suggests that the Fixed Associations condition shows the predicted pattern of extension of the statistical associations established in the Shapes block to the Coloured Splats block, whereas pairs in the Random Associations condition have to establish colour-shape correspondences from scratch; pairs in both conditions then extend those associations, with declining fidelity, to the subsequent blocks, and many participants in the Emotions block establish new emotion-shape associations which are unrelated to their established colour-shape associations.

Table 1: Counts of colour-label correspondences in the Coloured Splats bock across all pairs in the Random Associations condition (highest association in each row in bold). Recall that every pair was allocated only 4 of these 7 labels.

	○	✚	⬡	☆	◇	⬠	□
Grey	**97**	42	69	38	36	59	83
Pink	60	68	62	39	**75**	62	58
Red	69	**106**	40	51	34	40	84
Yellow	67	69	30	**132**	36	53	37

Non-arbitrary colour-shape correspondences

We were surprised that participants in the Random Associations condition were so successful at bootstrapping a signalling system for colour, leading to a smaller-than-expected (but still clear and significant) difference between conditions in the Coloured Splats block. Table 1 shows the frequency with which Senders in the Random Associations condition used each label for each colour in the Coloured Splats block. There are clear preferences for certain colours to be conveyed using particular shapes, which we had not anticipated when designing our stimuli and which pairs were able to exploit to rapidly coordinate on semantic extensions. Some of these are in hindsight obvious (yellow is strongly associated with "star"), some have a conceivable retrospective justification (red seems to be associated with "cross"; this could be due to the emblem of the Red Cross, the international humanitarian charity, or the fact that red and crosses are both associated with prohibition), and some are more baffling (grey is associated with circles and squares, although only a philistine would consider those to be boring shapes). Only pink seems to lack a clearly preferred shape. These impressions receive support from a simple χ^2 test of independence run on the tables of associations or individual rows from that table: the overall table shown in Table 1 is significantly non-uniform ($p<.001$), as are all of the rows associated with each colour apart from pink ($p=.050$ for pink; $p<.001$ elsewhere). [2]

Discussion

Our results indicate that participants were able to draw on both metonymic and metaphorical associations in extending the meaning of labels to apply to colours, and then subsequently to more concrete (objects) and more abstract meanings (emotions). Extension via grounding in metonymic and metaphorical associations has been argued to form an important mechanism in both the early evolution of linguistic systems (e.g. Smith & Höfler, 2015), and in subsequent language change (e.g. Traugott & Dasher, 2001). Participants used a range of different sources of information to establish the meaning of the symbols. Our results suggest that semantic extension is facilitated by the presence of metonymic associations (in our Fixed Associations condition) that are part of the shared perceptual environment for a pair, presumably since these are reliably part of the common ground and therefore highly likely to be grasped by the audience, and this advantage persists across subsequent extensions of those labels. However, even without such salient associations, our participants were able to exploit other metonymic associations that are plausibly part of common ground (e.g. regarding the colours of stars and crosses) in order to converge on a usable communication system.

One additional finding, clearest in the Emotions block, is that the degree to which a grounding can be assumed to be common ground has an important influence on which grounds will be exploited in communication. This can be seen in the contrast between the Objects and Emotions blocks. The colour of an object is broadly uncontroversial: we can be confident that even an entirely unknown interlocutor will know that e.g. bananas are yellow. However, associations between colours and emotions are likely to be more subjective and therefore less likely to be shared between interlocutors (e.g. while love is typically associated with pink, associating love with tumultuous passion could lead to an individual associating love with red), which could explain the decreased tendency to rely on established colour-shape associations in the Emotions block as compared to the Objects block; if in a given pair each person had different colour-emotion associations, they would have had to negotiate emotion-shape correspondences from scratch. Other emotion-shape correspondences may also have provided an alternative means of grounding labels for emotions; for example, shapes with lots of corners and sharp angles are associated with anger or excitement; whereas rounded shapes with curving edges are associated with contentment or sadness (Sievers, Lee, Haslett, & Wheatley, 2019). However, this also suggests that the specific nature of the grounds for semantic extension may be less important than the fact that there is a motivation for semantic extension, one that is sufficiently easily accessible to the interpreter (or deemed so by their interlocutor) for them to be able to work out the intended extension.

Conclusion

This paper presents a method for exploring semantic extension, a key component of language change and grammaticalization, in controlled experimental circumstances, and demonstrates that lab participants will bootstrap communication by extending label meanings on both metonymic and metaphorical grounds. We plan to extend this work in two ways: exploring how these same processes play out in larger groups, where we expect that the reliability of a shared basis for grounding a semantic extension will become increasingly important; using words rather than shapes as labels, allowing participants to exploit a richer set of common ground associations for extension.

[2] Note that this data violates the χ^2 assumption of independence, since each pair contributes multiple points; however, since we are not primarily interested in these non-arbitrary associations we consider this sufficient evidence that such associations probably exist.

Acknowledgments

This research received funding from the European Research Council under the European Union's Horizon 2020 research and innovation program (Grant 681942, held by K. Smith).

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