**Analogical structure mapping and the formation of abstract constructions: A novel construction learning study.**

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**Abstract:** This chapter reports an experimental study in which children aged 4;9-6;1 were taught two novel constructions with meanings of enabling/helping and preventing/stopping with OSV and VOS word order. The aim was to test Tomasello’s (2003) proposal that children form abstract constructions by performing analogical structure mapping across lexically-specific slot-and-frame patterns (e.g., He’s [X]ing it) and/or particular sentences that instantiate them. All surface cues were minimized, such that successful learning of the construction required children to align the relational structure (i.e., helper-action-helpee or preventer-action-preventee, as appropriate) of the training sentences. A forced-choice pointing test revealed that children did not successfully learn either the constructions’ global meanings or argument linking patterns (though a control group of adults succeeded at the latter task) [[1]](#footnote-1)

***1. Introduction***

Traditionally, accounts of syntax acquisition have assumed an important innate – and specifically linguistic – component. For example, children have been argued to acquire word-order (e.g., SUBJECT VERB OBJECT for English) by setting innate parameters (e.g., SV/VS and VO/OV; e.g., Sakas & Fodor, 2012). Partly in response to the difficulties encountered by such an approach (e.g., Boeckx & Leivada, 2013), many researchers have proposed alternatives, under which children acquire syntax gradually on the basis of the input (e.g., Clark, 1976; Peters, 1983; Pine & Lieven, 1993; Tomasello, 2003; MacWhinney, 2014; Ambridge & Lieven, 2015).

These so-called constructivist accounts posit a three-stage process. Children start out by acquiring rote-learned, unanalyzed holophrases (e.g., He’s+kicking+it; He’s+eating+it; He’s+drinking+it) from the input. Next, as soon as (in principle) two suitable holophrases have been acquired, children begin gradually to schematize across them to form partially-productive, semi-abstract schemas or slot-and-frame patterns (e.g., He’s ACTIONing it). Finally, children analogize across these patterns (and/or concrete sentences that instantiate them) to arrive at fully-productive adult-like abstract constructions that reflect both semantic generalizations (e.g., [AGENT] [ACTION] [PATIENT]) [[2]](#footnote-2) and how the semantics is syntactically realized (e.g., [SUBJECT-NOUN] [VERB] [OBJECT-NOUN]).[[3]](#footnote-3)

On our reading of the literature, the existence of (a) rote learned holophrases and (b) partially-productive slot-and-frame patterns is extremely well established. With regard to the former, four recent studies have demonstrated that young children’s utterances are more fluent and/or accurate when they are able to make use of a multi-word string that is of high frequency in the input (and hence potentially stored as a holophrase), even when controlling for the frequency of the relevant words and bigram sequences (Bannard & Matthews, 2008; Matthews & Bannard, 2010; Arnon & Snider, 2010; Arnon & Clark, 2011). With regard to the latter, many studies (see Ambridge & Lieven, 2015: 491-492 for a summary) have found that children are able to correctly produce particular sentence types only when they can potentially use a well-learned template such as He’s ACTIONing it (e.g., Dodson & Tomasello, 1998; Akhtar, 1999; Childers & Tomasello, 2001), It got ACTIONed by it (e.g., Savage, Lieven, Theakston & Tomasello, 2003) or What is he ACTIONing? (e.g., Ambridge, Rowland, Theakston & Tomasello, 2006; Rowland, 2007; Ambridge & Rowland, 2009).

The situation is dramatically different, however, for the third stage in the constructivist account of acquisition. In fact, we are not aware of a single empirical study which directly tests the idea that children acquire abstract constructions by analogizing across slot-and-frame patterns, or concrete sentences instantiating them (but see Goldberg, Casenhiser, & White, 2007; Otis, Waterfall, & Edelman, 2008 for related studies). A version of this claim is presented by Tomasello (2003: 164) who discusses the research of Gentner and colleagues into structure mapping (Markman & Gentner, 1993; Gentner & Markman, 1995, 1997; Kotovsky & Gentner, 1996; Gentner and Medina, 1998). For example, in Richland, Morrison and Holyoak (2006), children were shown a picture of a cat chasing a mouse above a picture of a boy chasing a girl, and were asked “what is like the cat in the bottom picture?”. Richland et al. found that 3 to 4-year-old children would reliably pick the boy, and 6 to 7-year-old children would reliably do so even when an identical cat was present in the bottom picture. That is, rather than choosing the best literal match – the identical cat – children align the relational structure of the two pictures (i.e., chaser-chasee) and hence perceive a deep structural similarity between the item playing the same role (chaser) in both. Even for this younger age group, Christie and Gentner (2010) showed that 3 to 4-year-old children, when given some scaffolding to compare across examples, can see past the superficial object differences and generalize a novel relational structure to a novel pair of objects.

Analogizing this and similar findings into the domain of language acquisition Tomasello (2003: 166) suggests “it is thus possible that abstract linguistic constructions are created by a structural alignment across different item-based constructions, or the utterances emanating from them”, offering the following “somewhat whimsical linguistic example” (p.165).

Consider the following two sequences of letters:

U R X

I M A B

Let us try to make an analogy. It is not easy because there is not much in common between the two strings; they even have different numbers of items. But what if we now translate them into English in a fanciful context. The situation is that we are role-playing with a child in a pretend game, and one role is to be a creature named X and another role is to be one of several honeybees. The above sequences now translate into “You are X” and “I am a bee”. We can now see that these are both predicate nominative constructions, and they are analogous: you corresponds to I as the one to be anointed, are corresponds to am as the identifying relation, and X corresponds to the two-word phrase a bee as the new identity taken on. Such correspondences can only be made once we know the functions of the items and structures involved. (Tomasello, 2003: 165).

Note that, exactly as with Richland and colleagues’ chaser-chasee example, the pairs that are to be analogized across need not share any surface similarity. Rather, what is crucial is that they share relational similarity; a similar relationship (chaser-chasee or person-identity taken on) holds between the members of each pair.

Ambridge and Lieven (2015) discuss how such an account could potentially explain the acquisition of basic transitive word order. Suppose, for example, that a child has formed the slot-and-frame patterns schemas I’m [ACTION]ing it and [KISSER] kissed [KISEE]. Although these patterns share no surface similarity, they do share some kind of AGENT-ACTION relation (I-[ACTION] and [KISSER]-kissed) and ACTION-PATIENT relation ([ACTION]it and kissed [KISSEE]). Tomasello’s (2003) claim is that this type of relational overlap (presumably between many such schemas, rather than just two) is sufficient for children to analogize across them, and hence move towards a fully-abstract [AGENT] [ACTION] [PATIENT] sentence-level argument-structure construction.

The aim of the present study is to begin to test this claim. Although several of Gentner and colleagues’ studies have demonstrated analogical structure mapping in a nonlinguistic context, we are unware of any previous experimental attempts to test Tomasello’s (2003) claim that this mechanism is operational in the domain of syntax acquisition (but see Goldwater et al., 2011 for computational simulations of such a process, and Goldwater, Tomlinson, Echols & Love, 2011 and Goldwater & Echols, in prep for evidence for structure mapping as a mechanism in children’s syntactic production of familiar constructions).

Methodologically speaking, the starting point for the present study was the novel construction learning studies of Goldberg and colleagues (e.g., Casenhiser & Goldberg, 2005; Boyd, Gottschalk & Goldberg, 2009; Boyd & Goldberg, 2012; Wonnacott, Boyd, Thomson & Goldberg, 2012), in which learners were taught a new appearance or approaching construction (e.g., The bird the flower moopoed). In this study, children watched short videos of events of appearance or approaching, (e.g., a bird appears on a flower), while hearing sentences describing the event using the novel word order. After a series of learning trials, children would be presented with test trials that presented two novel videos, one showing appearance, and one showing an event describable with a familiar construction, such as the transitive. On half of the test trials children heard a sentence with a novel construction, and half with a familiar construction. The children on average pointed to the appearance events when the novel construction was heard more than when a familiar construction was heard, consistent with having generalized the construction semantics and word order beyond the initial training set.

Because these previous studies were not concerned with investigating analogical structure mapping per se, they did not attempt to prevent learners from using surface rather than relational similarity. Thus a particular sentence position was always filled by an appearer or an approacher, and hence shared across trials a type of surface-level similarity (i.e., it always appeared, or always moved). In some studies, instantiations of the construction also shared surface similarity in the form of lexical overlap of the definite articles and the novel construction marker –o (e.g., The [THEME] the [LOCATION] [VERB]-o-s/ed). Thus in order to acquire the construction, learners did not necessarily need to align the underlying appearer-location (or approacher-location) structure of the training trials (although, of course, they may well have done so). In contrast, the present study – in addition to eliminating lexical overlap – required learners to align across preventer-action-preventee events and helper-action-helplee events. This is because being a preventer or helper requires both an action to prevent/help and a preventee/helpee. In contrast, the appearer and approacher roles in these previous studies could be understood without reference to the location role.

It is worth noting, that to more strictly test the role of structural alignment specifically, we moved away from how many natural language constructions work, thus potentially making the task more difficult for the learner. Consider ditransitive sentences such as John threw/kicked/gave/handed the ball to Bob. They all convey a meaning of transfer of an object from one possessor to another. The verb expresses the means of the transfer. Transfer in these sentences is a “first-order” relation in that it takes objects as its arguments. On the other hand, a “second-order” relation takes first-order relations as its arguments. The help and prevent relations of the current artificial constructions are second-order in this way, because what is helped or prevented is a whole event unto itself with its own first-order relation, as in an example animated event from our study, “The king helped the queen climb the ladder.” Here, the verb climb names the first-order relation that is the argument of the second-order help relation that is the meaning of the artificial construction. This is unlike the dative construction, wherein the verb fleshes out the specific means (e.g., throwing) of the first-order relation that the construction denotes in a more abstract way (transfer). Goldberg and colleague’s appearance semantics is more akin to natural construction semantics in this way.

A second modification from the prior work is that participants in the present studies were taught two novel constructions, as opposed to only one in the studies of Goldberg and colleagues. Although this, of course, makes the task more difficult for learners, it ensures that they cannot succeed on construction-meaning test trials by using a process of elimination. In these previous studies, learners heard either the novel construction (e.g., The frog the apple zoopos) or – for example – a transitive construction (e.g., The frog zoopos the apple) and had to choose between, for example, the frog appearing on the apple or the frog pushing the apple. Thus, for these test trials, it is possible that learners could have succeeded by mapping the transitive construction to the transitive actions and – by process of elimination – the novel construction to the non-transitive action. In the present study, learners were given a forced choice between two novel constructions.

A third modification was that in place of the subject-first word order used in some of these previous studies (which is somewhat similar to English), we used two word orders designed to be as dissimilar as possible to English: OSV and VOS. A fourth and final modification involved the used of familiar verbs, as opposed to novel verbs in the studies of Goldberg and colleagues. Because, in the present study, the construction meaning (helping/preventing) was independent of the meaning of the verb (e.g., leave, fall, hop, sit) it was felt that the use of novel verbs would unnecessarily increase the burden on learners.

To summarise, the aim of the present study was to investigate Tomasello’s (2003) claim that learners can acquire abstract syntactic constructions on the basis of underlying relational similarity between sentences that share no surface similarity. To this end, we taught children aged 4-6 two novel constructions: OSV and VOS. The different exemplars of each construction had no surface lexical material in common, but shared higher-order relational structure. For one construction, the SUBJECT prevented the OBJECT from performing the action denoted by the VERB (i.e., PREVENTER+ACTION and ACTION+PREVENTEE relations). For the other, the SUBJECT helped or helped the OBJECT to perform the action denoted by the VERB (i.e., HELPER+ACTION and ACTION+HELPEE). Subsequent forced-choice tests examined whether the participants had learned (a) the meaning of each of the two constructions (e.g., Naigles, 1990) and (b) the linking patterns of each (e.g., Gertner, Fisher & Eisengart, 2006).

Unlike an account that suggests children can learn construction meaning from higher-order relational structure alone, alternative accounts of construction generalization that rely on the distribution of lexical overlap across sentences (e.g., Chang, & Ambridge, 2014) would not predict much learning in the task. Following the results, we will describe the implications for several of alternative explanations in more depth.

**2. Method**

**2.1 Participants**

Participants were 24 children (13 male) aged 4;9-6;1 (M=5;7; SD=0;5), recruited from schools and nurseries in Greater Manchester (UK). The study was approved by the University of Manchester ethics committee, and parents gave written consent. This age range was picked to be consistent with work reviewed above that showed either successful artificial construction learning (by Goldberg and colleagues) or structure-mapping in language production (Goldwater et al., 2011).

**2.2. Materials and Procedure**

**2.2.1 Training.**

Each child was taught two novel constructions (with English words); one with OSV word order, the other with VOS word order (chosen to be as dissimilar as possible to English SVO order). One construction was with paired with the meaning of helping/enabling, the other with stopping/preventing (counterbalanced across children). Thus, according to the structure mapping theory, children should learn each construction by aligning, as appropriate, the helper-action-helplee or preventer-action-preventee structure of the training sentences. In order to ensure that children had to rely on this deep structural cue, as opposed to surface similarity, we took care to ensure that the precise means of helping/enabling or stopping/preventing, as illustrated in the accompanying animations, varied in every case (see Table 1). Thus the stopping/helping could be physical, by giving an order, removing/supplying some necessary object etc. Although all four roles (enabler, enablee, preventer, preventee) were always animate, we ensured that each was filled by both humans and animals, and that none had any consistent direction of motion between different animations. The animations, which used characters chosen to be familiar to most British children, were created in Anime Studio Pro and displayed using Processing (Reas & Fry, 2007). Each animation was displayed in the centre of the screen, accompanied by an animated robot head, below, who spoke the sentence. In order to minimize confusion, blocked presentation was used, such that children saw either 12 stopping/preventing videos then 12 helping/enabling videos or vice versa, as shown in Table 1. This entire training set was shown once per day for 3 consecutive days, for a total of 36 training trials per construction.

**Table 1. Training sentences and animations**

|  |  |  |  |
| --- | --- | --- | --- |
| Stopping/preventing training sentences | | | |
| OSV (CB Group A) | VOS (CB Group B) | | Animation |
| Homer Marge leave | leave Homer Marge | | Homer tries to exit screen left, but Marge drops a brick wall in his path |
| Lisa Bart come | come Lisa Bart | | Lisa tries to enter a building, but Bart (already inside) closes the door |
| Wendy Bob run | run Wendy Bob | | Wendy runs towards Bob (The Builder), who stops her by giving the "halt" signal |
| Grandpa Duck hop | hop Grandpa Duck | | Grandpa hops towards the duck, who kicks him over |
| Grandma Sheep laugh | laugh Grandma Sheep | | Grandma is laughing, but stops when sheep "Ssh"s her |
| Dora Frog talk | talk Dora Frog | | Dora says "Hi, I'm Dora the Ex…", but frog sticks a band aid over her mouth |
| Wolf Dennis sit | sit Wolf Dennis | | The wolf walks towards the chair but Dennis (The Menace) pulls it off screen right |
| Lion Tracy drink | drink Lion Tracy | | The lion reaches for a cup of water, but Tracy (Beaker) pours the water onto the floor |
| Dog Ash eat | eat Dog Ash | | Ash (a Pokemon character) reaches for a burger, but the dog pushes it off the table and into the bin |
| Tiger Fox fall | fall Tiger Fox | | The tiger runs towards the edge of a cliff, but the fox runs after him and drags him back |
| Bunny Elephant cry | cry Bunny Elephant | | The bunny is crying, but the elephant dabs his tears, and he stops |
| Cat Pig sing | sing Cat Pig | | The cat sings, but Piglet (from Winne The Poo)kicks the hi-fi system off the screen and the cat stops |
|  |  | |  |
| Helping/enabling training sentences | | | |
| VOS (CB Group A) | OSV (CB Group B) | Animation | |
| leave Bart Wendy | Bart Wendy leave | Bart walks right, Wendy kicks down a wall that blocks his path, and he exits screen right | |
| come Bob Homer | Bob Homer come | Homer (already inside) opens the door to a building, and Bob enters | |
| run Lisa Marge | Lisa Marge run | Marge runs behind Lisa, pushing her along, and causing her to run | |
| hop Dora Sheep | Dora Sheep hop | The sheep (walking on two legs) holds Dora's hand as she hops along | |
| laugh Grandpa Frog | Grandpa Frog laugh | The frog tickles Grandpa, and he laughs | |
| talk Grandma Duck | Grandma Duck talk | The dog removes a band aid from over Grandma's mouth, and she begins to speak | |
| sit Dog Tracy | Dog Tracy sit | Tracy drags in a chair, and the dog sits down | |
| drink Wolf Ash | Wolf Ash drink | Ash pours some water into a cup and the wolf drinks it | |
| eat Lion Dennis | Lion Dennis eat | Dennis brings some fruit to the lion, and he eats it | |
| fall Cat Elephant | Cat Elephant fall | The cat strolls towards the edge of a cliff and the elephant runs up and pushes her off | |
| cry Pig Tiger | Pig Tiger cry | The tiger hits piglet in the face and he cries | |
| sing Bunny Fox | Bunny Fox sing | The fox presses "play" on the hi-fi system, and the bunny starts to sing | |

**2.2.2 Test**

Immediately after the final training session, children completed (in random order) eight forced-choice pointing test trials (in one of four different versions counterbalanced for the side of the target, and for which particular character filled each role). Four trials (modeled on Naigles, 1990) assessed children’s learning of the meanings of the constructions (two trials each with the helping and stopping constructions as target, counterbalanced for side). These trials showed one helping video, and one preventing video, each with the same characters playing the corresponding roles (e.g., with Homer as preventer/helper of Marge). The goal was to point to the event that matched the construction meaning. Four trials (modeled on Gertner, Fisher & Eisengart, 2006) assessed their learning of the constructions’ semantics-syntax linking patterns (again, two trials each with the helping and stopping constructions as target, counterbalanced for side). These trials presented two events of the same type (either two preventing, or two helping), but which character played which role differed across the two videos (e.g., Homer was the helper and Marge was the helpee, or vice versa). The goal was the point to the event that matched the word order rule of the construction. Table 2 shows the test trials for children in the first counterbalance condition. Note that the test trials did not reuse any of the same characters or verbs as the training trials. For each trial, children saw a preview of, first, the left-hand video and, second, the right-hand video, before the two played simultaneously, accompanied by the audio sentence. The videos ended on a freeze frame that made it clear which was which (e.g., the man with his foot on the chicken vs the chicken running free) in order to give children as long as they needed to process the sentence and make their choice.

**Table 2. Test sentences and animations (correct choice shaded grey)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Test Type | Sentence | Animation (Left screen) | Animation (Right screen) | Meaning (Group A) | Target screen (Group A) |
| Construction meaning | Chicken man play | The chicken runs around squawking, but the man puts his foot on it and stops it | The man picks up the squawking chicken and dances around with it | Stop/  Prevent | L |
|  | Sleep panda woman | The panda is asleep in bed, but the woman shouts "wake up", and he does | The woman sings a lullaby to the panda, who then falls asleep, "zzzz" | Help/  Enable | R |
|  | Fish prince swim | The prince throws the fish into a bowl, and he starts swimming | The fish is swimming in a bowl, but the prince kicks it over, spilling the water and fish | Stop/  Prevent | R |
|  | Jump horse Princess | The princess rides a horse over a jump | The horse approaches a jump, but the princess - on the other side - raises her hands, "stop" | Help/  Enable | L |
| Semantics- syntax linking | Boy girl draw | The boy is drawing on a piece of paper, but the girl takes it away | The girl is drawing on a piece of paper, but the boy takes it away | Stop/  Prevent | L |
|  | Rabbit bear fly | The bear is flying around in a plane, but the (giant) rabbit punches it out of the sky | The rabbit is flying around in a plane, but the (giant) bear punches it out of the sky | Stop/  Prevent | R |
|  | Climb king queen | The king, atop the castle, throws down a ladder, and the queen climbs it | The queen, atop the castle, throws down a ladder, and the king climbs it | Help/  Enable | R |
|  | Dance cow zebra | The zebra plays the guitar while the cow dances | The cow plays the guitar while the zebra dances | Help/  Enable | L |

**3. Results**

All children made an unambiguous point on every trial, with no missing data. The data were analyzed using mixed effects models (using the lme4 package for R). Binomial models were used to compare the proportion of correct (1) vs incorrect (0) choices to chance (i.e., by comparing the intercept to 0.5). All models included random intercepts for participant. Random intercepts for trial were included in the semantics-syntax linking analysis, but caused convergence-failure in the construction-meaning analysis (random slopes were not possible, since the models contained no predictors, only the intercept).

For the construction-meaning trials (N=4), children made a mean of 57.29% correct points, which did not differ significantly from chance (intercept=0.29, SE=0.21, z=1.42, p=0.16). One factor in children’s poor performance may be a small (and not quite significant) bias towards the helping/enabling action (perhaps a pro-social effect), which they selected on 68% of trials (intercept=1.74, SE=0.09, Z=1.88, p=0.06, n.s.). Note that, because they are making a forced-choice between these two alternative meanings, it is not meaningful to compare children’s performance on the stopping and helping target trials (children appear to show better performance for the latter, but this is only because of their overall bias towards the helping videos).

For the semantics-syntax linking trials (N=4) children made a mean of 58.33% correct points, which again did not differ significantly from chance (intercept=0.34, SE=0.21, z=1.625, p=0.10). Children’s performance on the linking trials did not differ significantly between the stopping trials (56.25% correct) and helping trials (60.42% correct); adding trial type as predictor did not improve model coverage (Chi1=0.17, p=0.68, n.s.).

**3. 1. Manipulation check**

Given the failure of the children to learn the constructions, it seemed important to verify that the constructions were, in principle, learnable; i.e., that we succeeded in our aim of teaching stopping/preventing and helping/enabling constructions with identifiable and distinct links between semantic and syntactic roles. We therefore repeated the study with eight adult volunteers at Northwestern University. For the semantics-syntax linking trials, adults made a mean of 91% correct points, which easily beat chance (intercept =2.27, SE=0.61, p<0.001). Although they did not significantly beat chance on the construction-meaning trials (81% correct points, intercept=5.38, SE=6.85, z=0.78, p=0.43, n.s.), this probably reflects nothing more than a lack of statistical power, as their performance on the linking trials demonstrates that these adults clearly learned the semantics of the two constructions. We also included two “fill in the blank” questions: “How did the language work?” and “Did you use a strategy (if so, what)?”. In their answers, all eight adults mentioned either stopping/preventing versus helping/enabling or some clearly related alternative formulation that mapped on to the manipulation (e.g., action complete/incomplete; action positive/negative). Thus while the constructions are, in principle, learnable, we cannot rule out the possibility that they are learnable only by means of an explicit strategy.

**4. Discussion**

The aim of the present study was to investigate Tomasello’s (2003) claim that learners can acquire abstract syntactic constructions on the basis of underlying relational similarity between sentences that share no surface similarity. Children aged 4-6 were taught two novel constructions, OSV and VOS, with the different instantiations of each exhibiting no surface similarity. For one construction (OSV for half of the children; VOS for the remainder), the SUBJECT prevented the OBJECT from performing the action denoted by the VERB (i.e., PREVENTER+ACTION and ACTION+PREVENTEE relations). For the other, the SUBJECT helped the OBJECT to perform the action denoted by the VERB (i.e., HELPER+ACTION and ACTION+HELPEE relations). Subsequent forced-choice tests found no evidence that children had learned either the global meaning of each construction (e.g., preventing/helping) or the particular linking patterns of each.

It is never easy to interpret (or publish) a null result because there is no straightforward way to choose between two competing possibilities: (a) the null result is real, meaning in this case that children cannot in fact learn syntactic constructions by performing structure mapping or (b) the null result is a consequence of some flaw in the design of the study, and the hypothesized effect – in this case children’s ability to learn syntax via structure mapping – is real (and would be detected by a better-designed study).

Let us take the least interesting possibility first. Although previous studies (and – to some extent – our adult manipulation check) demonstrate that something like the present paradigm is, in principle, capable of demonstrating construction learning, it may not be optimally suited to doing so. Perhaps, for example, the study was underpowered, in that we simply did not have enough participants to detect a relatively small effect. For example, Wonnacott et al’s (2015) study with 5-year-olds used 42 and 35 participants in Experiments 1 and 2 respectively, while ours used just 24 (and is potentially harder, in that children had to learn two constructions). Casenhiser and Goldberg’s (2005) study with 5-7 year olds tested 51 and 48 children in Experiments 1 and 2 respectively (and, again, is probably somewhat easier than ours). Although Boyd and Goldberg (2012) tested just 18 children in each of two age groups (5- and 7-year olds), they also failed to find an effect for the younger group (comparable in age to the participants of the present study). Perhaps, then, the present paradigm would also reveal evidence of learning if a larger sample were tested (we would be delighted to share our stimuli with any colleagues who would like to investigate this possibility).

It may also be the case that we did not include enough training trials (we used 36 per construction). This is somewhere in between the regimes of Wonnacott et al (2015) (48 trials) and Casenhiser and Goldberg (2005) and Boyd and Goldberg (2012) (16 trials in each case), though it is again important to remember that children in these studies were trained on only a single construction, and that the younger group in the latter study failed to learn it. However, it is also possible that there were too many trials. There is evidence from research on structure mapping in children’s category learning that more examples may have some negative effects on generalization (by overloading children), and that as few as six can be optimal for discovering abstract structural commonalities (Thibaut & Wit, 2015).

Another potential problem is that, like all construction-learning studies, the experimental scenario was too artificial to tap into children’s underlying abilities at analogical reasoning. Dunbar (2001: 313) discusses an analogical paradox, whereby “analogy is so easy in naturalistic settings, yet so difficult in the psychological laboratory”. Dunbar’s solution to the paradox is that the apparently irrelevant contextual cues that are stripped out in laboratory studies are actually crucial in allowing learners both to notice and encode structural regularities in the first place and to retrieve them in suitable situations. Perhaps, then, a more naturalistic version of our study, conducted in familiar surroundings with familiar, real-world protagonists, would be more likely to yield evidence of analogical structure mapping in syntax acquisition.

As discussed from the beginning, the final potential problem is that the types of relations to be learned in this study, higher-order relations, were more difficult than the first-order relations that are typical of basic argument structure constructions. It is worth noting that even adults, in a similar experimental context to the current one, sometimes do not spontaneously see second-order relational connections across events when the first-order relations are distinct (Goldwater, Bainbridge, & Murphy, 2016).[[4]](#footnote-4)

Indeed, there is some evidence from preferential-looking/pointing studies that at least one particular first-order relation, AGENT of an action, and its tendency to appear clause-initially in English, is acquired by 2;0, or even younger (Arunachalam & Waxman, 2010; Bavin & Growcott, 2000; Gertner, Fisher & Eisengart, 2006; Gertner & Fisher, 2012; Kidd, Bavin, & Rhodes, 2001; Naigles & Kako, 1993; Noble, Rowland, & Pine, 2011; Noble, Iqbal, Lieven & Theakston, in press; Pozzan, Gleitman & Trueswell, in press; Yuan & Fisher, 2009). Thus it may be that even young infants would show analogical structure mapping for a novel syntactic construction with simpler relations. On the other hand, there is some evidence that children of this age struggle to process sentences with inanimate agents. Chan, Lieven and Tomasello (2009) found that, when word-order and animacy cues were placed in conflict (e.g., The ball tams the chicken), Cantonese-, German-, and English-speaking children aged 2;6 did not show correct comprehension (though they did so by 3;6). This suggests that two-year-olds may have not yet acquired a true relational category – AGENT of an action – but rather a fuzzy, more probabilistic notion of the types of entities that tend to be mentioned first in the clause (human, animate, moves first, moves more etc.).

This brings us to the second of the possibilities set out above; that children do not in fact learn abstract constructions using relational structure mapping only in the manner suggested by Tomasello (2003). While it would, of course, be premature to accept such a conclusion without first running several more studies of this type, we suggest that this possibility is one that is worth taking seriously. Why? There are (at least) two kinds of alternative processes that can help children transition from lexically-based to fully abstract linguistic constructions. The first kind of alternative process is a more gradual form of structural alignment based learning rooted in the need for overlapping surface similarity for a prolonged period of time. This seems quite likely, given that unlike the nonlinguistic analogical reasoning studied by Gentner and colleagues, the type of analogical reasoning investigated in this study is hard Recall that all of the adults tested as part of the manipulation check reported the use of an explicit strategy. This chimes with our own intuitions: When we piloted the study on ourselves, we found that successfully learning the constructions required not only an explicit strategy, but considerable effort and concentration in order to apply it. Indeed, direct tests of children’s analogical reasoning ability, demonstrate that manipulations of cognitive load have large effects on their ability to solve analogies (e.g., Richland et al., 2006; Thibaut, French, Vezneva, 2010).

Further, there is direct evidence for this more graded form of analogical learning. The findings of Chan et al (2009) suggest that children may start out with non-relational categories that are formed largely on the basis of surface features (e.g., humanness and animacy for an early AGENT category). The surface similarities captured by this early category would then aid children’s acquisition of a truly relational AGENT (of an ACTION) category. There is strong evidence that children can more easily discover relational commonalities when the relational commonalities are correlated with superficial similarities, which then allows children to recognize when this common structure is present in more disparate exemplars (e.g. Loewenstein & Gentner, 2002).

Additional support for this more graded analogical learning (as discussed in Ambridge & Lieven, 2015) starts from the observation that children do not necessarily have to analogize between entirely dissimilar instances (e.g., very different types of AGENT-ACTION relations) in a single leap. Rather, the process of analogy could proceed via a series of baby steps. E.g., the KICKER-KICKEE relation is very similar to the HITTER-HITEE relation, which in turn is similar to the TOUCHER-TOUCHEE relation, the KISSER-KISSEE relation, and so on, right up to AGENT-ACTION relations that are very different to the KICKER-KICKEE relation with which we began. This is similar to the pattern of how 4 year-olds categorized arrays of objects in Kotovsky and Gentner (1996). The children could see the connection between a set of objects monotonically increasing in size from left to right with a set of objects monotonically increasing in luminance from left to right (showing evidence of understanding a general “monotonically increasing” relation) only after they had already made the connection between two sets of objects, each monotonically increasing along the same dimension (either size or luminance). There is some evidence of this progressive alignment in artificial construction learning (Goldberg, Casenhiser & White, 2007), and in children’s production of familiar constructions (Goldwater & Echols, in prep).

A third reason why a pure structure abstraction process is never truly engaged (also discussed in Ambridge & Lieven, 2015) is that children might not be learning purely abstract constructions, such as a single AGENT-ACTION-PATIENT (or SUBJECT-VERB-OBJECT) construction at all. Perhaps speakers have a family of distinct constructions that share similar word order and case marking, but need never analogize across them. For example, English speaking adults may have at least six different transitive constructions.

Contact (non-causative) [AGENT] [ACTION] [PATIENT] John hit Bill

Causative [CAUSER] [ACTION] [CHANGE] John broke the plate

Experiencer-Theme [EXPERIENCER] [EXPERIENCE] [THEME] John heard Bill

Theme-Experiencer [THEME] [EXPERIENCE] [EXPERIENCER] John scared Bill

“Weigh” Construction [THING] [MEASURE/COST/WEIGH] [AMOUNT] John weighed 100lbs

“Contain” Construction [CONTAINER] [CONTAIN] [CONTENTS] The tent sleeps four

Given that usage-based accounts such as that of Tomasello (2003) posit rampant redundancy (perhaps even the storage of every exemplar), there is certainly no a priori reason to reject the notion of multiple transitive constructions.

Aligned with these first three possible learning procedures, computational models of analogical learning simulate the processes of progressive alignment and the learning of related, but differentiated relational structures in a unified framework, similar to the variants of the transitive (Doumas, Hummel, & Sandhofer, 2008; Goldwater et al., 2011; Kuehne, Forbus, Gentner, & Quinn, 2000). Future studies using some of the modifications suggested above should explore these possibilities.

Last, we suggest that the second kind of alternative explanation for our results is the real possibility that children do not learn constructions via structural alignment, either purely abstractly or even with these more graded forms that may never produce pure abstraction. More specifically, this final proposal is highly consistent with Tomasello’s (2003) overall approach, as it emphasizes gradual generalization at a lexical level. Recall that Tomasello (2003) invoked structure mapping to solve the problem of how learners abstract across two instantiations of a construction that share no surface lexical material (e.g., I ate the cake; Sue kissed Bill). Indeed, when looking at just a single sentence pair, this problem does seem to require some very high-level, abstract solution, such as analogical structure mapping. But in fact (rather like the game Six Degrees of Kevin Bacon) structurally related sentences that are, on the surface, very different, can generally be linked by handful of sentences that differ by a single constituent:

I ate the cake

I like the cake

I like Bill

I kissed Bill

Sue kissed Bill

So if, as seems likely, children are abstracting across a large number of stored sentences, rather than just in a pairwise fashion, this abstraction could in principle proceed largely on the basis of surface lexical similarities. Similarly, children may be able to link slot-and-frame patterns on the basis that a single lexical item (here, kick) serves as a slot-filler in one pattern and (part of) the frame in another:

I’m [X]ing it [X= kick, hit, eat, push] + Kick [Y] [Y= the ball, the cat, the man]

🡪 I’m [X]ing [Y]

As we have already stressed, lower-level abstraction on the basis of surface similarities – both these lexical similarities and semantic similarities such as animacy, humanness etc. – need not necessarily replace structure mapping. It might. But equally, we have discussed evidence that lower-level similarities can facilitate more abstract analogical reasoning. Figuring out the relative contributions of lower and higher level abstraction mechanisms is an important goal for future research, and a question that is probably best tackled using computational modeling (see Chang, Dell and Bock, 2006; Twomey, Chang and Ambridge, 2014, for models that acquire something like abstract syntactic constructions on the basis of lexical-distributional overlap).

For now, the present study has provided no evidence for the claim that children acquire abstract syntactic constructions using analogical structure mapping (though – we hasten to add – only the most preliminary and indirect evidence against this claim). However, our endeavours will not have been wasted if we have succeeded in persuading researchers that this hypothesis is one that can – indeed, must – be investigated empirically, perhaps using some (improved) version of the paradigm that we have established here.

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   Keywords: syntax; construction learning; constructivist approach; structure mapping; analogy; relational structure [↑](#footnote-ref-1)
2. To be clear, we are not committing to any particular formal account of the transitive construction semantics. Given the vast variety of meanings that the transitive construction can express, there have been many proposals that have either tried to find a single highly abstract generalized meaning such as *[MORE PROMINENT EVENT PARTICIPANT] [EVENT] [LESS PROMINENT EVENT PARTICIPANT]*, propose a cluster of several distinct more concrete meanings, or even propose that the transitive is so abstract it has no meaning, unlike other more semantically constrained constructions such as the resultative (see Jackendoff, 2002, among others for thorough discussion). For now, we will simply assume that construction representations reflect the semantic and syntactic generalizations of their exemplar utterances [↑](#footnote-ref-2)
3. Constructivist accounts tend to make less of a sharp distinction between syntactic and semantic representations as traditional linguistics approaches do because the constructivist claim is that the same bundle of domain-general learning processes decipher both from the same input, and so at many points in development their representations are inter-twined. For the present paper, we will simply assume that constructions have some semantics, and some word order that expresses that semantics, but focus more on the learning mechanisms of the semantics than specific ways semantics and syntax are learned together, independently or sequentially, though see Ambridge & Lieven, 2015, for discussion. [↑](#footnote-ref-3)
4. The editor of this volume raised on more potential design flaw: “for some animations, the goal must be inferred, and for others this is not the case. Consider the wolf heading to the chair; one must infer the intention to sit. In other chases, the action is in motion (e.g., the cat singing) when it is halted”. While we agree that this certainly makes learning more difficult, it may actually be rather typical of real-world language scenarios, where not every event referred to linguistically is realized. [↑](#footnote-ref-4)