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Syntactic Representations Are Both Abstract and Semantically Constrained: Evidence From Children's and Adults' Comprehension and Production/Priming of the English Passive

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Abstract

All accounts of language acquisition agree that, by around age 4, children's knowledge of grammatical constructions is abstract, rather than tied solely to individual lexical items. The aim of the present research was to investigate, focusing on the passive, whether children's and adults' performance is additionally semantically constrained, varying according to the distance between the semantics of the verb and those of the construction. In a forced-choice pointing study (Experiment 1), both 4- to 6-year olds (N = 60) and adults (N = 60) showed support for the prediction of this *semantic construction prototype* account of an interaction such that the observed disadvantage for passives as compared to actives (i.e., fewer correct points/longer reaction time) was greater for *experiencer-theme* verbs than for *agent-patient* and *theme-experiencer* verbs (e.g., *Bob was seen/hit/frightened by Wendy*). Similarly, in a production/priming study (Experiment 2), both 4- to 6-year olds (N = 60) and adults (N = 60) produced fewer passives for *experiencer-theme* verbs than for *agent-patient/theme-experiencer* verbs. We conclude that these findings are difficult to explain under accounts based on the notion of A(rgument) movement or of a monostratal, semantics-free, level of syntax, and instead necessitate some form of semantic construction prototype account.

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1. Introduction

The passive occupies a special place in investigations of children's language acquisition, across languages as varied as Sesostho (Demuth, 1989) and Spanish (Pierce, 1992), Inuktitut (Allen & Crago, 1996), Indonesian (Aryawibawa & Ambridge, 2018), German (Abbot-Smith & Behrens, 2006), and Greek (Tsimpli, 2006). The reason for the passive's status as something of a test-bed for theories of acquisition research is that, due to its low frequency in many languages (but see Demuth, Moloi, & Machobane, 2010; Kline & Demuth, 2010) and noncanonical ordering of semantic roles, the passive is one of very few sentence-level constructions for which children (and even adults; Dabrowska & Street, 2006) make errors, in both comprehension and production (e.g., Fox & Grodzinsky, 1998; Gordon & Chafetz, 1990; Hirsch & Wexler, 2006; Maratsos, Fox, Becker, & Chalkey, 1985; Meints, 1999; Pinker, Lebeaux, & Frost, 1987; Sudhalter & Braine, 1985), a finding that holds across languages including Catalan, Cypriot Greek, Danish, Dutch, English, Estonian, Finnish, German, Hebrew, Lithuanian, and Polish (Armon-Lotem et al., 2016).

With regard to the English passive, an increasing number of studies have provided evidence that children's knowledge of the passive is fully abstract from as young as 3 to 4 years (Bencini & Valian, 2008; Brooks & Tomasello, 1999; Huttenlocher, Vasilyeva, & Shimpi, 2004; Messenger, Branigan, & McLean, 2011a, 2011b; Messenger, Branigan, McLean, & Sorace, 2012; Messenger & Fisher, 2018), counter to older findings (e.g., Maratsos et al., 1985; Meints, 1999; Savage, Lieven, Theakston, & Tomasello, 2003, 2006; Sudhalter & Braine, 1985). Exactly what is meant by "abstract" is not always made explicit, and it varies somewhat from theory to theory. Here we therefore adopt a working definition that is designed to cover most, if not all, theoretical bases: A child's knowledge of the passive construction (or any construction) is "abstract" if she can use and comprehend in that construction a verb that she has not heard used in that construction.

This *abstract* view contrasts with an older view (Maratsos et al., 1985; Pinker et al., 1987; Sudhalter & Braine, 1985) under which children's knowledge of the passive is semantically constrained by an affectedness constraint such that

> [B] (mapped onto the surface subject [of a passive]) is in a state or circumstance characterized by [A] (mapped onto the *by*-object or an understood argument) having acted upon it. (Pinker et al., 1987, p.249)

That is, this *early semantic constraint* account posits that children's earliest passives are restricted to verbs in which the passive subject undergoes some change of state or circumstances: *agent-patient* verbs (e.g., *hit, bite, kick, pull, push*) and psychological *theme-experiencer* verbs (e.g., *frighten, scare, annoy, surprise, upset*). Only later does their knowledge of the passive broaden out to encompass psychological *experiencer-theme* verbs (e.g., *see, hear, like, love, remember*) in which the passive subject is often barely affected at all. Only at this later point can their knowledge be said to be "abstract."

Traditionally, these accounts have been viewed as rivals: Either young children's passive representations are abstract or they are semantically constrained. The aim of the present series of studies, however, is to test a third possibility: that children's knowledge of the passive is both abstract and semantically constrained at the same time. Under this view, by 4–6 years (the age tested in the present study), children's knowledge of the passive is abstract in that they can, in principle, comprehend and produce passives with any verb. However, their knowledge of the passive is also semantically constrained such that comprehension/production is facilitated for verbs that are consistent with what Pinker et al. (1987) call the "semantic core" of the construction (i.e., with the affectedness constraint set out above). Indeed, these types of semantic effects have been previously observed in studies of the passive with adults who—under all accounts—certainly have abstract knowledge of the construction (e.g., Ambridge, Bidgood, Pine, Rowland, & Freudenthal, 2016; Aryawibawa & Ambridge, 2018; Ferreira, 1994).

We call this view the *semantic construction prototype* account because it assumes that adults' and children's performance with a given passive is inversely related to the distance between the semantics of the verb and the semantics of the construction as set out by Pinker et al. (1987). Importantly, in positing a construction prototype, the account assumes "abstract" knowledge according to the definition set out above, since unwitnessed verbs can be used in the construction, provided they meet some minimum threshold for semantic compatibility. However, it is important to be clear at the outset that the present studies do not allow us to differentiate between a view under which a semantic construction prototype is actually stored in memory (e.g., Abbot-Smith & Tomasello, 2006) and a view under which it is merely emergent across stored exemplars of the construction (e.g., Ambridge, 2019).

Two previous studies provide support for the *semantic construction prototype* account. In two elicited-production studies, Marchman, Bates, Burkardt, and Good (1991) found that children aged 3–11 and adults were more likely to produce passives with prototypical *agent-patient* transitive verbs (*lick, hit, bite, bump, peck, hop on, hug, kiss, butt, touch, walk on, push, pet, jump over*) than with intransitive (*hop, run, fly*), dative (*give to, show to, throw to*), and locative verbs (*crawl under, walk into, slide on*). Note, however, that—unlike studies that contrast *agent-patient, theme-experiencer,* and *experiencer-theme* verbs—the three verb types are not matched for the number of arguments that they usually take. Meints (1999) reports similar findings from elicited-production and act-out comprehension studies with children aged 2–4. These studies used a five-level prototypicality measure created by manipulating the animacy of the passive subject and "intentionality, result, duration, degree of activity of the action and direct physical contact during the action" (p.6), although the verbs used are not listed. In addition to a semantic prototypicality effect, Meints (1999) found that overall comprehension and production of passives increased with age. Nevertheless, the finding that, in both studies, the youngest children were able to both comprehend and produce passives suggests at least some level of abstract knowledge.

Although both of these studies constitute support for the *semantic construction prototype* account, this support is limited because neither directly contrasted performance with passives and actives (although of course participants could, and often did, produce actives during the elicited production studies). Two child and adult studies conducted by Messenger et al. (2012; see also Gordon & Chaftez, 1990; Hirsch & Wexler, 2006) that did directly compare passives and actives yielded findings that would seem to constitute evidence against the *semantic construction prototype* account and for an *abstract-only* account. These studies investigated passive comprehension and priming with actional *agent-patient* verbs (e.g., *hit*), psychological *theme-experiencer* verbs (e.g., *frighten*), and psychological *experiencer-theme* verbs (e.g., *see*). The *semantic construction prototype* account clearly predicts that—relative to the other two types—*experiencer-theme* passives will show a disadvantage in both comprehension and production/priming tasks. That is, in a forced-choice comprehension task, we would expect both children and adults to be less accurate at selecting the matching picture (over a foil with the roles reversed) for *Bob was seen by Wendy* (*experiencer-theme*) than for *Bob was frightened by Wendy* (*theme-experiencer*) or *Bob was hit by Wendy* (*agent-patient*). In a production/priming task, again across both children and adults, we would expect less-prototypical *experiencer-theme* passives to yield lower rates of passive priming than more-prototypical *theme-experiencer* or *agent-patient* passives.

Yet no such differences were observed by Messenger et al. (2012): In the production/priming task, neither children nor adults produced significantly more passive sentences following *agent-patient* or *theme-experiencer* than *experiencer-theme* passive primes. In the forced-choice comprehension task, although participants did display higher error rates for *experiencer-theme* than *agent-patient/theme-experiencer* PASSIVES, they also showed higher error rates for *experiencer-theme* than *agent-patient/theme-experiencer* ACTIVES. No significant interaction of verb-type (*agent-patent/theme-experiencer/experiencer-theme*) by sentence-type (active/passive) was observed, suggesting that participants struggled not with *experiencer-theme* PASSIVES (per se), but with *experiencer-theme* VERBS. Messenger et al. (2012) suggest that this difficulty with *experiencer-theme* verbs, at least as compared with *agent-patient* verbs, may be at least partly attributable to the picture-selection task itself: *Experiencer-theme* verbs such as *see* (e.g., *Bob was seen by Wendy*) are more difficult to illustrate in still pictures (c.f. *Bob was hit by Wendy*), particularly in a way that clearly distinguishes the participant roles (recall that participants had to choose from two otherwise-identical pictures with the roles reversed).

Of course, null results are never easy to interpret, and we cannot rule out the possibility that Messenger et al.'s (2012) study was simply underpowered to detect an underlying disadvantage for *experiencer-theme* passives. Indeed, Messenger et al. (2012) are careful to note, with regard to their comprehension task, that "we cannot of course conclude on the basis of this experiment that children are able to interpret experiencer-theme verb passives as well as agent-patient verb passives" (pp. 584–585). Nevertheless, if these null results are taken at face value, the findings of Messenger et al. (2012) would appear to cast doubt on the idea that children (and adults) who possess abstract knowledge of the passive additionally show a semantic constraint on this construction.

The aim of the present research was to test this possibility by modifying the methods used by Messenger et al. (2012) in ways that, in our view, increase the probability of observing any underlying disadvantage for *experiencer-theme* versus *theme-experiencer/agent-patient* passives (controlling, of course, for any such differences observed for actives).

For the forced-choice comprehension task, we replace still pictures with animations in an attempt to reduce, at least to some extent, the particular difficulty inherent in illustrating *experiencer-theme* (and *theme-experiencer*) verbs, and introduce—for adults only—a more sensitive reaction-time measure. The *semantic construction prototype* account predicts an interaction of sentence type (active/passive) by verb type (*agent-patient/theme-experiencer/experiencer-theme*) such that the anticipated disadvantage for passives as compared to actives (i.e., fewer correct points for children; longer reaction time for adults) will be greater for *experiencer-theme* verbs than for *agent-patient/theme-experiencer* verbs, for both children and adults. Of course, adults are likely to outperform children, if only for task-related reasons such as better memory and concentration. Thus, the semantic construction prototype account does not predict that children and adults will show identical performance, simply that both groups will show this crucial interaction.

Incidentally, the semantic construction prototype account makes no clear prediction regarding the comparison between *agent-patient* and *theme-experiencer* verbs, as the relative compatibility of these two verb types with the prototype depends on exactly how the prototype is formulated. In normal circumstances, we would probably say that Bob is more affected if he is "hit by Wendy" [*agent-patient*] than "frightened by Wendy" [*theme-experiencer*]. On the other hand, affectedness is central to the meaning of *theme-experiencer* verbs in a way that it is not for *agent-patient* verbs. For example, it is possible to say "Bob was hit by Wendy, but he didn't notice, "but not" Bob was frightened by Wendy, but he didn't notice." If Bob was not affected, he was not frightened. In any case, the prediction that the anticipated passive-vs-active disadvantage will be greater for *experiencer-theme* verbs than the other two verb types is clear, since it is perfectly possible for Bob to be seen, heard, liked, loved, remembered (etc.) by Wendy, without him even being aware of it, much less affected. The *abstract-only* account predicts no such interaction (i.e., that the passive-vs.-active disadvantage will be equal for all three verb types). Note that our use of a Bayesian analysis strategy avoids the problem of inferring the absence of an effect from a frequentist null finding (e.g., Dienes, 2014).

For the production/priming task, we vary the verb-type (*agent-patent/theme-experiencer/experiencer-theme*) not of the PRIME verb (as in Messenger et al., 2012), but of the TARGET verb. A clear prediction of the semantic construction prototype account is that participants will produce more passives with *agent-patient* (e.g., *hit*) and *theme-experiencer* target verbs (e.g., *frighten*) than with *experiencer-theme* target verbs (e.g., *see*), simply because verbs of the latter type are less compatible with the putative semantic construction prototype set out above (Pinker et al., 1987). Note that testing this prediction involves treating the priming element of the task as simply a way of increasing participants' overall levels of passive productions, which would otherwise almost certainly be very close to zero.[1] Under this approach (which was our original one when designing the experiment), it is not appropriate to include prime sentence type (active/passive) or its interaction with target verb type (*agent-patient/theme-experiencer/experiencer-theme*) in the analysis since, on this view, the semantic construction prototype account make no predictions regarding priming.

That said, a second possible prediction of the semantic construction prototype account is an interaction of prime sentence type (active/passive) by target verb type (*agent-patient/theme-experiencer/experiencer-theme*) such that the anticipated priming effect (i.e., more passives produced following passive than active primes) is smaller for *experiencer-theme* verbs than for *agent-patient/theme-experiencer* verbs (again, this prediction applies to both children and adults, though the groups may show different performance for task-related reasons). In our view, this prediction is less clear cut because there is little agreement in the literature about exactly what drives syntactic priming effects, and hence how such an effect would be predicted to vary according to verb type. As an anonymous reviewer noted, "If unprimed baseline passive rates are 10%, 20%, and 30% across conditions. . .how should the prime affect that? Is it linear? Multiplicative? Because of the baseline differences, it might matter a lot how this is specified." Although, in our view, this second prediction is less clear cut, we nevertheless test both, in what we label the "Production" and "Priming" analyses, respectively. This second analysis also allows us to test for a simple priming effect (i.e., more passives following passive than active primes) which would confirm that both children and adults have abstract knowledge of the passive construction at some level.

2. Experiment 1: Forced-choice comprehension

2.1. Methods

2.1.1. Participants

The participants were 60 children aged 4–6 years old (4;5–6;10, M = 5;6) and 60 adults aged 18–25. The former age group was chosen to be slightly older than the children tested in Messenger et al. (2012) to ensure that all children could be assumed, on the basis of the previous studies outlined above, to have acquired fully abstract knowledge of the passive construction. The children were recruited from primary schools and nurseries in the North West of England and the adults were all undergraduate students at the University of Liverpool. All participants were monolingual speakers of English and had no known language impairments. Participants were mainly from middle-class backgrounds, although no SES information was collected; neither was gender recorded. No a priori power analysis was conducted (no power-analysis methods for mixed-effects models were available at the time of data collection), but this problem is partially addressed by the use of Bayesian analysis methods. We do not mean to imply that Bayesian methods obviate the need for power analysis, simply that they can, in principle, provide positive evidence for the absence of an effect (here, a credible interval narrowly centered on zero) in a way that the failure to reject a frequentist null hypothesis does not, unless the sample size is based on an a priori power analysis specifying a minimum effect size of interest.

2.1.2. Test items

All sentences followed the form *Bob was VERBed by Wendy, Wendy was VERBed by Bob*, *Homer was VERBed by Marge* or *Marge was VERBed by Homer*, and active equivalents (*Wendy VERBed Bob*, etc.). These characters were chosen to be cartoon characters familiar, as far as possible, to both adults and children, although participants also completed a short pre-training in which they were introduced to the characters in question. Accompanying animations were created, using *Anime Studio Pro 5.5*, to depict the event. For example, the sentence *Bob was hit by Wendy* was accompanied by one animation of Wendy hitting Bob (the target) and another of Bob hitting Wendy (the distractor). The same animation was used for both the passive and active versions of each sentence.

The verbs used were 12 agent-patient (*agent-patient*) verbs (e.g., *hug*), 12 theme-experiencer (*theme-experiencer*) verbs (e.g., *frighten*), and 12 experiencer-theme (*experiencer-theme*) verbs (e.g., *see*); all 18 verbs used by Messenger et al. (2012) were included in our set. Verbs were divided into two lists of 18 verbs, each containing 6 verbs of each type, 3 of which were also used by Messenger et al. Details of the verbs used in each list are provided in Appendix A. Participants each heard sentences from one of the verb lists, divided across 2 days. They heard the active sentence on one day and the passive on the other for each verb. Half of the sentences on each day were active and half passive. Two versions of each list were created so that half of the participants heard each verb in a passive sentence on the first day and half heard it in an active sentence on the first day. Whether the correct animation appeared on the left or right of the screen was random. For half of the verbs (randomly selected), the correct animation on the second day remained on the same side of the screen; for the other half, the correct animation was on the opposite side. Trial orders were pseudo-randomized such that no more than three verbs of each type or three sentences of each type appeared in consecutive trials. Two random orders were created for each sub-list. Half of the verbs had the same subject in their sentences on both test days, with the subject and object being switched in the sentences for the other half of the verbs on the second day. The set of verbs to which this switching was applied was different for each of the random playlists created. These counterbalancing and randomization procedures resulted in the creation of eight different stimulus orders.

2.1.3. Procedure

Animations were presented on a computer screen, using *Processing 3* (www.processing.org). Participants were shown one animation, slightly above the middle on the left-hand side of the screen, accompanied by the phrase *Look what's happening here*. A second animation then played in the middle of the right-hand side of the screen depicting the same event but with participants reversed. This was accompanied by the phrase *Oh look, now it's the other way around.* To make the animations maximally distinct from each other, all animations appearing on the left of the screen depicted the active subject starting on the right of the frame, while those on the right of the screen depicted the active subject starting on the left side of the frame. To further minimize the visual confusability of the two animations, the animations on the left of the screen had beige backgrounds and those on the right had white backgrounds. This was also the reason for displaying the animations at different heights. Target side, and therefore both the height and background color of the target animation, was fully counterbalanced.

After watching both animations separately, participants were shown both together and heard an active or passive sentence immediately following the end of the animation. Adult participants indicated the matching animation (freeze-framed on an informative frame) by pressing a key on the keyboard as quickly as possible to give their response. Children pointed to the matching animation and the experimenter then pressed the corresponding key on their behalf. For adults, we collected reaction-time data on the assumption that a correct-choice measure would be subject to a ceiling effect; indeed, this group displayed an overall accuracy level of 96.3% (see Fig. 1 final panel for a breakdown). For children, we did not collect reaction-time data, on the assumption that these data would be too noisy to be reliable.

2.2. Results

We adopted a fully Bayesian approach to statistical analysis, using brms version 2.10.5 (Bürkner, 2018) and R version 3.6.2 (R Core Team, 2019) to build mixed-effects models. We were therefore able to include all random intercepts and slopes that are justified given the design (e.g., Barr, Levy, Scheepers, & Tily, 2013) without convergence failure. Although the decision to use a Bayesian approach was primarily motivated by the convergence failure of equivalent frequentist models, this approach is also beneficial in that it allows us to calculate *pMCMC* values ("Bayesian *p* values") and credible intervals (cf. frequentist confidence intervals) that have more intuitive interpretations than their frequentist counterparts. The *pMCMC* value for a particular fixed effect is simply the proportion of samples that have values of zero or lower (or, for negative effects, zero or higher). In the tables below, we subtract the *pMCMC* value from 1 (column headed "B < > 0") so that the value shown represents the direction-corrected probability that the true mean value for the effect in question is greater than zero. Similarly, the probability that the true value of the mean lies within the 95% credible intervals shown is 0.95, an intuitive interpretation that does not hold for frequentist confidence intervals.

Since we did not have meaningful, well-motivated priors for any of the effects under investigation, we did not conduct Bayesian hypothesis testing (e.g., using Bayes Factors) but instead adopted the approach of "estimation with quantified uncertainty," what Kruschke and Liddell (2018) call "The Bayesian New Statistics." That is, we used a very wide, uninformative prior ($M = 0$, $SD = 10$, with all predictors converted into Z scores)

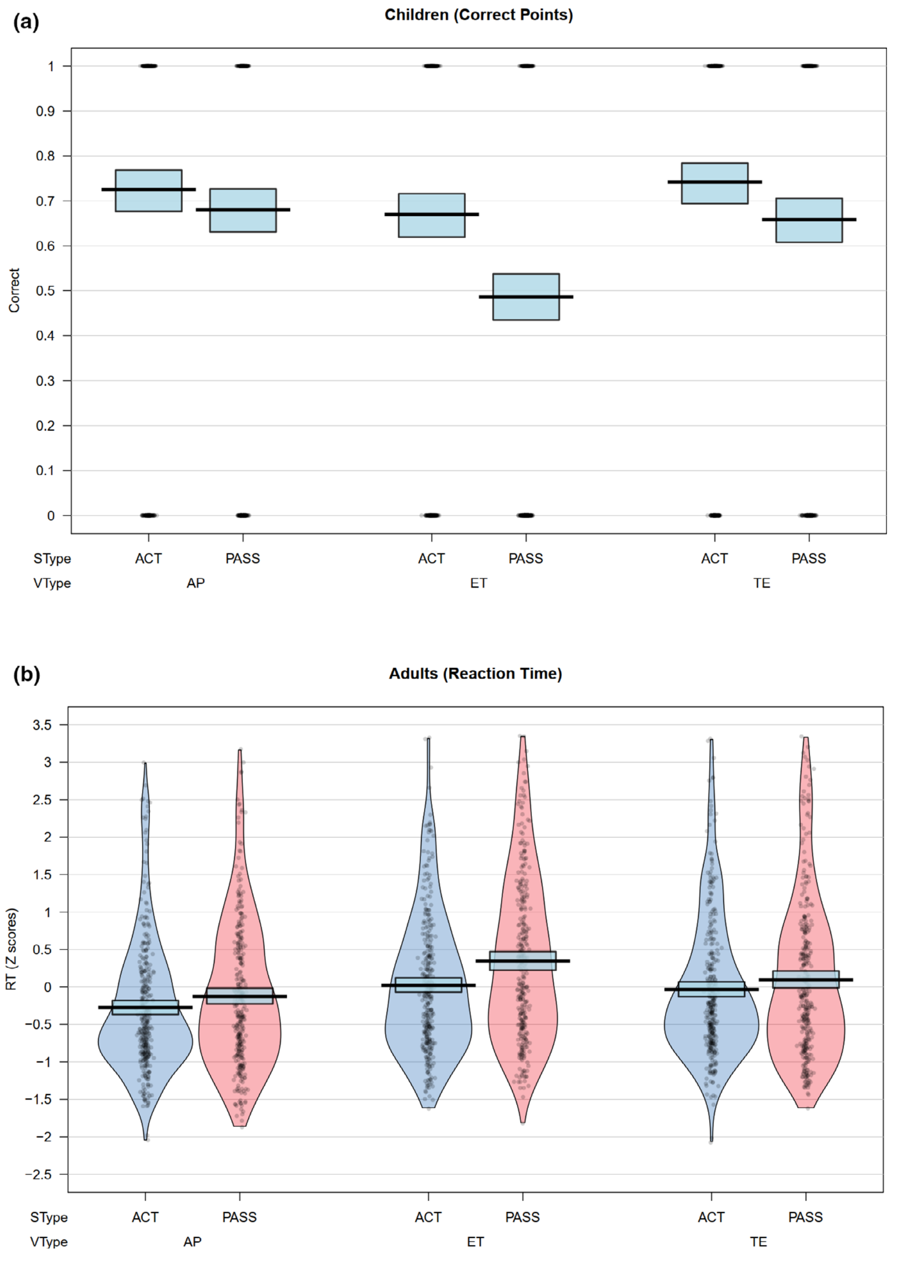

Fig. 1. (a) Proportion of correct points (children) for actives and passives containing *agent-patient* (e.g., *hit*), *experiencer-theme* (e.g., *see*), and *theme-experiencer* (e.g., *frighten*) verbs, and 95% highest density intervals (HDIs). (b) Reaction time (in SD units) for correct points (adults) for actives and passives containing *agent-patient* (e.g., *hit*), *experiencer-theme* (e.g., *see*), and *theme-experiencer* (e.g., *frighten*) verbs, and 95% highest density intervals (HDIs). (c). Proportion of correct results for adults for actives and passives containing *agent-patient* (e.g., *hit*), *experiencer-theme* (e.g., *see*), and *theme-experiencer* (e.g., *frighten*) verbs, and 95% highest density intervals (HDIs) (not further analyzed).

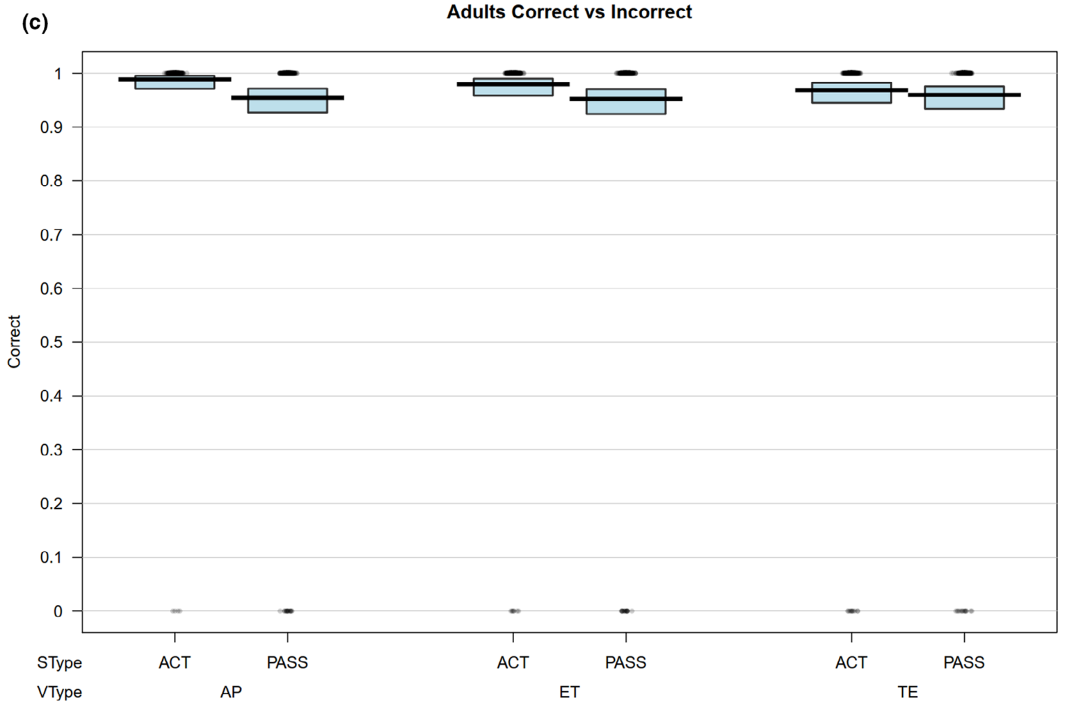

Fig. 1. Continued

for all analyses, and we used *pMCMC* values and credible intervals to estimate the probability that each fixed effect is greater than zero. Readers used to thinking in frequentist terms can—if they choose to do so—interpret any effect with a probability of >0.95 as "statistically significant." But one of the great advantages of a Bayesian approach is that it avoids such arbitrary dichotomies: If the data suggest that the probability of an effect greater than zero is 0.94, we can simply say so, and leave it for readers to decide how seriously to take it.

For all forced-choice comprehension (Experiment 1) models, predictor variables were Sentence Type (active/passive), Verb Type (*agent-patient*/*theme-experiencer*/*experiencer-theme*), and the interaction term. Because the main prediction under investigation relates to an interaction, and interactions are difficult to interpret with treatment coding (Singmann & Kellen, 2019), we used sum coding (a form of effect coding) for both predictor variables: Sentence Type (active = 1, passive = −1), Verb Type (a*gent-patient* = 1, *theme-experiencer* = 0, *experiencer-theme* = −1). As in Messenger et al. (2012), the dependent variable for the children in our study was correct (1) versus incorrect (0) responses, necessitating the use of binomial models (Bernoulli distribution). Children's age (in months) was included as a control predictor but, because it does not relate to the theoretical predictions under investigation, not as part of any interaction terms. Thus, the main model for the child analysis (in brms syntax) was as follows:

brm(formula = Correct ~ SentenceType*VerbType + AgeMonths + (1 + SentenceType*VerbType|Participant) + (1 + SentenceType + AgeMonths|Verb), data = DataChildren, family = bernoulli(), set_prior("normal(0,10)," class = "b"), warmup = 5000, iter = 20000, chains = 4, cores = 4,save_all_pars = F, control = list(adapt_delta = 0.99)).

Following Ambridge et al. (2016), the dependent variable for the adults in our study was reaction time (ms). In principle, we would have liked to use the same dependent measure for adults and children, to allow for direct investigation of developmental changes; but reaction-time measures are too noisy to be used reliably with children, and a binary correct/incorrect measure is too insensitive for adults who show near-ceiling performance. Note that only correct responses were included in this analysis, although the adults were performing very close to ceiling (96.3% accuracy). Following recommendations outlined in Ratcliff (1993), trials with reaction times greater than 1.5 *SD*s above the grand mean of the whole experiment were removed, as were those with reaction times below zero: Reaction times were recorded from the onset of the verb, as this is the point at which the correct picture choice starts to become possible. The experiment was not coded in such a way as to automatically prevent or discard button presses before zero, hence the need for subsequent exclusion of any such trials. Following recent recommendations (e.g., Lo & Andrews, 2015), we did not apply a nonlinear transformation to the reaction-time data, as this not only yields a smaller increase in power than a cutoff (Ratcliff, 1993), but can also yield misleading findings (e.g., Balota, Aschenbrenner, & Yap, 2013). A *z*-score transformation, which does not affect the parameter estimates, was applied simply for ease of interpretation of the coefficients and to allow for potential comparison across studies. As the dependent variable for this analysis was continuous, adult models were based on the Gaussian (rather than Bernoulli) distribution. Visual inspection of Fig. 1 shows that the distribution was indeed broadly Gaussian, although a relatively small number of datapoints fell into a long tail of long reaction times. Age was not recorded for adults. Thus, the main model for the adult analysis (in brms syntax) was as follows:

brm(formula = RTz ~ SentenceType*VerbType + (1 + SentenceType*VerbType|Participant) + (1 + SentenceType|Verb), data = DataAdCor, family = gaussian(), set_prior ("normal(0,10)," class = "b"), warmup = 2000, iter = 5000, chains = 4, cores = 4, save_all_pars = F, control = list(adapt_delta = 0.99)).

Fig. 1 shows (1a) the mean proportion of child points to the matching picture, (1b) the mean adult reaction time to select the matching picture (in SD units), and (1c) the mean proportion of adult points to the matching picture, in each case broken down by Sentence Type (active/passive) and Verb Type (*agent-patient/experiencer-theme/theme-experiencer*). Jittered black dots represent the raw datapoints (with considerable over-plotting in 1a and 1c, since all responses are either 1 or 0), black bars the means, and boxes 95% Bayesian credible intervals (specifically Highest Density Intervals, HDIs). The means—for the continuous reaction-time data only—are a smoothed density curve showing the distribution of the data. For adults, the overall mean reaction time to select the correct animation, after all exclusions, was 1,990 ms (*SD* = 943 ms). Note that the data shown in Fig. 1c are not analyzed further and are included solely to illustrate that the adult responses discarded as incorrect—mainly on passive trials—patterned almost identically across Verb Type.

Visual inspection of Fig. 1a,b suggests support for the prediction of the *semantic construction prototype* account of an interaction of Sentence Type (active/passive) by Verb Type (*agent-patient/theme-experiencer/experiencer-theme*) such that, for both age groups, the disadvantage for passives as compared to actives (i.e., fewer correct points for children; longer reaction time for adults) is greater for *experiencer-theme* verbs than for *agent-patient* and *theme-experiencer* verbs. Indeed, the statistical models for children (Table 1) and adults (Table 2) confirm that the (direction-corrected) probability of the crucial interaction being greater than zero (B < > 0) is 0.97 and 0.99 for children and adults, respectively. For children, the analysis revealed only a weak suggestion of an effect of age (B < > 0 = 0.91) such that the number of passives produced increased with age (age was not recorded for adults).

Caution is required when interpreting main effects in the presence of an interaction (Singmann & Kellen, 2019) and, in any case, the theoretical prediction under investigation relates to the interaction only. However, to the extent that they are interpretable, for both children and adults, both main effects were observed with a probability of 0.99 or greater. That is, both groups showed better performance for actives than passives (collapsing across verb type) and worse performance for *experiencer-theme* than *agent-patient* and *theme-experiencer* verbs (collapsing across sentence type).

The models shown in Tables 1 and 2 constitute evidence that the interaction in question is present in some form, but do not test the specific prediction of the *semantic construction prototype* account of an interaction such that the disadvantage for passives as

Table 1
Mixed-effects models for children's pointing data

Covariate	Estimate	Est.Error	l–95% CI	u-95% CI	B < > 0
Intercept	−0.53	1.08	−2.64	1.61	0.69
SentenceType	−0.35	0.08	−0.52	−0.19	1.00
VerbType	0.34	0.14	0.06	0.63	0.99
AgeMonths	0.02	0.02	−0.01	0.05	0.91
SentenceType:VerbType	0.15	0.08	−0.01	0.31	0.97

Table 2
Mixed-effects models for adults' reaction-time data

Covariate	Estimate	Est.Error	l–95% CI	u-95% CI	B < > 0
Intercept	0.03	0.08	−0.14	0.19	0.62
SentenceType	0.11	0.02	0.06	0.16	1.00
VerbType	−0.21	0.04	−0.28	−0.14	1.00
SentenceType:VerbType	−0.06	0.02	−0.10	−0.01	0.99

compared to actives is greater for *experiencer-theme* verbs than for *agent-patient* and *theme-experiencer* verbs (i.e., it could hypothetically reflect a difference between *agent-patient* and *theme-experiencer* verbs only). To directly test this prediction, we recoded Verb Type in such a way as to directly contrast *experiencer-theme* verbs (set to -1) with *agent-patient* and *theme-experiencer* verbs (both set to 1) and reran the models. These models (see Data S1, Tables S1 and S2) confirm that the (direction-corrected) probability of the crucial interaction being greater than zero (B < > 0) is 0.96 and 1.0 for children and adults, respectively.

Finally, we investigated whether the findings observed for adults depended crucially on using 1.5 *SD*s as a reaction-time cutoff. Repeating the two adult analyses outlined above with a cutoff of 2.0 *SD*s (Data S1, Tables S3 and S4) reduced the probabilities of the observed effects to 0.88 (main analysis) and 0.87 (recoded analysis). Thus, while the child comprehension findings are clear, the adult findings must be considered tentative pending replication using a pre-registered design specifying detailed trial-level inclusion/exclusion criteria.

2.3. Discussion

In general, the patterns displayed by children and adults were similar, despite the use of different dependent measures, respectively, the binary measure of correct/incorrect picture choice and the continuous measure of RT to select the correct picture. Children and, to a lesser extent, adults showed support for the prediction of the *semantic construction prototype* account of an interaction of Sentence Type (active/passive) by Verb Type (*agent-patient/theme-experiencer/experiencer-theme*) such that the disadvantage for passives as compared to actives (i.e., fewer correct points/longer reaction times) is greater for *experiencer-theme* verbs than for *agent-patient* and *theme-experiencer* verbs. Of course, these findings do not constitute evidence against the view that 4- to 6-year-old children's knowledge of the passive is "abstract," in the sense that they can generalize unwitnessed verbs into this construction (whether in comprehension or production). After all, adults—whose knowledge is certainly abstract in this sense—showed a similar pattern of results to children. However, these results are difficult to reconcile with the view that adults' and children's knowledge of the passive is ONLY abstract, in the sense that it does not additionally include a semantic affectedness constraint. That is, these results are difficult to reconcile with the view that "syntactic representations do not contain semantic information" (Branigan & Pickering, 2017, p. 8), a point to which we return in Section 4.

That said, it is important to consider an alternative possible explanation for our findings: that the observed pattern of results can be explained away as an advantage for adjectival passives (e.g., Meints, 1999). It is true that this could explain the observed advantage for *theme-experiencer* verbs, all of which exist in identical passive participle and adjective form (e.g., *Wendy was very frightened, scared, annoyed, surprised, upset*) over *experiencer-theme* verbs, many of which do not (e.g., *Wendy was very ?seen, ?heard, liked, loved, ?remembered*). However, it cannot explain why *agent-patient* verbs, which generally do not exist in identical passive participle and adjective form (e.g., *Wendy was very ?hit, ?bitten, ?kicked, ?pulled, ?pushed)*, also show an advantage over *experiencer-theme* verbs. Thus, while coexistence as an adjectival form may well play some role in passivisability, it cannot explain the full pattern of results observed here (or in Experiment 2).

Before moving on, it is instructive to compare the results of the present study with those of Messenger et al. (2012), particularly the child studies which are more or less directly comparable (save for the use, here, of animations as opposed to still pictures). Unfortunately, Messenger et al. (2012) do not report any parameter estimates for the non-significant interaction of Verb Type by Sentence Type, reporting only that "none of the interactions reached significance ... $p > .1$" (p. 581). Nevertheless, the data pattern very similarly to the present study in that the difference between the number of correct points to actives versus passives was numerically larger for *experiencer-theme* verbs (32 more points) than for either *agent-patient* verbs (9) or *theme-experiencer* verbs (12). Thus, the most likely explanation for the very different conclusions drawn in Messenger et al.'s (2012) comprehension study and the present study was simply the larger sample size in the latter (60 participants at each age, as opposed to 24).

3. Experiment 2: Production/priming

Although Experiment 1 revealed that performance with *experiencer-theme* verbs was especially impaired for passives, as compared to actives—indicated by the significant interaction of verb-type by sentence-type—we cannot entirely rule out the possibility that these results were affected in some way by a general task-related difficulty with such verbs. Indeed, as Fig. 1 shows, at least numerically, *experiencer-theme* verbs were associated with lower levels of correct performance and longer reaction times even for active sentences. It therefore seemed important to corroborate this pattern of findings using a second method: production/priming. A particular advantage of this method is that it allows us to confirm, via the presence of a priming effect, that the present participants are in possession of an abstract construction, and hence that any effect of semantics exists in addition to—rather than as an alternative to—abstract knowledge. The assumption here (e.g., Branigan, 2007; Branigan & Pickering, 2017; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Pickering & Ferreira, 2008) is that syntactic priming effects reflect the activation of some form of abstract representation of the passive construction; and hence, that the existence of such an effect for passives demonstrates abstract knowledge of this construction among both children (e.g., Bencini & Valian, 2008; Huttenlocher et al., 2004; Messenger, Branigan, & McLean, 2011a, 2011b; Messenger et al., 2012; Savage, Lieven, Theakston, & Tomasello, 2003, 2006) and adults (e.g., Bock, 1986; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992).

Recall, however, that the most straightforward prediction of the semantic construction prototype account treats the priming manipulation solely as a way of eliciting a reasonable number of passive sentences from participants, holding simply that participants will produce more passives with *agent-patient* (e.g., *hit*) and *theme-experiencer* target verbs (e.g., *frighten*) than with *experiencer-theme* target verbs (e.g., *see*), since verbs of the latter type are less compatible with the putative semantic construction prototype. We test this prediction in a "Production" analysis, that is, an analysis that treats the study simply as an elicited-production—rather than syntactic-priming—study.[2]

We follow this analysis with a "Priming" analysis which—in addition to testing for a simple priming effect, and hence for abstract knowledge of the construction—tests a second possible prediction of the semantic construction prototype account: an interaction of prime sentence type (active/passive) by target verb type (*agent-patient/theme-experiencer/experiencer-theme*) such that the anticipated priming effect (i.e., more passives produced following passive than active primes) is smaller for *experiencer-theme* verbs than for *agent-patient/theme-experiencer* verbs.

3.1. Methods

3.1.1. Participants

The participants were 60 children aged 4–6 years old (4;2–6;5, M = 5;6) and 60 adults aged 19–24, none of whom had taken part in Experiment 1. The children were recruited from primary schools and nurseries in the North West of England and the adults were all undergraduate students at the University of Liverpool. All participants were monolingual speakers of English and had no known language impairments. Participants were mainly from middle-class backgrounds, although no SES information was collected; neither was gender recorded. As for Experiment 1, no a priori power analysis was conducted; hence, the findings must be considered preliminary, pending an appropriately powered replication.

3.1.2. Test items

All prime and target verbs are given in Appendix B. In all, 16 different playlists were created, each of 36 trials. Target verbs were the same verbs used in Experiment 1. Prime sentences used 18 different *agent-patient* verbs, each of which appeared in both an active and a passive sentence, on separate trials (note that 24 *agent-patient* verbs were used as primes altogether, but only 18 per participant, with the remaining six *agent-patient* verbs used as targets for that playlist). A further six *agent-patient* verbs were used as target verbs, along with six each of the *theme-experiencer* and *experiencer-theme* verbs. Participants in each action were the same TV characters as used in the materials for Experiment 1. Playlists were pseudo-randomized such that no more than two sentences of the same type (active/passive) or two verbs of the same type (*agent-patient/theme-experiencer/experiencer-theme*) appeared in a row. Active and passive sentences containing the same verb were never used in consecutive trials. The prime sentence always contained different characters to the target sentence, to minimize lexical overlap.

For each prime and target verb, animations were created, using *Anime Studio Pro 5.5*, to depict the action. The same animation was used for both the active and passive versions of prime and target sentences.

3.1.3. Procedure

Experimenter 1 took turns with the participant to describe animations presented on a computer screen, using *Processing 3* (www.processing.org). A second experimenter, who was unable to see the screen, gave "clue words" (the prime/target verbs in non-finite form, e.g., *bite*) to Experimenter 1 and the participant. Experimenter 2 noted participants' responses, although sessions were also audio-recorded, using *Audacity*, as a backup. Following Rowland, Chang, Ambridge, Pine, and Lieven (2012), we used a "bingo game" to motivate the participants to produce responses. For each sentence produced by Experimenter 1 or the participant, Experimenter 2 looked for a bingo card that matched the sentence. In fact, Experimenter 2 had all of the bingo cards, but the game was fixed so that the participant always won the game. As the playlists were relatively long, they were divided into four "games" of nine trials, with participants requiring six bingo cards to win. Before starting, the game was introduced to participants with three practice trials, using verbs that were not included in the experiment proper, in active locative sentences (e.g., *Homer poured water into the cup*).

3.2. Results

Participants' responses were coded for sentence type, irrespective of prime condition: correct active, correct (full) passive, incorrect active (with participants reversed), incorrect (full) passive (with participants reversed), other use of the verb, and excluded (target verb not used/no response). A response was coded as a correct active if it was an accurate description of the event, and contained both a subject and direct object with the appropriate role (agent/patient/theme/experiencer) and the target verb. A response was coded as a correct passive if it was an accurate description of the event, and contained both a subject and object with the appropriate role (agent/patient/theme/experiencer), an auxiliary verb (*get* or *be*), the target verb, and the preposition *by*. These criteria are similar to those used by Messenger et al. (2012), with the exceptions that (a) participants in the current study were required to use the target verb and (b) the range of semantic roles was more varied, as we used *agent-patient*, *experiencer-theme*, and *theme-experiencer* verbs as targets, whereas Messenger et al. used only *agent-patient* verbs as targets.

Table 3 shows the frequency of each response type, broken down by sentence type and target verb type, for adults and children. This breakdown shows that, for both adults and children, almost all attempted passives are well formed, and considerably fewer passives are attempted for *experiencer-theme* than *agent-patient* or *theme-experiencer* verbs. Numerically, "Other"- and "No-use-of-target verb" utterances are more frequent for *experiencer-theme* than *agent-patient* verbs, but most frequent of all for *theme-experiencer* verbs. Thus, we can be confident that any passive disadvantage observed for *experiencer-theme* verbs as compared to *agent-patient* and *theme-experiencer* verbs does not simply reflect different rates of nontarget or avoidance responses.

We followed the same general analysis strategy as for the binomial (child) comprehension data in Study 1. As in Messenger et al. (2012), the dependent variable was coded as correct active (0) or correct passive (1), with all other responses excluded. The exclusion

Table 3
Categorization of responses by age group

	Agent-Patient Verbs (e.g., *hit*)		Experiencer-Theme Verbs (e.g., *see*)		Theme-Experiencer Verbs (e.g., *frighten*)	
	Active Prime	Passive Prime	Active Prime	Passive Prime	Active Prime	Passive Prime
Adults						
Correct Active	275	225	316	276	256	196
Correct Passive	60	100	19	43	75	127
Incorrect Active	2	7	8	17	3	4
Incorrect Passive	0	1	1	1	5	6
Other use of target verb	20	25	9	12	3	11
No use of target verb	3	2	7	11	18	16
Total passive attempts	**60**	**101**	**20**	**44**	**80**	**133**
Children						
Correct Active	288	247	249	229	184	158
Correct Passive	11	34	3	11	19	55
Incorrect Active	0	9	15	23	3	3
Incorrect Passive	0	1	0	1	2	2
Other use of target verb	23	32	20	24	14	23
No use of target verb	38	37	73	72	138	119
Total passive attempts	**11**	**35**	**3**	**12**	**21**	**57**

of all other responses is particularly important in the present study (in some studies, they are retained and scored as incorrect) since it ensures that—for the Priming Analysis—the predicted interaction of Prime Sentence Type by Target Verb Type captures the difference between active and passive production for each verb type.

3.3. Production analysis

This analysis, which treats the study as a simple elicited-production study, included as predictor variables Target Verb Type (*agent-patient/theme-experiencer/experiencer-theme*), Age Group (Adult/Child), and the interaction term. Participant and Target Verb were included as random effects (i.e., as random intercepts and with all random slopes justified given the design):

Production = brm(formula = CorrectPassives ~ VerbType*AgeGroup + (1 + VerbType|Participant) + (1 + AgeGroup|TargetVerb), data = Data, family = gaussian(), set_prior("normal(0,10)," class = "b"), warmup = 5000, iter = 20000, chains = 4, cores = 4, save_all_pars = F, control = list(adapt_delta = 0.99))

This model is shown in Table 4, with the accompanying means, raw data, and 95% HDIs shown in Fig. 2. Visual inspection of the plots suggests support for the prediction of the *semantic construction prototype* account that both children (coded as −1) and adults (coded as 1) will produce significantly fewer passives for *experiencer-theme* verbs (e.g., *see*) than for *agent-patient (e.g., hit*) and *theme-experiencer* verbs (e.g., *frighten*). Indeed, despite the presence of an interaction with Age Group (*B* <> 0 = 0.98), Target Verb Type showed a *B* <> 0 value of 1.0 when collapsing across age group (see main model, Table 4), and also in separate models built for children (Table 5) and adults (Table 6), the former of which additionally included age (*B* <> 0 = 0.77). The same was true for recoded models directly comparing *experiencer-theme* verbs (coded as -1) to the other two verb types combined (coded as 1; see Data S1, Tables S5–S7).

In summary, when looking simply at production data, the present study unequivocally shows that both children and adults produce significantly fewer passives for *esxperiencer-*

Table 4
Mixed-effects models for production analysis (all participants)

Covariate	Estimate	Est.Error	l–95% CI	u-95% CI	B < > 0
Intercept	0.13	0.02	0.10	0.17	1.00
VerbType	0.07	0.01	0.04	0.10	1.00
AgeGroup	0.05	0.01	0.03	0.08	1.00
VerbType:AgeGroup	0.02	0.01	0.00	0.04	0.98

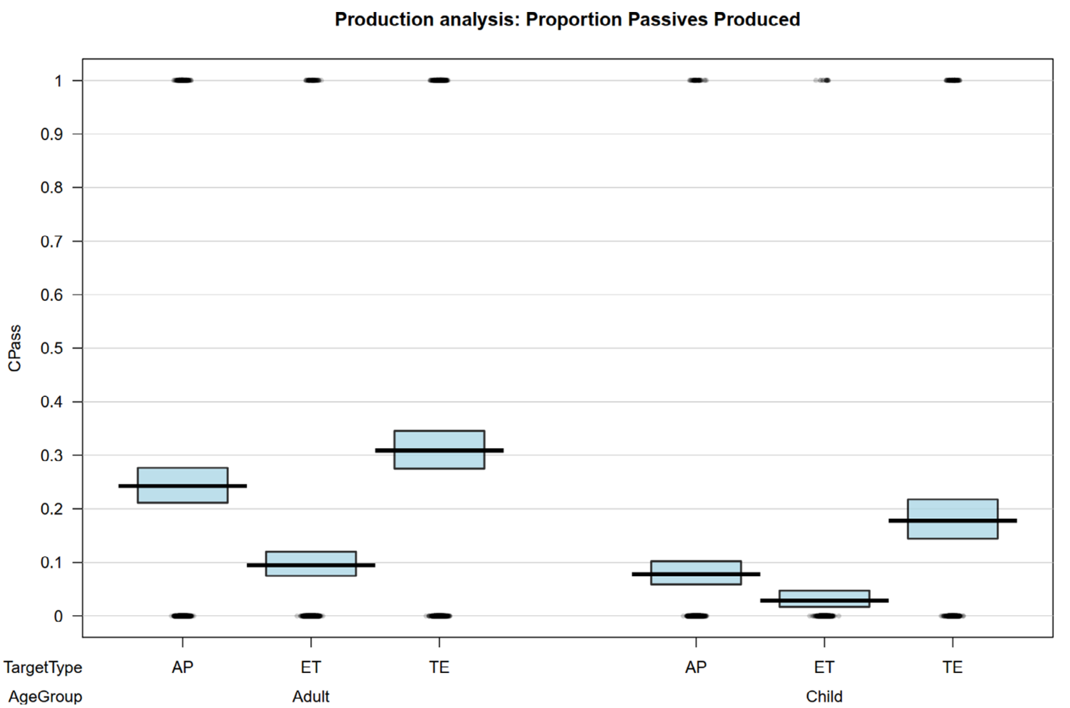

Fig. 2. Proportion of correct passives produced, by adults and children, with agent-patient (AP) verbs (e.g., hit), experiencer-theme (ET) verbs (e.g., see), and theme-experiencer (TE) verbs (e.g., frighten).

Table 5
Mixed-effects models for production analysis (children)

Covariate	Estimate	Est.Error	l–95% CI	u-95% CI	B < > 0
Intercept	0.18	0.13	−0.08	0.43	0.91
VerbType	0.05	0.02	0.01	0.10	1.00
Age	0.00	0.00	−0.01	0.00	0.77

Table 6
Mixed-effects models for production analysis (adults)

Covariate	Estimate	Est.Error	l–95% CI	u-95% CI	B < > 0
Intercept	0.19	0.02	0.15	0.23	1
VerbType	0.09	0.02	0.06	0.12	1

theme verbs (e.g., *see*) than for *agent-patient (e.g., hit*) and *theme-experiencer* verbs (e.g., *frighten*), as predicted by the semantic-construction-prototype account.

3.4. Priming analysis

This analysis, designed to investigate whether any observed priming effect varies by verb type (see Introduction) adds to the predictor variables for the previous analysis, Prime Sentence Type (active/passive) and its two- and three-way interactions with Target Verb Type and Age Group:

Priming = brm(formula = CPass ~ PrimeSentenceType*VerbType*AgeGroup + (1 + PrimeSentenceType*VerbType|Participant) + (1 + PrimeSentenceType*AgeGroup|TargetVerb), data = Data, family = gaussian(), set_prior("normal(0,10)," class = "b"), warmup = 5000, iter = 20000, chains = 4, cores = 4, save_all_pars = F, control = list(adapt_delta = 0.99))

Visual inspection of the relevant plots (see Fig. 3) suggests, for both adults and children, support for the prediction of the *semantic construction prototype* account of an interaction of Prime Sentence Type (active/passive) by Target Verb Type (*agent-patient/theme-experiencer/experiencer-theme*) such that the priming effect (i.e., more passives produced following passive than active primes) is smaller for *experiencer-theme* verbs than for *agent-patient/theme-experiencer* verbs.

However, the statistical models (see Table 7) revealed only suggestive support for this interaction ($B <> 0 = 0.90$); a pattern that held also for separate models built for children ($B <> 0 = 0.82$; see Table 8) and adults ($B <> 0 = 0.87$; see Table 9), and for recoded models that directly compare *experiencer-theme* verbs against the other two types (Data S1, Tables S8–S10).

The—on the face of it—convincing evidence for the main effects of Prime Sentence Type and Target Verb Type, respectively, should be interpreted with caution, given the

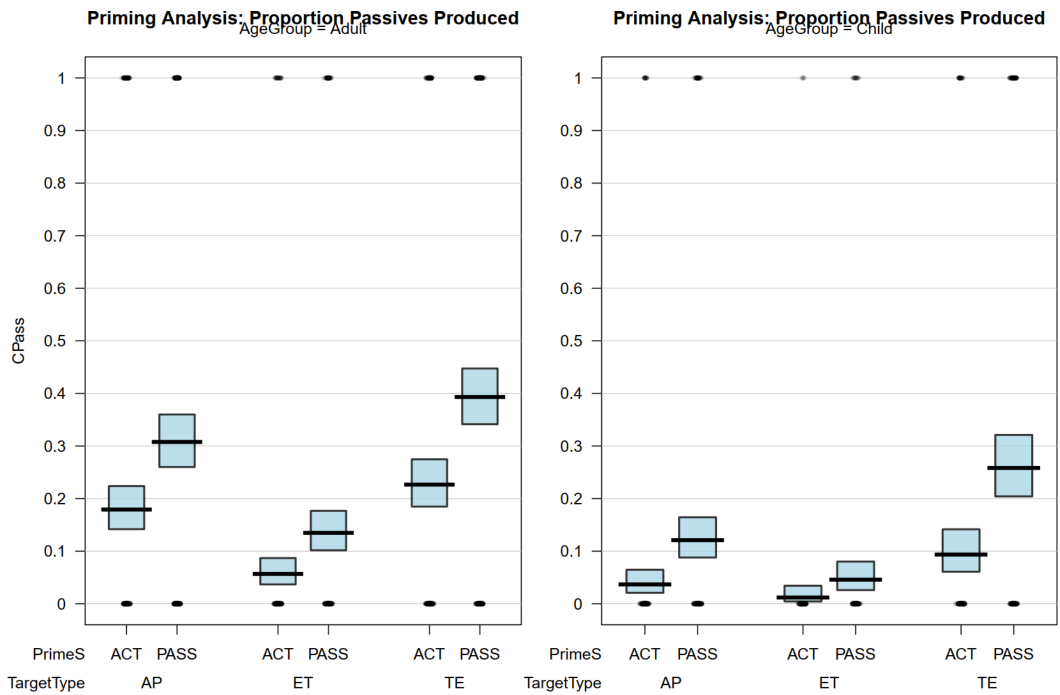

Fig. 3. Proportion of correct passives produced, by adults and children, with *agent-patient* (AP) verbs *(e.g., hit*), *experiencer-theme* (ET) verbs (e.g., *see*), and *theme-experiencer* (TE) verbs (e.g., *frighten*), with active and passive primes.

Table 7
Mixed-effects models for priming analysis (all participants)

Covariate	Estimate	Est.Error	l–95% CI	u-95% CI	B < > 0
Intercept	0.16	0.02	0.12	0.20	1.00
PrimeSentenceType	0.05	0.01	0.04	0.07	1.00
VerbType	0.05	0.02	0.01	0.09	0.99
AgeGroup	0.06	0.01	0.03	0.08	1.00
PrimeSentenceType:VerbType	0.01	0.01	−0.01	0.03	0.90
PrimeSentenceType:AgeGroup	0.01	0.01	−0.01	0.02	0.81
VerbType:AgeGroup	0.02	0.01	0.00	0.05	0.99
PrimeSentenceType:VerbType:AgeGroup	0.00	0.01	−0.01	0.01	0.54

presence of an interaction (Singmann & Kellen, 2019). If taken at face value, the former —which reflects the fact that more passives were produced following passive than active primes—constitutes evidence for abstract knowledge of the passive construction. The latter simply confirms the finding from the Production analysis that more passives overall were produced with *agent-patient* and *theme-experience* than *experiencer-theme* verbs.

In summary, in contrast to the Production analysis, the Priming analysis provides only suggestive evidence for the possible prediction of the *semantic construction prototype*

Table 8
Mixed-effects models for priming analysis (children)

Covariate	Estimate	Est.Error	l–95% CI	u-95% CI	B < > 0
Intercept	0.19	0.13	−0.06	0.44	0.93
PrimeSentenceType	0.05	0.01	0.03	0.07	1.00
VerbType	0.02	0.03	−0.03	0.07	0.79
Age	0.00	0.00	0.00	0.00	0.75
PrimeSentenceType:VerbType	0.01	0.01	−0.01	0.03	0.82

Table 9
Mixed-effects models for priming analysis (adults)

Covariate	Estimate	Est.Error	l–95% CI	u-95% CI	B < > 0
Intercept	0.22	0.03	0.17	0.27	1.00
PrimeSentenceType	0.06	0.01	0.03	0.09	1.00
VerbType	0.07	0.02	0.03	0.12	1.00
PrimeSentenceType:VerbType	0.01	0.01	−0.01	0.03	0.87

account of an interaction of Prime Sentence Type (active/passive) by Target Verb Type (*agent-patient/theme-experiencer/experiencer-theme*) such that the observed priming effect (i.e., more passives produced following passive than active primes) is smaller for *experiencer-theme* verbs than for *agent-patient/theme-experiencer* verbs. The finding of a priming effect (i.e., the main effect of Prime Sentence Type) constitutes evidence that 4- to 6-year-old children do have at least some kind of abstract knowledge of the passive construction. Recall, however, that—as noted by an anonymous reviewer, it is unclear whether or not the prediction of a Prime Sentence Type by Verb Type interaction indeed follows from the semantic construction prototype account. However, the finding from the Production analysis that children and adults produced fewer passives with *experiencer-theme* than *agent-patient* and *theme-experiencer* verbs is exactly as predicted by the semantic construction prototype account, and indeed is difficult to reconcile with the view that adults' and children's knowledge of the passive is ONLY abstract, in the sense that it does not additionally include a semantic affectedness constraint.

Before moving on, it is again instructive to compare the results of the Priming analysis with those of Messenger et al. (2012), who conducted similar studies varying the type of the prime verb (split across two separate studies) rather than target verb. In fact, the findings are quite similar: In both the present Priming analysis and Messenger et al.'s (2012) Experiment 2, which compared *theme-experiencer* and *experiencer-theme* verbs, the pattern of the means was in accordance with that predicted by the *semantic construction prototype* account, but it was not statistically significant. In all likelihood, however, both studies were underpowered to detect this interaction (N = 24 per age group in Messenger et al., N = 60 in the present study).

4. General discussion

The aim of the present research was to test a *semantic construction prototype* account under which children's and adults' knowledge of the passive is both abstract and semantically constrained at the same time: "abstract" in the sense that speakers can use any verb (and any NOUN PHRASEs) in that construction; "semantically constrained" in that, in both comprehension and production, speakers' performance with a given passive is inversely related to the distance between the semantics of the verb and the semantics of the construction (approximately speaking, "subject affectedness"; Pinker et al., 1987).

In a forced-choice pointing study (Experiment 1), children and adults showed support for the prediction of the *semantic construction prototype* account of an interaction of Sentence Type (active/passive) by Verb Type such that the disadvantage for passives as compared to actives (i.e., fewer correct points/longer reaction time) is greater for *experiencer-theme* verbs than for *agent-patient* and *theme-experiencer* verbs. Similarly, in a production/priming study (Experiment 2), children and adults produced fewer passives for *experiencer-theme* verbs than for *agent-patient/theme-experiencer* verbs (though an additional analysis yielded only weak evidence that the observed priming effect differed by verb type; a possible—though by no means straightforward—prediction of this account). While both of these findings suggest that children's and adults' knowledge of the passive is semantically constrained, the large priming effect observed in the production/priming study suggests that this knowledge is, at the same time, also abstract. This raises the question of what type of account of passive acquisition, and of language acquisition more generally, can explain this pattern. We can see four possibilities.

First, traditional generativist-nativist accounts (e.g., Borer & Wexler, 1987; Chomsky, 1993[3]; Fox & Grodzinsky, 1998; Gordon & Chafetz, 1990; Hirsch & Wexler, 2006) assume that the passive is formed by rules that act on variables (e.g., A[rgument] movement), rather than individual lexical items. Such accounts would seem to have little option but to describe the present findings as mere effects of usage that are not represented in the underlying grammar (as Newmeyer, 2003, puts it "grammar is grammar, and usage is usage"). A potential problem for this position is that the same semantic feature that is associated with slower and less accurate interpretation/production for the present passive sentences (i.e., affectedness) also offers an explanation of why some verbs cannot be passivised at all (e.g., **$5 was cost by the book*; **Five people are slept by this tent*; Pinker et al., 1987). Thus, semantic affectedness affects not mere usage, but which passives are and are not possible English sentences—information that must be represented somehow in the grammar.

Second, shallow-syntax accounts (e.g., Branigan & Pickering, 2017; Culicover & Jackendoff, 2005) eschew movement, positing that syntax is represented at a single "level of representation [that] includes syntactic category information but not semantic information (e.g., thematic roles) or lexical content" (Branigan & Pickering, 2017, p. 8). This would preclude an explanation of the present findings in terms of sematic or lexical information stored at the level of syntax. However, Branigan and Pickering (2017, p. 50) propose that "thematic relations and other semantic information are represented separately from syntactic structure and are mapped to syntactic representations.... Not surprisingly, some mappings are preferred over others," which suggests that the present findings could be explained by a preferred link between—for example—highly affected PATIENTS and the first NOUN PHRASE slot of the passive construction. A problem for this account is that one of the main motivations for the monostratal level of syntax assumed has recently been challenged by new data. Bock and Loebell (1990) famously showed that passive sentences such as *The construction worker was hit by the bulldozer* prime intransitive locative (i.e., *non*-passive) sentences such as *The 747 was landing by the airport's control tower*. This finding motivates a shallow level of syntax, in which the two sentences are represented identically, that is, [NP] [VERB] by [NP], rather than [SUBJECT] BE [VERB] by [OBJECT] (passive) versus [SUBJECT] [VERB PHRASE] [PREPOSITIONAL PHRASE] (intransitive locative). However, a recent modified replication of this study (Ziegler, Bencini, Goldberg, & Snedeker, 2019) suggests that Bock and Loebell's (1990) effect was driven by overlap of *by*, which was both necessary and sufficient for priming to occur. That is, no priming of passives occurred following locatives that lacked *by* (e.g., *The 747 was landing next to the airport's control tower*). Conversely, priming of passives did occur following sentences that included *by* but a different shallow-syntactic structure (e.g., *The pilot landed the 747 by the control tower*; i.e., [NP] [VERB] [NP] by [NP], as opposed to [NP] [VERB] by [NP]).

The third possibility—suggested by an anonymous reviewer—is that semantic information and/or relative passivisability is stored at the level of the verb, and not at the level of some form of abstract passive construction. We do not find this possibility convincing because it effectively treats the relationship between semantic affectedness and passivisability observed in the present study (and in Ambridge et al., 2016; Aryawibawa & Ambridge, 2018) as a coincidence: If the relative passivisability of a verb—as stored at the verb level—is arbitrary, why do we find no *experiencer-theme* verbs that can be readily passivised, or *theme-experiencer* verbs that cannot? But if the relative passivisability of a verb—as stored at the verb level—is NOT arbitrary, where does it come from?

The only answer we can see—bringing us to the fourth possible account—is that relative passivisability stems from compatibility with some kind of passive *semantic construction prototype* (e.g., Ambridge et al., 2016; de Villiers & de Villiers, 1985; Maratsos et al., 1985; Marchman et al., 1991; Meints, 1999; see Ibbotson, Theakston, Lieven, & Tomasello, 2012, for a similar account of the English transitive construction, and Ibbotson & Tomasello, 2009, for a review of prototype accounts in language acquisition more generally). On this view, learners build an increasingly abstract passive construction by schematizing and analogizing across concrete passive utterances that they hear in the input (e.g., Tomasello, 2003). The adult endpoint is a passive construction [SUBJECT] BE/GET [VERB]ed/en by [OBJECT] that is fully abstract in the sense that it can be used to comprehend and generate passive utterances with any verb (except highly non-actional verbs like *cost* and *sleep*), but at the same time is semantically constrained: The naturalness of the resulting passive (and hence its ease of comprehension and its production probability) varies continuously as a function of the extent to which the semantics of the particular verb overlap with the semantics of the VERB slot, defined as subject-affectedness (in the sense of Ambridge et al., 2016; Pinker et al., 1987). Where do the semantics of the VERB slot come from? They are simply a function of the semantics of all the individual verbs that have appeared in that slot in the input utterances that gave rise to the construction (whether this function is a simple averaging and, if so, whether over types or tokens has not yet been made explicit under such accounts).

As we noted in the Introduction, the present studies do not allow us to differentiate between a view under which a semantic construction prototype is actually stored in memory (e.g., Abbot-Smith & Tomasello, 2006) and a view under which it is merely emergent across stored exemplars of the construction (e.g., Ambridge, 2019). Future studies may be able to differentiate between these possibilities by manipulating lexical overlap: If participants show an advantage (whether in comprehension or production) for patterns of verbs and arguments that have occurred frequently in the input, or have been recently presented during priming (e.g., *He was killed by*...), this would appear to constitute evidence that exemplars are retained with considerable lexical detail (though the jury is still out with regard to exactly when such lexical boosts occur, and exactly what they mean; e.g., Carminati, van Gompel, & Wakeford, 2019; Scheepers, Raffray, & Myachykov, 2017).

In the meantime, the present findings have provided evidence that while 4- to 6-year-old children—like adults—certainly have abstract knowledge of the passive construction, they additionally possess lexical knowledge of the (types of) verbs that are semantically most consistent with this construction; specifically, *theme-experiencer* verbs (e.g., *frighten*) and *agent-patient* verbs (e.g., *hit*), but not *experiencer-theme* verbs (e.g., *see*). Any future account of the acquisition of the passive, or of the acquisition and representation of syntax more generally, will need to account for these findings.

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Open Research badges

This article has earned Open Data badge. Data are available at https://osf.io/vrjuw/.

Notes

1. Since all animations can be felicitously described with canonical active utterances, and there exist no discourse-pragmatic factors, such as topicality of the PATIENT, that would pull for the use of a passive instead.
2. Note that a separate analysis is necessary, rather than just testing for this main effect in the "Priming" analysis. This is because the interpretation of main effects (here Verb Type) in the presence of an interaction (here, Verb Type by Sentence Type) is not straightforward (e.g., Singmann & Kellen, 2019).
3. In fact, Chomsky (1993, p.4) takes a rather radical position in specifically denying the existence of the passive as an independent grammatical construction: "Constructions such as…[the] passive remain only as taxonomic artifacts, collections of phenomena explained through the interaction of the principles of UG, with the values of the parameters fixed."

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Data S1. Mixed model tables for all analyses.

Appendix A:

Verbs used in Experiment 1. AP = agent-patient verb, ET = experiencer theme verb, TE = theme-experiencer verb. * denotes verbs also used in Messenger et al. (2012)

List A		List B	
bite*	AP	carry*	AP
chase	AP	dress	AP
hit*	AP	hug	AP
kick	AP	pat*	AP
push	AP	pull*	AP
squash*	AP	wash	AP
forget	ET	hate	ET
hear*	ET	ignore*	ET
know	ET	like*	ET
love*	ET	remember*	ET
see*	ET	smell	ET
understand	ET	watch	ET
amaze	TE	annoy*	TE
bother	TE	frighten*	TE
impress	TE	please	TE
scare*	TE	shock*	TE
surprise*	TE	tease	TE
upset*	TE	worry	TE

Appendix B

Verbs used as primes and targets in Experiment 2. AP = agent-patient verb, ET = experiencer theme verb, TE = theme-experiencer verb. * denotes verbs also used in Messenger et al. (2012)

Prime verbs		Target verbs		
all AP		AP	ET	TE
avoid	hold	bite*	forget	amaze
bite*	hug	carry*	hate	annoy*
call	kick	chase	hear*	bother
carry*	kiss	dress	ignore*	frighten*
chase	lead	hit*	know	impress
cut	pat*	hug	like*	please
dress	pull*	kick	love*	scare*
drop	push	pat*	remember*	shock*
eat	shake	pull*	see*	surprise*
follow	squash*	push	smell	tease
help	teach	squash*	understand	upset*
hit*	wash	wash	watch	worry