Disentangling effects of input frequency and morphophonological complexity on children's acquisition of verb inflection: an elicited production study of Japanese.

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Abstract

This study aims to disentangle the often-confounded effects of input frequency and

morphophonological complexity in the acquisition of inflection, by focusing on simple and

complex verb forms in Japanese. Study 1 tested 28 children aged 3;3-4;3 on stative (complex)

and simple past forms, and Study 2 tested 30 children aged 3;5-5;3 on completive (complex)

and simple past forms, with both studies using a production priming paradigm. Mixed effects

models for children's responses were built to test the prediction that children's verb use is

explained by the relative bias in input frequency between the two inflectional forms.

Although Study 1 did not show a significant effect of input bias (apparently due to problems

with item selection), Study 2, which corrected for this problem, yielded the predicted

relationship. These findings suggest that input frequency effects, at the level of different

inflectional forms of the same verb stem, hold even after controlling for morphophonological

complexity.

1. Introduction

Input frequency has been shown to be a key factor in explaining the pattern of children's

language development. Indeed, it is almost certainly the factor that has received the greatest

degree of empirical attention and support. Effects of input frequency have been observed in

many different domains including phonology, vocabulary, simple and complex syntax, and –

the focus of the present article – inflectional morphology (see Ellis, 2002, and Ambridge,

Rowland, Theakston & Kidd, 2015, for reviews). However, this factor is confounded with

various other factors (e.g., Lieven, 2010; Tomasello & Stahl, 2004), most notably, at least in

the domain of inflectional morphology, morphophonological complexity. Whether one is

counting phonemes, morphemes, syllables or objective duration, high frequency forms (e.g.,

walk) tend to be shorter and simpler than lower frequency equivalents (e.g., *walks, walking,*

ambulates). Thus, virtually all previous findings of (apparent) frequency effects at the level

of inflectional morphology could, in principle, be effects of morphophonological complexity

in disguise. The goal of this study is to disentangle these two factors, by focusing on

Japanese; a language whose system of agglutinative morphology allows for frequency and

complexity to be dissociated at the level of individual verb stems.

1.1.Effects of frequency in child language

Input-based accounts of language acquisition claim that patterns in children's usage and error

reflect distributional properties of the input language. Although input-based accounts have

been proposed from a variety of theoretical perspectives (see Ambridge et al, 2015, for a

review), they sit most naturally with the constructivist view, under which children build their

linguistic knowledge on the basis of their experience with language, and hence are predicted

to show frequency effects at all levels (e.g., Bybee, 2006; Ellis, 2002; Tomasello, 2003).

Indeed, many studies have found a relationship between children's use of linguistic forms

and the frequency with which these forms occur in the input language (e.g., Goodman, Dale

& Li, 2008; Smiley & Huttenlocher, 1995; Naigles & Hoff-Ginsberg, 1998, Theakston,

Lieven, Pine & Rowland 2002, 2004; Zamuner, Gerken, & Hammond, 2005).

The domain of inflectional morphology is particularly well suited to the

investigation of frequency effects, because it is possible to look for relative frequency effects

at the levels of individual verb (or noun) stems. It is generally agreed that because, in this

domain, frequency effects arise as a result of probabilistic competition between semantically

very similar forms (e.g., *play* vs *plays*) it is the *relative* rather than *absolute* frequency of each

form (most simply captured as a simple proportion or ratio) that is the appropriate

input-frequency measure (see Ambridge et al, 2015: 247 for discussion). For example,

Räsänen, Ambridge and Pine (2014) investigated children's errors of using bare/nonfinite

forms instead of finite forms in English (e.g., *He play* for *He plays*), and found that the

by-verb error rate in an elicited production study was explained by the proportional frequency

of these verbs in bare versus 3sg -*s* form in child-directed speech. For example, *fit* occurred

relatively often in 3sg form in Räsänen et al.'s input sample, and was never produced

incorrectly in the experiment, whereas *find* never occurred in 3sg form in the input sample

and was produced incorrectly 50% of the time. Similarly, in a study of zero-marking errors

for English noun plural marking, Matthews and Theakston (2006) found an effect of relative

input frequency such that, for example, children often produced errors such as *two mouse*

(for *two mice*) but rarely produced errors such as *two tooth* (for *two teeth*), because the ratio

of *mouse:mice* (roughly 7:1) is much greater than the ratio of *tooth:teeth* (roughly 1:6).

Importantly, particularly with regard to the present study, effects of proportional

input frequency are observed not only for error rates, but also for patterns of (correct) usage.

For instance, Tatsumi and Pine (2016) showed that, in Japanese, the proportional frequency

of past-inflected forms varies greatly across verbs in a child-directed speech sample, and that

this frequency measure predicted children's usage of the inflection. Specifically, the

proportional frequency of past tense forms versus all other inflectional forms in each child's

data correlated highly with that in his/her caregivers' child-directed speech. Moreover, this

result held even after controlling for the general semantic-distributional properties of

Japanese child-directed speech by partialling out the proportional frequency of past tense

forms averaged across the speech of the other caregivers in the sample.

1.2. Frequency and morphophonological complexity in verb inflection

On the face of it, the fact that by-verb variation in the proportional frequency of

different inflectional forms predicts both children's error rates and patterns of correct usage

would seem to constitute powerful support for an account under which linguistic knowledge

builds up as a result of input-based learning. On closer inspection, however, this evidence is

less than compelling because, in many of these cases, frequency is confounded with

morphophonological complexity. This point is perhaps most clearly illustrated by studies of

children's 'defaulting' errors; so called because children are claimed to default to a particular

form in the inflectional paradigm when they have difficulty retrieving the target form. For

example, in a dense corpus study, Aguado-Orea and Pine (2015) found that the majority of

verb-agreement errors produced by two Spanish-speaking children involved the use of 3rd

person singular (3sg) forms in non 3rd person singular contexts (e.g., *Tú [2sg] come [3sg],

for Tú [2sg] comes [2sg]. 'you eat'). While Aguado-Orea and Pine (2015) characterized these

errors in terms of children's defaulting to the form of each verb with the highest input

frequency (i.e., 3sg), at least two other defaulting-based explanations are possible. First, 3sg

could constitute a morpho-syntactic default; a form that can be used even when its agreement

features (third person, singular) are not licensed by the subject (e.g., Radford &

Ploennig-Pacheco, 1995). Second, as Aguado-Orea and Pine (2015) themselves note, Spanish

3sg forms are not only the most frequent, but also the most phonologically prototypical and

simple forms in the paradigm (e.g., come vs comes/emos/éis/en), whether measured in

phonemes, morphemes or objective duration. (In the present article, we abstract away from

the question of how complexity is best measured, and use "morphophonologically complex"

as a catch-all term for forms that are longer on all three of these dimensions). Indeed, as the

example of *come for comes shows, the form to which children are defaulting is often –

phonologically speaking – the target form with one or more phonemes omitted.

A similar situation holds for Finnish-speaking children's person-number agreement

errors. Children sometimes misuse both the 3sg form (as in Spanish) and the 2sg imperative

form in contexts in which these forms are ungrammatical (Räsänen, Ambridge & Pine, 2016).

Again, these forms are not only highly frequent forms but also morphophonologically simple

forms. For example, the 2sg imperative form bears no overt morphological marking, and is

phonologically indistinguishable from the stem form (Laalo, 2003).

Consequently, it is not possible, for any of these previous studies, to determine

whether apparent frequency effects are in fact caused by a confound with

morphophonological complexity, underlining the need to distinguish these often-confounded

factors. One possible way to do so is to consider languages that show by-verb variation in the

frequency of morphophonologically simple and complex forms, such that the more complex

form is less frequent than the corresponding simple form for some verbs, but *more* frequent

than the corresponding simple form for others. The present study focusses on Japanese,

which has this property for (at least) two classes of complex form: statives (Study 1) and

completives (Study 2).

1.3.Morphological characteristics of Japanese verb inflection

Japanese has a relatively rich system of verb inflection in which a number of distinctions,

including tense, aspect, voice, polarity and politeness are expressed by means of suffixation

on verb stems. It is worth emphasizing that the notion of inflection in Japanese is different

from 'Latin-type' fusional inflection. As Shibatani (1990: 221) states, inflectional endings

"are fairly clearly segmentable, and the segmented endings (or suffixes) are correlated with

inflectional categories in a one-to-one fashion". The simplest verb form consists of a verb

stem with a tense-marking suffix (non-past or past), as in *tabe-ru* (eat-NONPAST) and

tabe-ta (eat-PAST). Because Japanese verb morphology is agglutinative, more suffixes can

be attached to these simple forms, in each case between the stem and the tense-marking

suffix. In the present article, we focus on two aspectual suffixes: the stative and the

completive marker.

The stative inflection[i] is marked with the suffix *-te*, as in *tabe-te-ru*

(eat-STATIVE-NONPAST), 'be eating' and *tabe-te-ta* (eat-STATIVE-PAST), 'was/were

eating'. The meaning of this aspectual marker is usually described as stative or progressive

(this paper uses the label 'stative' for convenience), depending on the meaning of the verb. A

stative interpretation is most natural when this suffix is combined with verbs that have the

semantic feature of completion or achievement such as *tsuk-* 'arrive', as in *tsui-te-ru* 'be

arrived' (i.e., to be present). A progressive interpretation is most natural when this suffix is

combined with action verbs, as for the above example of *tabe-te-ta*, 'was/were eating' (e.g., *I

was eating, when suddenly the phone rang*).

The completive inflection[ii] is marked with the suffix –*chaw* (which changes to –

chat when followed by the PAST marker), as in *tabe-chat-ta* (eat-COMPLETIVE-PAST).

Crosslinguistically, the completive form marks an action that has been done "thoroughly and

to completion" (Bybee, Perkins & Pagliuca, 1994:318), though in Japanese it often has an

additional implication of negativity or unexpectedness (e.g., *I was on a diet but ate the whole*

meal).

In terms of frequency of use, although complex forms generally outnumber simple

forms in terms of types (i.e., different inflectional forms of the same verb stem), simple forms

are generally more frequent in terms of tokens (in line with a language-general distributional

pattern; e.g., Zipf, 1935; Anglin, Miller & Wakefield, 1993). For example, in the corpus

counts used in the present Study 1, simple past forms outnumber stative past forms by almost

a factor of 10 (7,545:791). This is not surprising, given the well-known tendency to find a

strong negative correlation between frequency and complexity, whereby frequently-used

forms become reduced and simplified. However, despite this general pattern, for some verbs,

certain complex forms (including the stative and completive forms investigated in the present

study) outnumber their corresponding simple forms. It is this feature of Japanese that makes

it ideal for dissociating the roles of token frequency and morphophonological complexity.

1.4. Previous studies of frequency and morphophonological complexity in Japanese

The findings of a number of previous studies of Japanese verb inflection suggest that both (a)

high input frequency and (b) morphological simplicity aid acquisition (to our knowledge,

none have attempted to dissociate these factors). But at the same time, some studies have

found that certain complex forms appear early and/or are used often by children.

Differences in the emergence and usage of inflected verb forms have been

explained in terms of input frequency in many studies (e.g., Otomo, Miyata & Shirai, 2015;

Shirai, 1993). For example, as noted above, Tatsumi and Pine (2016) studied the distribution

of inflectional forms in a naturalistic speech sample and demonstrated that children's usage

of different inflectional forms of the same verb (e.g., *tabe-ta* 'eat-PAST' vs *tabe-ru*

'eat-NONPAST') correlates highly with that of their caregivers. In a follow-up elicitation

study, Tatsumi, Pine and Ambridge (submitted) investigated the effect of input frequency in

children's misuse of past-tense forms in nonpast contexts and vice versa (e.g., *tabe-ta*

'eat-PAST', describing an action that is planned to take place *ashita*, 'tomorrow'). The

findings showed that children's error rate is explained by the by-verb frequency distribution

of these two tense forms in a sample of child-directed speech. For example, children were

most likely to use a past-tense form in a nonpast context for a past-biased verb such as

mitsuke 'find' for which the proportional frequency of past versus nonpast forms in the

dataset was 0.96. Conversely, children were more likely to use a nonpast-tense form in a past

context for a nonpast-biased verb such as *tsukaw* 'use', for which the proportional frequency

of past versus nonpast forms was 0.11.

A higher degree of morphophonological complexity is generally considered to

negatively affect learning. Many corpus-based studies of verb inflection in child Japanese

report that most of children's earliest forms are morphologically simple (e.g. Clancy, 1985;

Otomo et al., 2015; Shirai, 1993, 1998; Shirai & Miyata, 2006). On the basis of these and

similar observations, Iwatate (1981) and Takanashi (2009) proposed a learning process

whereby children generally proceed from simple forms to complex forms by the addition of

morphemes.

At the same time, however, some of these corpus studies show that certain complex

forms are observed even in the very early stages, and suggest that input frequency might be a

particularly important factor for these complex forms (e.g. Clancy, 1985; Otomo et al., 2015).

For example, Iwatate (1981) (though arguing that in general children learn simple forms

earlier than complex forms), observed the production of complex forms like *tabechatta*

(eat-COMPLETIVE-PAST) during the earliest observable stage (e.g., at 2;1).

Together, these previous studies suggest that both input frequency and

morphophonological complexity are important factors in the acquisition of Japanese

inflection, further highlighting the need for a study designed to pull apart these

often-confounded factors.

1.5. The present study

In summary, many previous studies of inflectional morphology (including studies of English,

Finnish, Spanish and Japanese) have observed apparent effects of input frequency. However,

since frequency is negatively correlated with morphophonological complexity, it remains

possible that many apparent frequency effects are in fact complexity effects in disguise. The

aim of the present study is therefore to dissociate these factors by focusing on Japanese; a

language that shows by-verb variation in the frequency of simple and complex forms, such

that the more complex form is less frequent that the corresponding simple form for some

verbs, but *more* frequent than the corresponding simple form for others[iii]. Specifically, we

predict a positive correlation across verbs between the ratio of complex: simple forms in a

representative input corpus and children's experimental production data. The two pairs of

complex and simple forms are (**Study 1**) stative past (e.g., *tabe-te-ta* (eat-STATIVE-PAST)

'was eating') versus simple past (e.g. *tabe-ta* (eat-PAST) 'ate') and (**Study 2**) completive

past (e.g., *tabe-chat-ta* (eat-COMPLETIVE-PAST) 'have eaten') versus simple past (e.g.

tabe-ta (eat-PAST) 'ate'). Thus, we predict that the proportion of stative vs simple forms

produced by children in Study 1 will be higher for verbs like *wasure* 'forget', for which

stative past forms outnumber simple past forms (17 tokens vs 7 tokens in the child-directed

speech sample mentioned above) than verbs like *araw* 'wash', for which stative past forms

are less frequent than simple past forms (1 tokens vs 23 tokens). Similarly, we predict that the

proportion of completive vs simple forms produced by children in Study 2 will be higher for

verbs like *wasure* 'forget', for which completive past forms outnumber simple past forms (24

tokens vs 5 tokens) than verbs like *moraw* 'get', for which completive past forms are less

frequent than simple past forms (1 tokens vs 21 tokens).

       The reason for choosing these particular inflectional forms is that both statives and

completives are relatively frequent in child (and child-directed) speech. Importantly, because,

in both cases, the difference in meaning between the complex and simple forms is mainly

aspectual, it is straightforward to devise experimental settings in which the use of either form

is natural.

2. Study 1: Simple past vs complex stative past

2.1. Method

2.1.1. Participants

Twenty-eight children (19 boys and 9 girls) aged 3;3-4;3 (mean=3;10), recruited from

nurseries in Tokyo, participated in the experiment. All were native monolingual speakers of

Japanese reported as showing no linguistic impairment.

2.1.2. Design and Materials

Twenty verbs were selected for use in the target pictures to be described by children: 10

biased towards simple past and 10 towards stative past forms in terms of input frequency.

Frequency counts were taken from all combined child-directed speech (both mothers and

fathers) in the MiiPro corpus (Miyata & Nisisawa, 2009, 2010; Nisisawa & Miyata, 2009,

2010) in the CHILDES database (MacWhinney, 2000). For each verb, the token frequency of

(a) the simple past form (e.g. *arat-ta* 'washed') and (b) the stative past form (e.g. *arat-te-ta,*

'was washing') was obtained, using the FREQ function of the CLAN program (MacWhinney,

2000). In order to ensure that our experimental verbs spanned the full range of

simple-past-biased and stative-past-biased verbs (see Table 1), verbs were selected, where

possible, on the basis that they showed a bias that was significantly different from chance

(i.e., from 50/50) by binomial test ($p<.05$). However, in order to obtain a sufficient number of

verbs (bearing in mind their suitability for illustration in still pictures and familiarity to

children), we also included 5 stative-biased verbs and 2 simple-biased verbs where the bias

was not statistically significant. In addition to these 20 target verbs for use by children, 20

unbiased verbs (by binomial test) were selected for use by the experimenter (see Table 1).

However, after conducting this study (and Study 2), we realized that the simple

proportion of simple versus stative past forms is not a true measure of verb bias. Because

simple past forms outnumber stative past forms by a ratio of – in this dataset – around 10:1

(7,545 vs 791), a verb that exhibits a more modest "preference" for simple forms – such as

nor, 'ride' (5:1, 85 vs 17) – is actually biased *against* the simple form, and in favour of the

stative form, at least in the context of all the verbs in the corpus. In other words, given that,

on average, the Japanese speaker's communicative goals require the use of a stative past form

around 8% of the time, a verb that occurs in the stative past form 20% of the time is

displaying a rather considerable bias towards this form. To address this problem, as outlined

in more detail below, we used a chi-square statistic as a measure of verb bias. Note that the

point of using this statistic is not to establish which verbs show a significant bias towards the

simple or the stative form, but rather to provide a measure of verb bias that controls for the

overall bias towards simple forms in the language as a whole.

Table 1. Target verbs for use by children

	verb	meaning	Input frequency (simple past)	Input frequency (stative past)	Binomial test	verb bias by binomial test	directional chi-square statistic (log-transformed)	**verb bias by chi-square statistic**
C1	araw	wash	23	1	<.001	simple	-0.58	simple
C2	fum	step on	13	2	<.001	simple	0.23	stative
C3	hair	enter	173	57	<.001	simple	4.18	stative
C4	hippar	pull	11	1	<.001	simple	-0.02	simple
C5	taore	fall down	11	2	0.002	simple	0.42	stative

C6	nor	ride	85	17	<.001	simple	1.97	stative
C7	tsukamae	catch	26	1	<.001	simple	-0.72	simple
C8	mawar	turn	6	3	0.090	simple	1.94	stative
C9	nak	cry	28	15	0.016	simple	3.51	stative
C10	nom	drink	10	5	0.059	simple	2.39	stative
C11	wasure	forget	7.0	17.0	0.011	stative	4.67	stative
C12	shir	know	0.0	23.0	<.001	stative	5.40	stative
C13	mot	hold	11.0	13.0	0.271	stative	4.04	stative
C14	mat	wait	4.0	6.0	0.172	stative	3.43	stative
C15	hashir	run	0.0	3.0	<.001	stative	3.39	stative
C16	nokor	remain	2.0	4.0	0.109	stative	3.17	stative
C17	kabur	put on hat	1.0	4.0	0.031	stative	3.40	stative
C18	hak	wear	1.0	4.0	0.031	stative	3.40	stative
C19	waraw	laugh	1.0	3.0	0.063	stative	3.04	stative

	verb	meaning	Input frequency (simple past)	Input frequency (stative past)	Binomial test	verb bias by binomial test	directional chi-square statistic (log-transformed)	**verb bias by chi-square statistic**
C20	kakure	hide	1.0	3.0	0.063	stative	3.04	stative

Verbs for experimenter

	verb	meaning	Input frequency (simple past)	Input frequency (stative past)	Binomial test	verb bias by binomial test	directional chi-square statistic (log-transformed)	**verb bias by chi-square statistic**
E1	hik	play	1.0	0.0	0.5	unbiased	-0.10	simple
E2	sagas	look for	3.0	2.0	0.5	unbiased	1.86	stative
E3	odor	dance	1.0	0.0	0.5	unbiased	-0.10	simple
E4	oyog	swim	2.0	0.0	0.25	unbiased	-0.19	simple
E5	oki	get up	2.0	2.0	0.688	unbiased	2.16	stative
E6	asob	play	13.0	16.0	0.77	unbiased	4.27	stative
E7	narab	line up	0.0	1.0	1	unbiased	2.36	stative
E8	ur	sell	2.0	1.0	0.5	unbiased	1.09	stative
E9	tsukam	grab	0.0	1.0	n.a	unbiased	2.36	stative

E10	shaber	chat	1	2.0	0.875	unbiased	2.52	stative
E11	oshie	teach	3.0	4.0	0.773	unbiased	2.97	stative
E12	kuttsuke	stick	1.0	1.0	0.75	unbiased	1.57	stative
E13	aruk	walk	5.0	2.0	0.227	unbiased	1.38	stative
E14	fur	rainfall	3.0	2.0	0.5	unbiased	1.86	stative
E15	hos	dry	1.0	2.0	0.875	unbiased	2.52	stative
E16	mak	wind	0.0	2.0	n.a	unbiased	3.00	stative
E17	magar	bend	2.0	1.0	0.5	unbiased	1.09	stative
E18	yorokob	be pleased	3.0	2.0	0.5	unbiased	1.86	stative
E19	sak	bloom	2.0	1.0	0.5	unbiased	1.09	stative
E20	ker	kick	3.0	1.0	0.313	unbiased	0.75	stative

2.1.3. Procedure

Children were tested individually in a classroom or teachers' room. Each child completed a

test session of approximately 10 minutes, together with a native Japanese-speaking

experimenter, in front of a laptop computer (Macbook Pro, 11 inch). Before the session, the

experimenter told each child that they would play a bingo game together in which they would

take turns to describe pictures, in order to win star cards to fill up a grid, with the first to fill

all six squares declared the winner (e.g., Rowland, Chang, Ambridge, Pine & Lieven, 2012).

The experiment was presented using Processing (https://processing.org/).

For each trial, the computer presented a still picture depicting a scene, and an audio

stimulus of the corresponding verb in a simple non-past form (described to children as the

"clue word"). The player (either the experimenter or the child) then described the picture.

The experimenter, who always went first, always described the pictures using stative past

forms in order to prime these forms for children (though simple past forms are also perfectly

acceptable in this context). This priming for the stative past inflection was necessary in order

to encourage children to use both stative and simple past forms. With no such priming

children would have been likely to use exclusively simple past forms, because simple past

inflection is generally far more frequent than stative past inflection, and because the

relatively general and neutral meaning of simple past makes this form more natural when

describing the pictures (it is not possible to create picture contexts that prefer stative to

simple past forms). It is important to note that, because we primed only complex forms, we

cannot conclude – if the results pattern in accordance with our predictions – that frequency

trumps morphophonological complexity; without priming, children would probably have

produced simple forms across the board. All that we can conclude – if the results pattern in

accordance with our predictions – is that frequency effects are observed even after controlling

for complexity; i.e., that when we invite children to produce exclusively complex forms (by

means of a priming task), their ability to do so depends on the frequency with which that verb

appears in complex versus simple form.

For the child's turn, the experimenter, following the clue word, provided the target

sentence except for the verb (always the final element of the sentence), to be supplied by the

child. In order to highlight the past-tense context (in which both stative past and simple past

forms are totally acceptable), all sentences began with the temporal adverb *kinoo,* 'yesterday'.

The following example shows a set of experimenter and child turns.

[Experimenter's turn]

Computer: *Hiku* (while showing a picture of a girl playing the guitar)

                   play-NON.PAST

                   'play'

Experimenter: *Kinoo Yuuchan wa gitaa o <u>hii-te-ta</u>.*

                    yesterday Yuuchan TOPIC guitar ACC <u>play-STATIVE-PAST</u>

                    'Yesterday Yuuchan was playing the guitar'

[Child's turn]

Computer: *Arau* (while showing a picture of a girl washing her hands)

                    wash-NON.PAST

                    'wash'

Experimenter: *Kinoo Yuuchan wa te o …*

                    yesterday Yuuchan TOPIC hand ACC

                    'Yesterday Yuuchan … her hands'

Child: <u>*Arat-te-ta / Arat-ta*</u>

                    <u>wash-STATIVE-PAST/ wash-PAST</u>

                    'was washing/ washed'

After each trial, the computer displayed a star or a cloud to indicate whether or not the player

received a star card. This was independent of the response given, and followed a

pre-determined sequence that ensured that the child won each game. Each session consisted

of two games, each consisting of 20 trials (10 turns for each player), such that every child

completed a target trial for every verb. Children's responses were recorded using Audacity

(http://www.audacityteam.org/) and a separate audio recorder for later transcription and

coding (by the first author).

2.1.4. Analyses

Children's responses were analysed on a trial-by-trial basis, using mixed effects models in R,

coded as 1 if the target verb was used in (complex) stative past form and 0 in simple past

form, with all other responses excluded (N=166). These excluded responses were 89 simple

non-past forms (reflecting use of the clue words), 10 other inflectional forms of the target

verb such as stative non-past forms, 34 responses using non-target verbs, and 33 responses of

other types such as nouns and adjectives (e.g., *hen* 'strange'). The number of unscorable

responses is not unexpected given the experimental design, in which children are free to

produce any response, with no direct instructions, and is similar to that observed in

comparable studies (e.g., Räsänen et al., 2014). Also excluded were a further 12 trials for

which children produced no response and 1 trial for which the experimenter failed to provide

the correct prime sentence, for a final total of 381 scorable responses.

Predictor variables were trial number (for investigating the possibility of

incremental priming throughout each experimental session, given that the experimenter

always produced stative past forms) and input bias (stative vs simple past). In order to take

into account the overall preponderance of simple past forms, this predictor was a chi-square

value (without Yates' correction) calculated from counts taken from the MiiPro corpus;

Miyata & Nisisawa, 2009, 2010; Nisisawa & Miyata, 2009, 2010). This value (see the

following formula and Table 2) represents the extent to which a verb's particular bias

towards stative vs simple past forms (or vice-versa) differs from the bias shown by all other

verbs in the corpus. Because the chi-square test is non directional, we set the sign to positive

if the ratio of stative:simple past forms was greater for the target verb than for all other verbs,

and otherwise to negative. The use of polarity (+/-) to indicate whether a verb is biased

towards or against a particular morpheme or (more usually) construction is standard for this

type of analysis (see, e.g., Gries, 2015, for discussion). Chi-square values were natural-log

transformed ($\ln(1+n)$) prior to any polarity change.

$$\chi^2 = (ad-bc)^2 *(a+b+c+d)/(a+c)(c+d)(b+d)(a+b)$$

Table 2. Contingency table for the chi-square calculation

|	Target verb	All other verbs	Row totals
Stative past form	a	b	a+b
Simple past form	c	d	c+d
Column totals	a+c	b+d	a+b+c+d

Linear mixed-effects models were fit using the lme4 package (Bates, Maechler, Bolker & Steven, 2014) of the statistical program R (R Core team, 2015). In addition to the fixed effects above, the models included random intercepts for participant and verb, and as many random slopes as possible without causing convergence failure (Barr, Levy, Scheepers & Tily, 2013). The model comparison (likelihood ratio test) method was used to determine the significance level of individual predictors (Baayen, Davidson, & Bates, 2008; Cohen-Goldberg, 2012; Barr et al., 2013). This method involves sequentially adding predictors – here (1) trial number, (2) the chi-square input-bias predictor and (3) the

interaction – to an initial baseline model that includes random effects only, and comparing

each pair of models by means of a chi-square test (using the anova function of R).

2.2. Results (Study 1)

A binomial mixed effect model was fitted to children's responses (stative/simple past forms)

with predictor variables of trial number and stative-vs-simple input bias (chi-square measure;

see Fig. 1), and the interaction. The final model that converged had by-subject and by-item

intercepts, and a by-subject slope for input bias. The model comparison procedure revealed

no significant effect of trial number (Beta=-0.001, SE= 0.02, χ^2= 0.17, p=0.68), indicating

that priming did not build up over the course of the study. Nor did the addition of input bias

(Beta=0.36, SE=0.29, χ^2=1.58, p=0.21) (see Fig. 1) or the interaction (Beta=0.02, SE=0.01,

χ^2=3.02, p=0.08) significantly improve the model[iv].

Fig. 1. Proportion of children's stative vs simple past forms by input bias (data points are

plotted with verb labels in English translation)
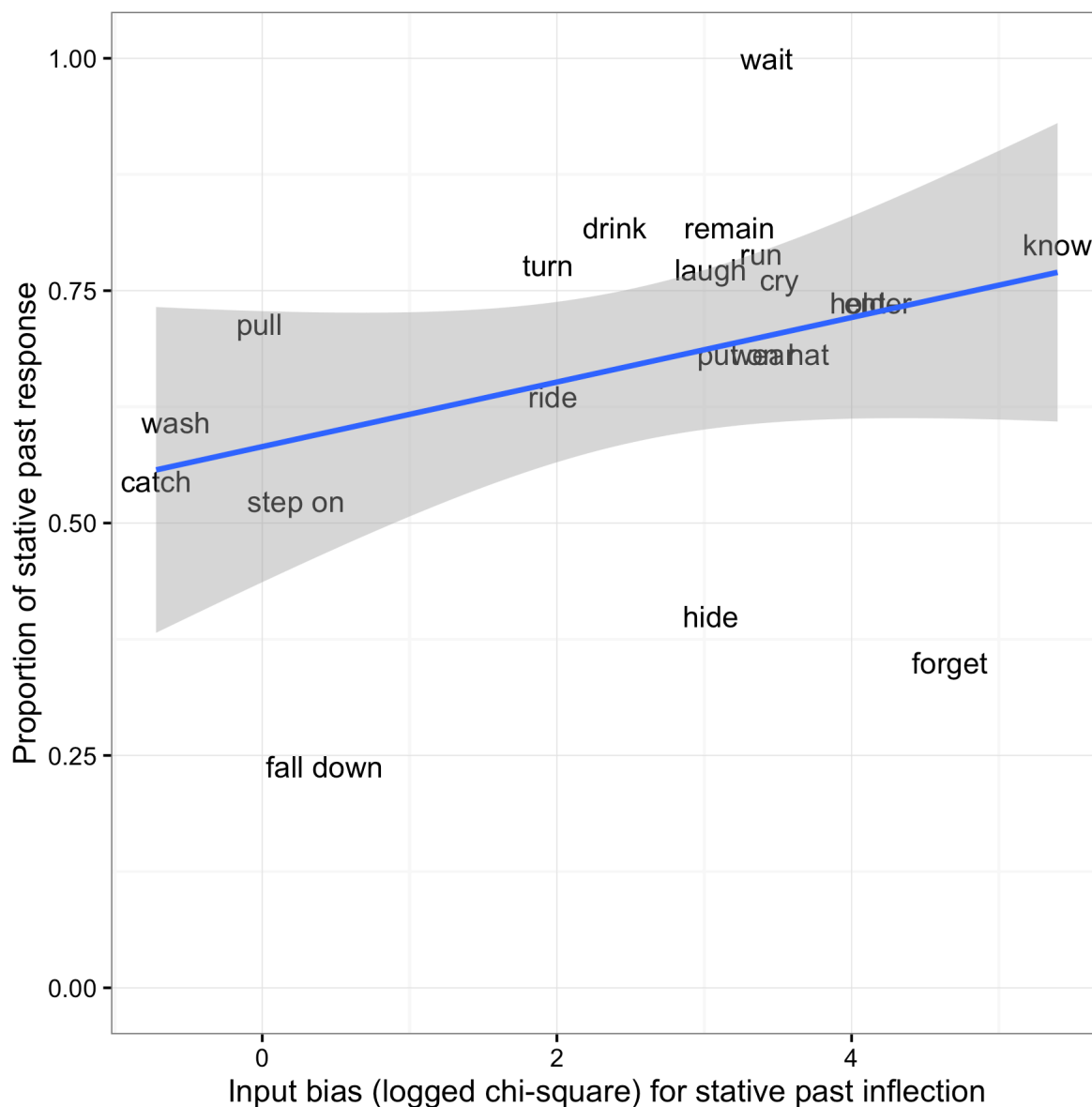
2.3. Discussion (Study 1)

Although the trend was in the predicted direction, Study 1 found no evidence to support the

hypothesis that children's relative by-verb production of simple versus complex forms (here,

simple- versus stative-past forms) reflects the frequency distribution of these forms in the

input.

Of course, one possible reason for this failure to find the predicted effect is that

there is no effect to find. Another is the influence of outliers: one (***mat* 'wait'**) produced

exclusively in stative-past form (presumably because waiting tends to constitute a continuous

activity) and three (***taore* 'fall down', *kakure* 'hide', *wasure* 'forget'**) produced on over 50%

of occasions in simple-past form. Indeed, an analysis of the data with these four verbs

removed showed a significant effect of input bias (Beta= 0.44, SE=0.15, χ^2=6.72 *p*=0.01),

with no significant effect of trial number (Beta= 0.01, SE=0.02, χ^2=0.02 *p*=0.88) and no

interaction (Beta= 0.01, SE=0.01, χ^2=1.25, *p*=0.26). A third possible reason for the lack of an

input effect is that children are not sensitive to the very subtle, mainly aspectual, semantic

distinction between simple and stative forms. This possibility is supported by the lack of a

priming effect, with children consistently producing stative forms at a rate of around 65%

from the beginning of the experiment. A fourth and final possible reason for our failure to

find an input effect lies with our choice of verbs. As shown in Fig. 1, although our

experimental verbs were selected on the basis that 10 of them were simple-biased and 10

complex-biased in absolute terms, for all but three of these verbs (*catch, wash* and *pull*), the

chi-square value is positive, indicating that the majority of verbs chosen as

"simple-past-biased" were actually stative-past-biased in the context of all the verbs in the

corpus. That is, although the remaining "simple-past-biased" verbs are more frequent in

simple- than stative-past in the input corpus, the extent of the bias is smaller than for verbs in

the corpus in general; presumably because the design of the experiment forced us to choose

"simple-past-biased" verbs that were nevertheless relatively natural in stative past form. This

raises the possibility that our failure to find an effect of input bias reflects the failure to

include verbs with a wide enough range of input biases to detect the effect.

In view of these possibilities, the absence of an input effect in Study 1 is difficult to

interpret. We therefore conducted a second study designed to address the potential

shortcomings of (1) outlier verbs, (2) insensitivity to the relevant semantic distinction and (3)

insufficient manipulation of the input-based predictor. This second study focuses on the

completive morpheme, which is both semantically more salient, and also allows for the

inclusion of verbs that are genuinely biased towards the simple form.

3.   Study 2: Simple past vs complex completive past

3.1.Method

3.1.1.   Participants

Thirty children (12 boys and 18 girls) aged 3;5-5;3 (mean=4;2), recruited from nurseries in

Tokyo, participated in the experiment. All were native monolingual speakers of Japanese

reported as showing no linguistic impairment.

3.1.2. Design and Materials

As in Study 1, children took part in a sentence-completion task that elicited simple past forms

and (complex) completive past forms for 20 verbs (10 biased towards simple past and 10

towards completive past forms). These verbs were selected on the basis of the frequency

distribution in the input, also taking into account their familiarity for children and the ease

with which they could be illustrated. Frequency counts were taken from the same sources as

for Study 1. For each verb, the token frequency of (a) the simple past form (e.g. *koware-ta*

'broke') and (b) the completive past form (e.g. *koware-chat-ta* 'have broken') was obtained,

using the FREQ function of the CLAN program (MacWhinney, 2000). In general,

simple-past-biased verbs and completive-past-biased verbs (see Table 3) were selected on the

basis that the relevant bias was significantly different from chance (i.e., to 0.5 simple past vs

stative past) by binomial test ($p<.05$). However, due to the fact that the instances of

completive past verbs are not so abundant in the speech sample, we included 7

completive-biased verbs for which the bias did not reach significance. In addition to these 20

target verbs for use by children, 20 unbiased verbs (by binomial test) were selected for use by

the experimenter (see Table 3). However, after subsequently realizing the problems

associated with raw proportions and the binomial statistic, we again calculated a chi-square

statistic as a measure of verb bias, in order to take into account the fact that simple past forms

outnumber completive past forms (in this dataset by 7,545 to 1047).

Table 3. Verbs for children

	verb	meaning	Input frequency (simple past)	Input frequency (completive past)	Binomial test	verb bias by binomial test	directional chi-square statistic (log-transformed)	**verb bias by chi-square statistic**
C1	moraw	get	21	1	<.001	simple	-0.79	simple
C2	tat	stand	10	1	0.001	simple	-0.09	simple
C3	kaw	buy	49	3	<.001	simple	-1.10	simple
C4	mi	look	57	2	<.001	simple	-1.67	simple
C5	mitsuke	find	14	2	0.002	simple	0.00	unbiased

C6	tsukur	make	30	1	<.001	simple	-1.20	simple
C7	ire	put in	17	2	<.001	simple	-0.05	simple
C8	tor	take	28	3	<.001	simple	-0.17	simple
C9	kak	write	37	3	<.001	simple	-0.60	simple
C10	nor	ride	16	2	0.000	simple	-0.02	simple
C11	nakunar	disappear	15	31	0.013	completive	4.89	completive
C12	otos	drop	8	13	0.192	completive	3.90	completive
C13	wasure	forget	5	24	0.000	completive	4.92	completive
C14	hazure	come off	4	9	0.133	completive	3.70	completive
C15	koware	break	17	27	0.087	completive	4.61	completive
C16	okkochi	fall down	3	10	0.046	completive	3.95	completive
C17	ware	split	2	5	0.227	completive	3.18	completive
C18	kire	cut	1	5	0.109	completive	3.38	completive
C19	nak	cry	8	12	0.252	completive	3.78	completive
C20	korob	tumble	1	4	0.188	completive	3.11	completive

Verbs for experimenter

	verb	meaning	Input frequency (simple past)	Input frequency (completive past)	Binomial test	verb bias by binomial test	directional chi-square statistic (log-transformed)	**verb bias by chi-square statistic**
E1	asob	play	1	1	0.75	unbiased	1.30	completive
E2	chirakas	mess up	1	1	0.75	unbiased	1.30	completive
E3	muk	peel	0	1	0.5	unbiased	2.11	completive
E4	hare	swell	1	1	0.75	unbiased	1.30	completive
E5	fue	increase	0	1	0.5	unbiased	2.11	completive
E6	mazar	mix	1	1	0.75	unbiased	1.30	completive
E7	tomar	stop	5	4	0.5	unbiased	2.28	completive
E8	nemur	sleep	1	1	0.75	unbiased	1.30	completive
E9	nokor	be left	1	1	0.75	unbiased	1.30	completive
E10	or	bend	1	1	0.75	unbiased	1.30	completive
E11	shime	shut	1	1	0.75	unbiased	1.30	completive

E12	sugi	pass	1	1	0.75	unbiased	1.30	completive
E13	tob	fly	1	1	0.75	unbiased	1.30	completive
E14	tsukaw	use	1	1	0.75	unbiased	1.30	completive
E15	yabur	tear	0	1	0.5	unbiased	2.11	completive
E16	yuzur	cede	0	1	0.5	unbiased	2.11	completive
E17	agar	ascend	1	2	0.5	unbiased	2.23	completive
E18	nug	take off	1	2	0.5	unbiased	2.23	completive
E19	okor	get angry	1	2	0.5	unbiased	2.23	completive
E20	watas	give	1	2	0.5	unbiased	2.23	completive

3.1.3 Procedure

The procedure was the same as for Study 1, the only difference being the use of the

completive instead of the stative inflection in the experimenter's prime sentences.

3.1.4. Analyses

Children's responses were dummy coded as 1 if the target verb was used in (complex)

completive past form and 0 in simple past form, with all other responses excluded (N= 133).

These excluded responses were 59 simple non-past forms (reflecting use of clue words), 2

target verbs with non-target inflections such as stative non-past forms, 52 responses using

non-target verbs, and 23 responses of other types such as nouns and adjectives (e.g., *okashi*

'snacks'). Also excluded were a further 5 trials for which children produced no response and

6 trials for which the experimenter failed to provide the correct prime sentence, for a final

total of 455 scorable responses; giving an exclusion rate comparable with both Study 1 and

previous studies. The data were analysed in the same way as in Study 1, including the use of

a chi-square measure as the measure of input bias (here, completive vs simple past).

3.2.Result and discussion (Study 2)

A binomial mixed effect model was fitted to children's responses (completive/simple past

forms) with predictor variables of trial number (see Fig. 2), completive-vs-simple input bias

(chi-square measure; see Fig. 3) and the interaction between these variables. The final model

had by-subject random slopes for the input bias and by-subject and by-item random

intercepts.

Fig. 2. Proportion of children's completive vs simple past forms by trial number
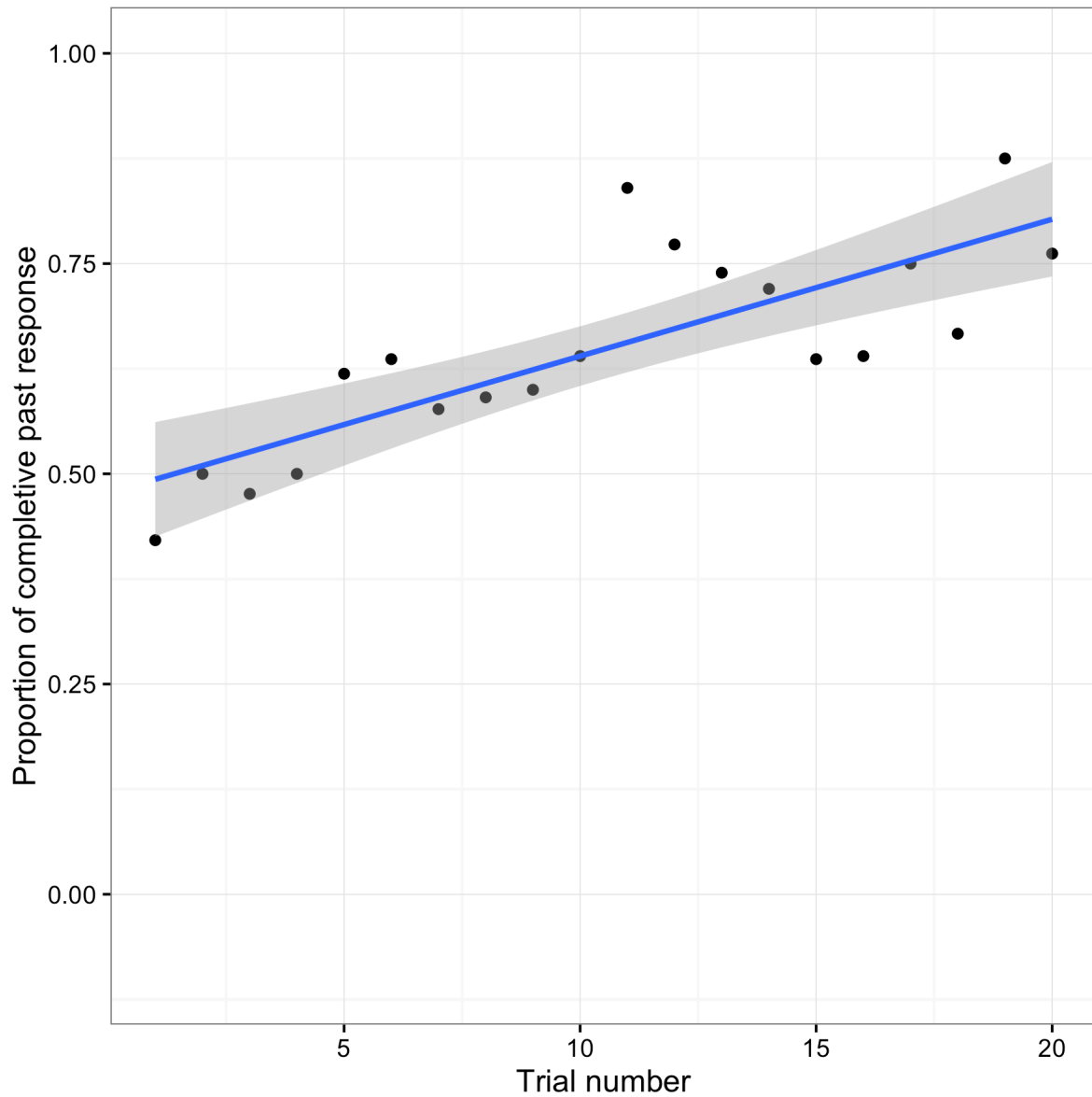
The model revealed a significant effect of trial number (Beta=0.38, SE=0.15, χ^2=24.11,

$p<$ .001), indicating that children's use of completive past forms increased as a result of the

incremental priming of these forms during the test session (see Fig. 2). Since trials were

presented in random order, this effect cannot be responsible for any observed effect of verb

bias. It does, however, have implications for the extent to which these findings can be

generalized to children's everyday language use; a finding to which we return in the General

Discussion.

Fig. 3. Proportion of children's completive vs simple past forms by input bias (data points are

plotted with verb labels in English translation)
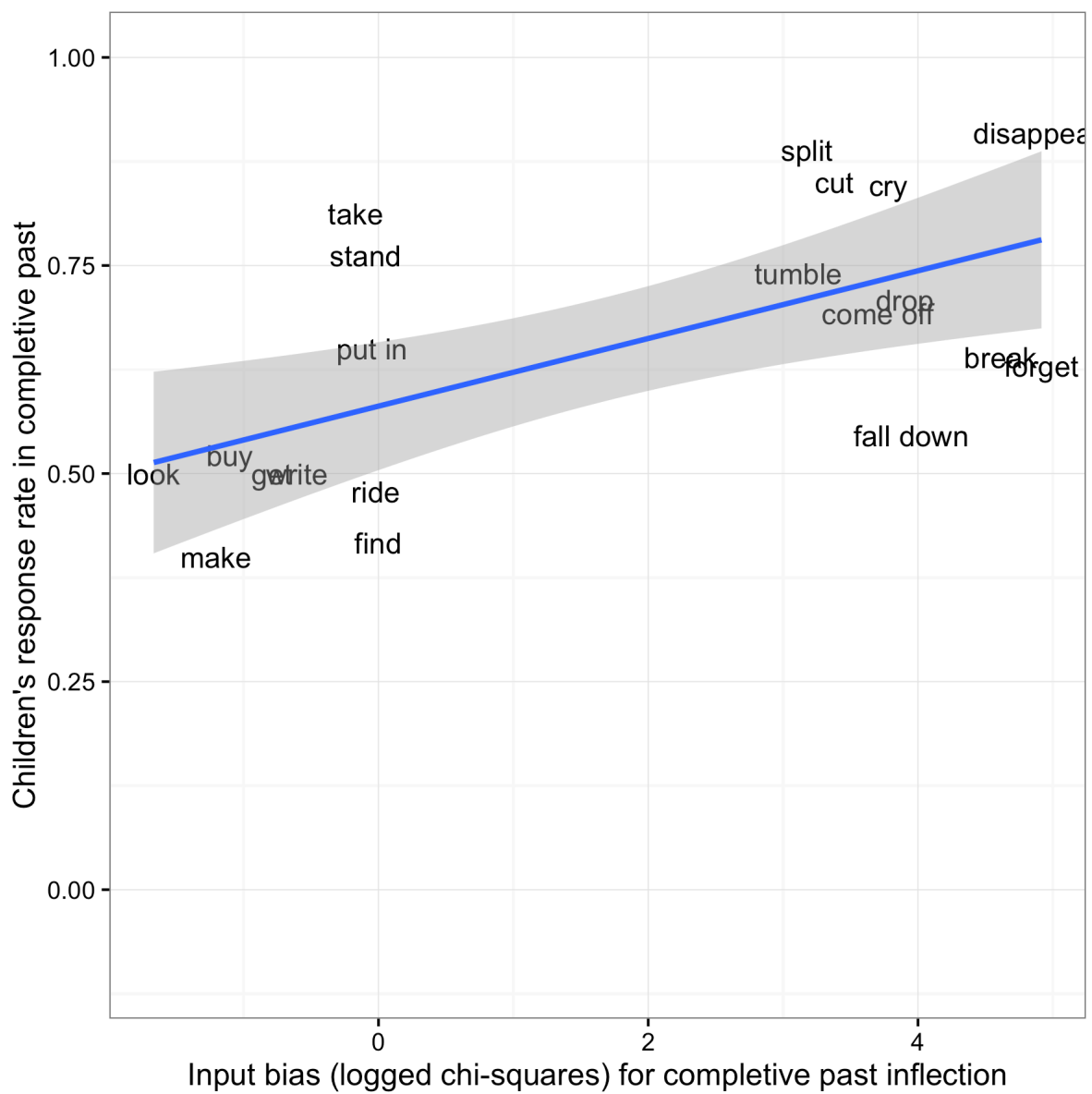
Crucially, the addition of input bias was found to significantly increase model fit (Beta=0.38,

SE=0.15, χ^2= 5.44, p=0.02; see Fig. 3). Unlike in Study 1, all but one of the verbs selected as

simple-biased (*mitsuke*, 'find') did indeed show this bias, relative to the verbs in the corpus as

a whole, on the chi-square measure (i.e., the chi-square measure has a negative value). The

interaction between these factors did not reach significance (Beta=0.02, SE=3.00, χ^2= 5.44,

p=0.08) (though see Footnote 1).

In summary, the findings of Study 2 show that children's choice between simple

and completive past forms reflects the probabilistic patterning of these whole inflected forms

in the input language. More broadly, these findings suggest that children's knowledge of

different inflectional forms reflects the relative strength of these forms in the input, and that

the failure of Study 1 to find such an effect is a reflection of our failure to select verbs that

were sufficiently biased towards simple-past forms.

4.   General Discussion

The goal of the present study was to investigate whether effects of input frequency,

as observed in a large number of previous studies, hold after controlling for a potentially

confounding factor present in virtually all previous studies: morphophonological complexity.

The present study focused on Japanese verb inflection, which constitutes a particularly

suitable test case because morphophonologically complex forms outnumber simple forms for

some verbs, but are less frequent for others. Across both experiments, the prediction of a

frequency-based account is that the likelihood with which children produce simple versus

complex forms for each verb reflects the relative frequency of the two forms in the input.

Such an effect was found for simple versus complex *completive* past forms (Study 2), but not

for simple versus complex *stative* past forms (Study 1).

Although, at first glance, the findings of Study 1 might appear to constitute

evidence against a frequency-based account, closer inspection of the set of verbs revealed (as

well as a number of outliers) an insufficient number that were truly biased towards the simple

past form. Although all verbs selected as "simple-past-biased" verbs were more frequent in

simple- than stative-past form in the input corpus, for all but three, the extent of the bias was

smaller than for verbs in the corpus in general. This problem is difficult to avoid for statives,

because the design of the experiment requires that all verbs selected be relatively natural in

stative past form, hence ruling out verbs with a large simple-past bias.

For Study 2, we therefore replaced statives with completives as the complex past

form. The fact that the predicted effect of input frequency emerged in this study provides

support not only for frequency-based accounts, but also for the possibility that the failure to find such an effect in Study 1 was due to the methodological problems addressed by Study 2.

Nevertheless, two other differences between the two studies merit further consideration. First, for Study 2 (completives), the observed rates of simple versus complex form production across verbs were essentially as would be expected on the basis of the input sample, with no clear outliers. In contrast, for Study 1 (statives), one verb (*mat,* 'wait') and three verbs (*taore,* 'fall down'; *kakure,* 'hide'; *wasure,* 'forget') were produced in their complex stative form considerably more and less often respectively than would be expected on the basis of the input. (Indeed, recall that the input predictor reached statistical significance with these outliers removed). One possible explanation for these outliers is an effect of semantics. Waiting, by its very nature, tends to be a stative activity, while falling-down and (possibly) hiding and forgetting tend to be more eventive or dynamic. Although we do not see any clear semantic tendency that could define the simple-biased and complex-biased verbs used in the study, these outlier verbs seem to highlight a point that is central to the present article; that any investigation of frequency effects must take great care to control for potentially confounding factors such as morphophonological complexity (which we controlled for largely successfully) and verb semantics (which we did not).

This brings us to the second important difference between the two studies. Although both stative (Study 1) and completive (Study 2) inflections mark aspectual distinctions and are roughly equivalent in terms of morphophonological properties (-*te* vs -*chat*), they differ with regard to the semantic distinction that each makes compared to the simple form. In particular, completive forms would seem to be more semantically marked – relative to simple forms – than stative forms. While completive inflection conveys some unexpected or unwanted, often negative implications, statives are more contextually and emotionally neutral. This could explain why children seemed to be relatively insensitive to the priming manipulation for statives (Study 1) as compared to completives (Study 2).

Before we end by drawing out a number of theoretical implications of the present findings, it is important to consider the extent to which the findings generalize to children's everyday language use. In terms of the *absolute* rates of simple versus complex verb forms produced, it is clear that children's behaviour in the experiment is very different from their behaviour in more everyday contexts. Across both studies, the vast majority of verbs were produced in complex form at a rate of between 50% and 80%, as opposed to around 10% in everyday language use. This is almost certainly due to our priming of complex forms; a conclusion supported by the fact that, at least for Study 2, the rate of complex-form

production increased over the course of the study. Presumably, had we not primed complex

forms, children would have produced them at a rate of 10%, or – given that the picture

contexts gave no particular reason to use complex over simple forms – even lower.

However, in terms of the *relative* (rather than absolute) rates of simple versus

complex form production across verbs, the finding of a correlation between children's

production data and distributional corpus data (albeit from adult speakers) is in itself

evidence that the findings of this study generalize to everyday spoken Japanese. We can see

no plausible mechanism by which boosting the usage of complex forms either (a) overall or

(b) at an increasing rate as priming built up over the course of the study could yield the

observed by-verb pattern (given that trials were always presented in random order)

Given that the priming methodology almost certainly considerably boosted the use

of complex forms, the present results do not constitute evidence that frequency *trumps*

morphophonological or semantic complexity. Presumably even the verbs with the highest

proportion of complex uses would have been produced overwhelmingly in simple form, had

we not primed complex forms[v]. What the results do show is that if we *control for*

morphophological complexity – by effectively asking children to produce a complex form on

every trial, an effect of relative input frequency is still observed.

The present study therefore provides perhaps the clearest evidence to date for an effect of input frequency on children's acquisition of inflectional morphology. Most – indeed, perhaps all – previous studies that have found apparent effects of input frequency in this domain have failed to control for morphophonological complexity (i.e., for the fact that high-frequency forms tend to be shorter and simpler). By focusing on a system that shows by-verb variation in the relative frequency of simple and complex forms, the present study has allowed us to investigate, and demonstrate, an effect of input frequency, controlling for morphophonological complexity.

From a broader language-acquisition perspective, these types of frequency effects (see Ambridge et al., 2015 for a review) are clearly most straightforwardly compatible with input-based constructivist accounts, under which systems of inflectional morphology – and, indeed all linguistic subsystems – are built gradually on the basis of the input. They are not necessarily incompatible *per se* with accounts that assume innate knowledge of formal categories, principles or parameters (see, for example, Yang, 2004). They do, however, present a considerable challenge in that such accounts need to incorporate a role for input-based learning and at the same time explain exactly what role in the learning process is

being played by innate formal knowledge (whose inclusion has traditionally been motivated

by the presumed insufficiency of input-based learning).

From a broader cognitive-science perspective, these findings contribute to a

growing body of evidence which suggests that effects of input frequency are ubiquitous in

almost every domain of human and animal learning and behaviour, including music (e.g.,

Temperley, 2007), mate-choice (Grammer & Thornhill, 1994) and solving logic puzzles

(including, for pigeons, the famous Monty-Hall problem; Herbranson, & Schroeder, 2004).

They also add to a growing consensus that what is important in learning is not raw frequency

(after all, in absolute terms, most of the complex forms elicited in the present study are

extremely rare), but contingency: the link between a "predictor" (here, the verb root) and a

particular "outcome" (here a simple vs a completive form), relative to the background rates of

those occurrences (here, overall rates of simple vs completive forms in the corpus, collapsing

across all verbs). In fact, the importance of contingency has long been appreciated in the

animal learning literature (e.g., Rescorla & Wagner, 1972), it has only recently begun to

make inroads into the domain of cognitive science and, in particular, language acquisition

(e.g., Ramscar, Dye & Klein, 2013; Ramscar, Sun, Hendrix and Baayen, in press).

In conclusion, the present research (particularly Study 2; completives) provides

support for the prediction of an input-based account that the relative accessibility or

representational strength of simple and complex forms of the same verb is related to the

relative frequency of these competing forms in the input. The challenge for future work is to

situate these types of competition effects into an account of the acquisition of inflectional

morphology that is consistent with what we know about both language acquisition and human

learning in general.

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i The stative form diachronically is a reduced form from the combination of connective *-te* and subsidiary verb *i-* 'be, exist' (cf. Kudo, 1995). Therefore *tabe-te-ta* is reduced from a compound verb construction *tabe-te i-ta*, and the reduced form is common in spoken Japanese.

ii The completive form is also a reduced form, and the non-reduced construction consists of connective *-te* and a subsidiary verb *shimaw-* 'end'. The reduced form is very common in spoken language.

iii Another advantage of focusing on this system is that the agglutinative nature of Japanese verb inflection (verbs can be modified by attaching one or many morphemes) allows a clear definition of the simple and complex forms, compared to more fusional systems like Spanish person/number marking (e.g., *-a* (3rd person singular) is more prototypical than *-amos* (1st person plural) in terms of phonology but not necessarily of morphology or of function).

iv To the extent that the non-significant interaction is interpretable, the positive sign suggests that the effect of input bias – though itself non-significant – showed a tendency to increase slightly over the course of the experiment.

v Consequently, our results do not straightforwardly constitute evidence against account under which children proceed developmentally from simple forms to complex forms by the addition of morphemes (Iwate, 1981; Takanashi, 2009).