Memorization and Learning with no Feedback in the German Case System

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Abstract

An essential element in second language acquisition is the ability the memorize and learn many small grammar rules about the given language. In german in particular, the case system of modifying articles adds a degree of difficulty to english speakers learning the language. In this study, we look deeper into this memory aspect of language learning, where human participants and a model built from ACT-R are to learn new articles, translations, and rules governing these articles once and are expected to remember the facts as the experiment continues. From our model we predicted a downward trend in response time, and a semi-U-shaped curve in regards to accuracy. Likewise we found in testing on humans our results are again seen. These findings can be seen as a mixture of the fan effect and primacy/recency effect where with no feedback there is a general decreasing trend in accuracy, but a few areas of increase in accuracy when more familiar articles are seen and a decrease in timing taken to respond.

Background

In German there are four main cases, Nominative, Accusative, Dative, and Genitive where, unlike English which has lost almost all forms of declension, depending on the specific case of a noun its accompanying article will be inflected in a certain way. Nominative is the subject of a sentence, that which carries out the action. Accusative is the direct object, that which is acted upon. Genitive is the possessor of something. And finally Dative is the indirect object, as in when an object is given to someone.

As an example, here is an english phrase,
The ***man*** *tells a* ***story*** *to the* ***child*** *of the* ***woman****.*

Translated verbatim is the grammatically incorrect german translation,
Der ***Mann*** *erzählen eine* ***Geschichte*** *das* ***Kind*** *die* ***Frau***

To correctly translate this german phrase one needs to know the gender of the noun in question, its case, and finally the inflection that corresponds to these facts. Looking at ***Mann*** because it is the subject of the sentence we know it's nominative and given prior knowledge we could know ***Mann*** is also masculine. Thus we could look up a case table and see that the correct inflection is

Definite Articles (the)				
Fall Case	**Männlich** Masculine	**Weiblich** Feminine	**Sächlich** Neuter	**Mehrzahl** Plural
Nom	**der**	**die**	**das**	**die**
Akk	**den**	**die**	**das**	**die**
Dat	**dem**	**der**	**dem**	**den**
Gen	**des**	**der**	**des**	**der**
Indefinite Articles (a/an)				
Fall Case	**Männlich** Masculine	**Weiblich** Feminine	**Sächlich** Neuter	**Mehrzahl** Plural
Nom	**ein**	**eine**	**ein**	**keine***
Akk	**einen**	**eine**	**ein**	**keine***
Dat	**einem**	**einer**	**einem**	**keinen***
Gen	**eines**	**einer**	**eines**	**keiner***
*__Note:__ *keine* is the negative of *eine*, which has no plural form. But *keine* (no/none) can be used in the plural: "Er hat **keine** Bücher." (He has no books.) - "In Venedig gibt es **keine** Autos." (In Venice there are no cars.)				

in fact *Der* (Shmitz, 2010). However, looking at ***Frau*** because it is the possessor of something and that it is feminine we can look to the table to see that the correct article inflection is in fact, *der.*

If we were to translate the english phrase correctly we would get the grammatically correct german phrase,

*Der **Mann** erzählt eine **Geschichte** dem **Kind** der **Frau**.*

In the case of our experiment, the only words in question are the articles which must be decided if they are correctly translated or not.

The Experiment

In this experiment we sought to understand memory in the application of learning the german article case system. We had eight english-speaking volunteers with no knowledge of the german or comparable case systems (such as in Latin) participate in this experiment to compare with the ACT-R model. In the experiment, participants were given a short explanation prior about the conceptual idea of the case system in much the same way as described in the background above. After this short explanation of case and instructions on performing the experiment, participants would begin the ACT-R human test ((germanCase-experiment 'human)). The test was split into 12 rounds with a total of 186 trials for participants to complete, generally taking 20-30 minutes. In the experiment, prior to every new round two new facts from the above article-table would be presented to the subject. These facts would be presented

```
the/of the/to the

der is the masculine, nominative case
```

```
a/an/of an/to an

ein is the masculine, nominative case
```

sequentially one after the other for 10 seconds each, where the subjects were expected to memorize the facts to the best of their ability. Once both facts are shown the round begins with 2 sentences; an english sentence and a possibly incorrect german translation.

English:	a	crab	kills
German:	der	Krebs	totet

In the sentence the participants are to look at the pink highlighted word and type “A” if the highlighted translation was correct and “Z” if it was incorrect. In order to answer the question the subject must identify the case (nominative, accusative, dative, or genitive), the gender (masculine, feminine, neuter), and then remember if the given german article correctly corresponds given this context. The latter fact is provided in that red nouns are masculine, blue nouns are feminine, and green nouns are neuter, and the former fact can be logically deduced from the definition of the cases as given in the background. Once a participant has answered, no feedback would be provided but instead will go on to the next trial.

As rounds progress the sentences get longer and the subject will be expected to remember facts from previous rounds in order to answer correctly.

English:	a	man	breaks	the	fruit
German:	eine	Mann	bricht	den	Frucht

Once the experiment is complete the data is printed onto a text file with two tuples of numbers for each round corresponding to whether a given trial was right or wrong and the response time the subject took to answer said question.

The Model

The ACT-R Model is provided the same experiment as the human subjects, except in place of visually picking up the study facts presented at the beginning of each round, prior to each round the facts, two chunks called grammar-fact, are merged into declarative memory, which represents the facts to be memorized.

```
(defun add-study-fact-to-memory (round)
  (merge-dm-fct (list (list 'isa 'grammar-fact
                          'word (nth 0 (nth round *definite-case-rules*))
                          'gender (nth 1 (nth round *definite-case-rules*))
                          'gcase (nth 2 (nth round *definite-case-rules*))
                          'definite "1")))
  (merge-dm-fct (list (list 'isa 'grammar-fact
                          'word (nth 0 (nth round *indefinite-case-rules*))
                          'gender (nth 1 (nth round *indefinite-case-rules*))
                          'gcase (nth 2 (nth round *indefinite-case-rules*))
                          'definite "0"))))
```

With this, the model loops through every round and within every round, a loop of trials are called. At this point the model is run and tries to solve the trial question. It does so with partial matching and base-level activation enabled to simulate grammar-facts being given and decaying with time with no feedback.

```
(define-model germanCases
(sgp :rt -3 :esc t :v nil :act nil :ans 0.5 :mp 2.35 :lf 2.85 :bll 0.25 :mas 1.6)
```

The model begins by first finding the highlighted, unintended article in question and then attending to that visual-location.

```
(p find-unattended
   =goal>
     ISA          goal
     state        start
    ==>
    +visual-location>
       ISA          visual-location

       color        pink
       < screen-y     125
   =goal>
       state      attending)

(p attend-to-english-article
   =goal>
     isa       goal
     state     attending
   =visual-location>
     ISA          visual-location
  ?visual>
      state       free
==>
  =goal>
     state        articlesearch
  =visual-location>
  +visual>
     cmd          move-attention
     screen-pos   =visual-location)
```

Once it has done so it decides whether the article is definite or not. Because it is supposed to model a native english speaker I simply put in what constitutes a definite and indefinite article by having it pattern match on the respective articles. Once it has decided it is definite or indefinite it moves focus to the nearest noun, this is the noun that modifies the noun and in it, it makes a retrieval request for the gender-fact which maps a color to a gender. Because gender-facts are given, I gave them very high levels of activation.

```
(p is-definite
 =goal>
    ISA         goal
    state       articlesear
 =visual>
   ISA          visual-obje
   value        =char
   - value      "a"
   - value      "ofXa"
   - value      "toXa"
 =visual-location>
    < screen-y   125
    screen-x    =currx
 ?imaginal>
    buffer     empty
    state      free
 ==>
 +imaginal>
    isa      grammar-fact
    definite "1"
 +visual-location>
    > screen-y    125
    > screen-x    =currx
    - color       pink
    - color       black
    :nearest    current-x
 =goal>
    isa       goal
    state     gendersearch)
```

```
(p not-definite
=goal>
   ISA        goal
   state      articlesearch
=visual>
  ISA         visual-object
  value       =char
  - value     "the"
  - value     "ofXthe"
  - value     "toXthe"
=visual-location>
   < screen-y   125
   screen-x   =currx
?imaginal>
   buffer    empty
   state     free
==>
+imaginal>
   isa      grammar-fact
   definite "0"
+visual-location>
   > screen-y    125
   > screen-x    =currx
   - color       pink
   - color       black
   :nearest   current-x
=goal>
   isa      goal
   state    gendersearch)
```

```
(p find-gender
  =goal>
     isa      goal
     state    gendersearch
 =visual-location>
     color    =col
     - color pink
     - color black
 =imaginal>
 ?retrieval>
     buffer     empty
     state      free
 ==>
 +retrieval>
     isa        gender-fact
     col      =col
 =imaginal>
 =visual-location>
 =goal>
     isa        goal
     state      casesearch)
```

After this one of four productions is called, is-nominative, is-accusative, is-dative, or is-genitive. Due to the simplicity of the sentences given and the intuitive nature of the cases themselves as concepts to an english speaker, I simplified the model so that it simply checks what position in the sentence the noun is. If it is the first noun it is nominative, if it is the second it is accusative, third dative, and fourth genitive. Once it finds a production that matches it has all that it needs to make a guess. It thus then moves its attention to the english article while making a request in declarative memory for an article that matches the gender, case and indefinite/definiteness of the german version in question.

```
(p is-nominative
 =goal>
    isa      goal
    state    casesearch
 =visual-location>
    - color pink
    - color black
    < screen-x 250
 =imaginal>
    isa       grammar-fact
    definite =val
 =retrieval>
    isa       gender-fact
    gender   =gen
 ==>
 +retrieval>
    isa       grammar-fact
    gender    =gen
    gcase     "nominative"
    definite =val
 -imaginal>
 +visual-location>
    color     pink
    > screen-y 125
 =goal>
    isa       goal
    state     respond)
```

```
(p attend-to-german-article
    =goal>
      isa       goal
      state     respond
    =visual-location>
     ISA          visual-location
   ?visual>
      state       free
==>
   =visual-location>
   +visual>
     cmd          move-attention
     screen-pos   =visual-location
    =goal>
      isa     goal
      state   final)
```

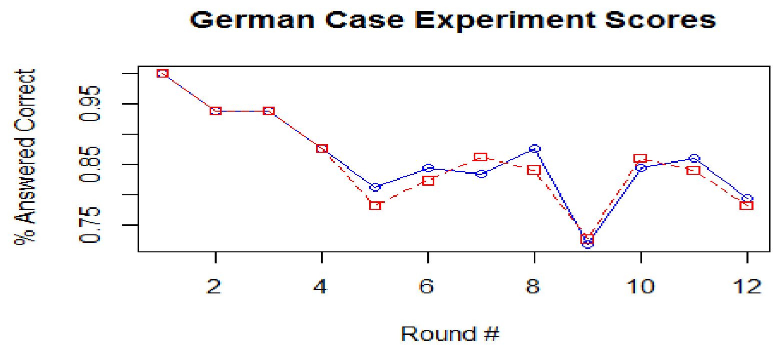
At this point, the model will match the retrieved article (because partial matching is enabled) against the article in its visual location, if the two match that means given the facts of the sentence it thinks the translation is correct and will reply “A”, else it will reply “False”, and so it ends the trial. Once the model is finished looping through all rounds and all trials within each trial it returns a text file just like in the human participants.

To run the model type in (germanCase-experiment), to run as a human type in (germanCase-experiment ‘human).

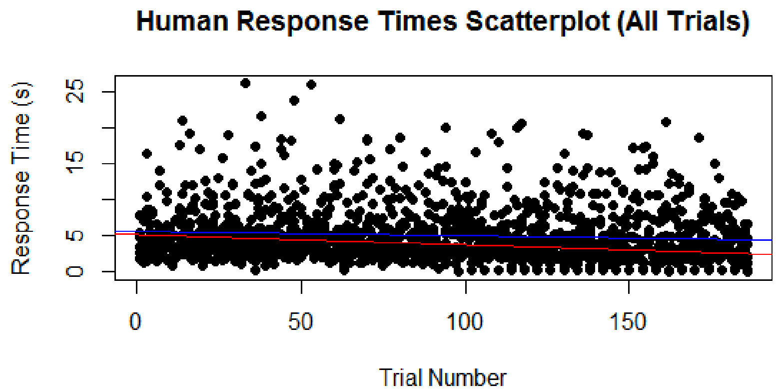
Results

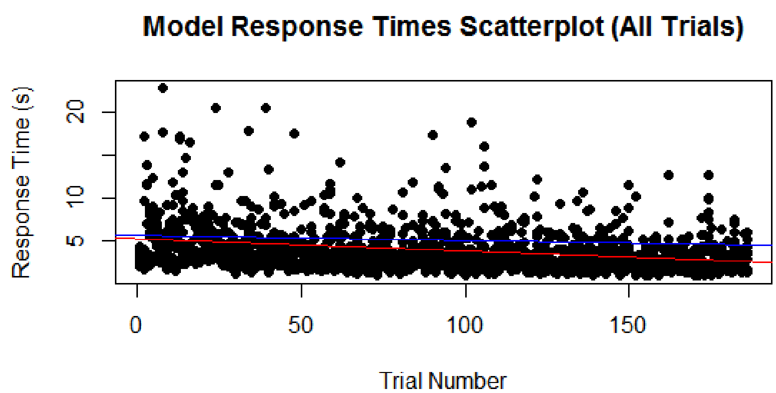
The results of these experiments were found by running the experiment and model as indicated above. The printed data is then put into Rstudio where the response times of all 8 human subjects and 8 random calls of the model are plotted on a scatterplot, and the mean response accuracy of each round is plotted on a simple line graph.

Below are the results from the responses of both groups with the model in red and human participants in blue.

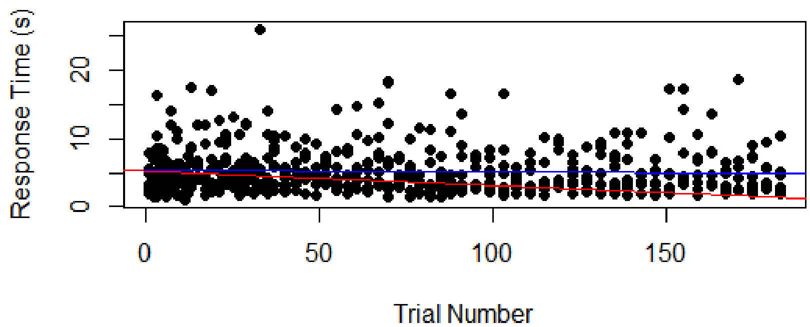


Along with the accuracy are results of the timing data represented below as scatter plots with the model's best fit in red and the human's best fit in blue, and their associated data in the right and left sides respectively.

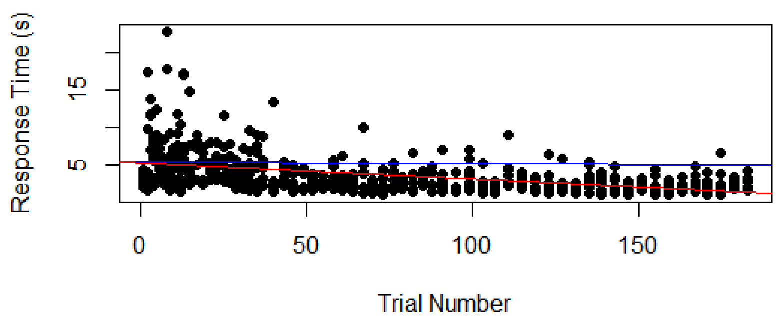




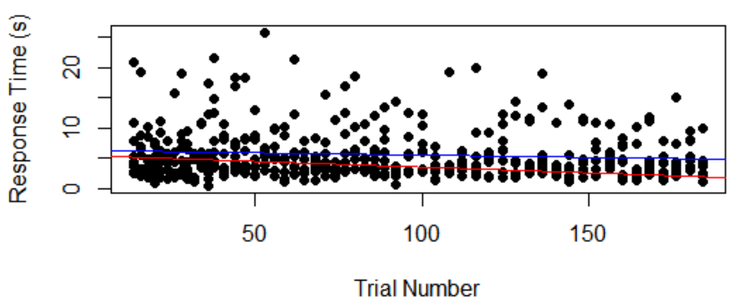
Human Response Times Scatterplot (Nominative Trials)



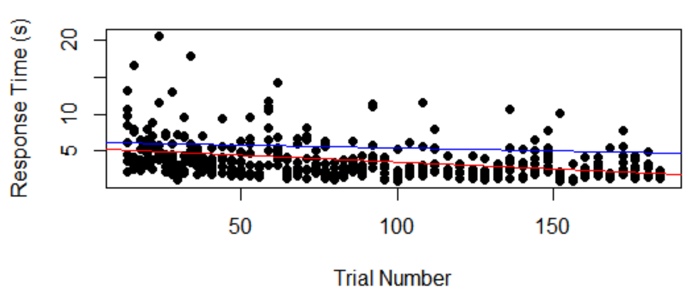
Model Response Times Scatterplot (Nominative Trials)

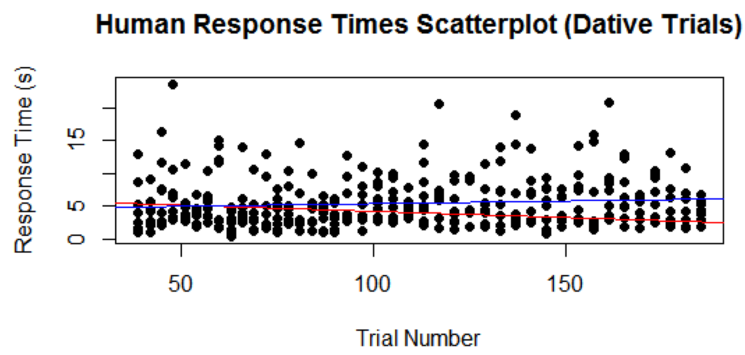


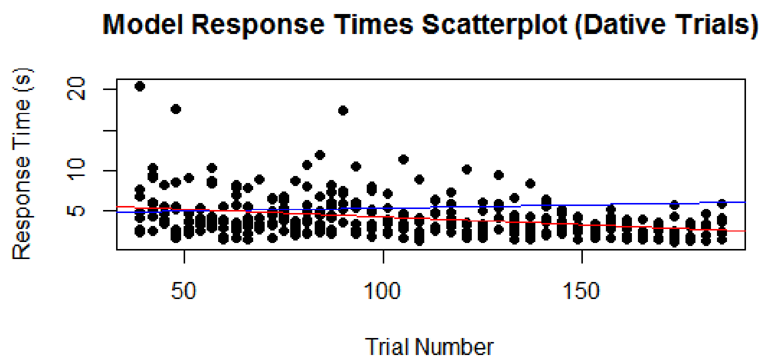
Human Response Times Scatterplot (Accusative Trials)

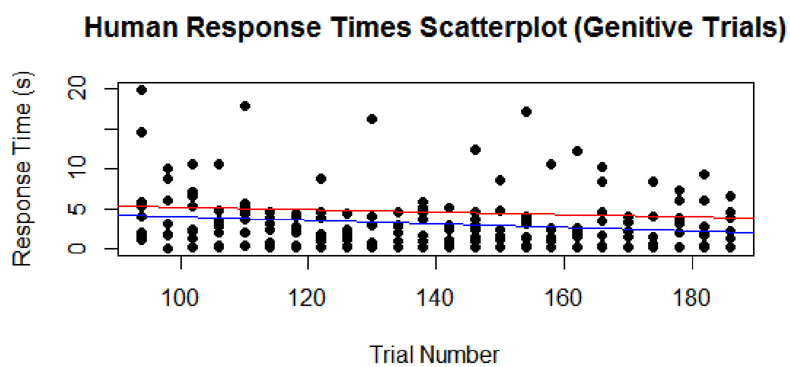


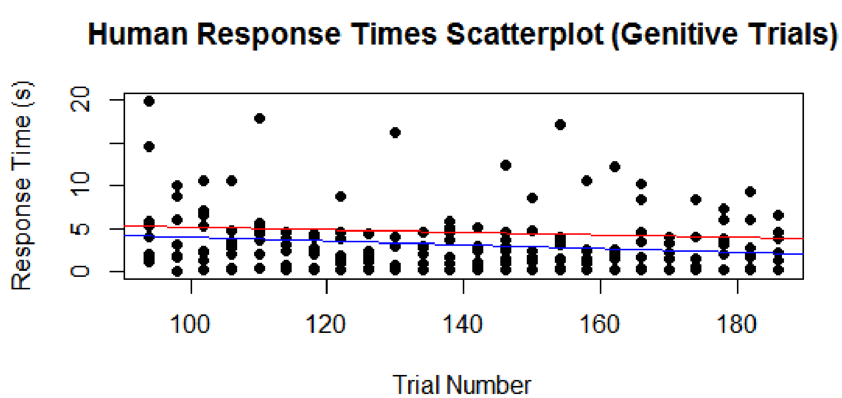
Model Response Times Scatterplot (Accusative Trials)




Human Response Times Scatterplot (Dative Trials)
Response Time (s)
0
5
15
50
100
150
Trial Number


Model Response Times Scatterplot (Dative Trials)
Response Time (s)
5
10
20
50
100
150
Trial Number


Human Response Times Scatterplot (Genitive Trials)
Response Time (s)
0
5
10
20
100
120
140
160
180
Trial Number


Human Response Times Scatterplot (Genitive Trials)
Response Time (s)
0
5
10
20
100
120
140
160
180
Trial Number

Analysis

Both the models and the human subjects appear in terms of accuracy to start at 100% accuracy and gradually decline with more facts being introduced. While the model has since been fitted by adjusting the latency factor (:lf) and partial matching parameters (:mp), prior to testing the model predicted a gradually decline in accuracy, a big dip in inaccuracy at around round 9, and gradual increase in accuracy afterward, which later appeared in the human data as well. However, from running the experiments on humans we noticed there also was a small increase in accuracy before the drop off predicted by model around round 9 and a small dip at around round 12. After adjusting the previously mentioned parameters these effects became more prominent.

While unintuitive initially there are some possible explanations for the results. First, the small increase in accuracy between rounds 5-8 could be attributed to the similarities between different articles. Prior to that point nearly all articles were unique and so there was more to memorize leading to significant decrease in accuracy, however around the accusative and dative cases a few articles (such as der, das, and die) could match to multiple cases (as indicated by the table above), this suggests that perhaps a variant of the fan-effect is occurring whereby the model and participants make associations between different instances of articles and thus are strengthened in declarative memory resulting in more accurate answers. This would also explain the gradual increase after the sharp drop at round 9 since these articles (einer and der) have also already been introduced as instances of different cases. The sharp decrease in accuracy around round 9 could simply be the result of too much cumulative facts for the model and people to handle.

The timing of both the model and the human participants was generally pretty sporadic as shown by the scatter plots, though the variance among the model was significantly more stable than the human participants. Both did show a slight decline in response time with more trials, and this could be attributed to familiarity with the format of the experiment being more decisive than the increased difficulty of recalling facts. This is seen in all the kinds of article facts except in the human dative case. Interestingly enough at this point the timing actually increases slightly though nearly constant, while the model decreases as in the other cases. This may correspond to the drop around round 9 where the sharp decrease and increase in response time may correspond to the an increased difficulty in the dative cases.

Conclusions and Reflection

Ultimately this experiment shows the relationship between associations in declarative memory of different facts can have a notable effect on learning an aspect of language, in our situation the german article system, and also the relationship and trade off between being trained on more data and the decay in activation of some of these facts due to recency. These associations as shown in our data can lead to increased accuracy with familiar words and a decrease in time taken to answer facts about these words. However with no feedback and being forced to remember facts leads to a general decline in accuracy in spite of the decline in response times.

There are still some issues with the experiment and the model, because the sample size of human participants for this experiment was so small there was quite a bit of variation, as evidenced by the response times above in the human data. As a result while my model did predict a few key features present in the human data, it still had to have its parameters to be adjusted to match some other features which may or not be present in a sufficiently large sample of humans.