Filler-gap dependency processing by Japanese ESL learners, whose L1 is not an obligatory wh-movement language*

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1. Introduction

In English sentences, wh-phrases have to be moved from their original position to the clause initial position. Nevertheless, they need to be interpreted in their original position, and assigned a theta role (semantic role) there. For example, in (1) below, the initial wh-phrase *which car* is the object of the verb *buy*, and therefore needs to be interpreted after *buy*. In addition, *buy* gives *which car* a theta role named theme (the topic of discussion).

    (1) Which car did the man buy?

In sentence processing, a displaced element like an English wh-phrase is called a *filler*, and its original position the *gap*. In order to understand a sentence with displacement, readers need to determine the filler-gap dependency correctly; they first build the dependency and then interpret the semantic relationship. If they have a problem with the interpretation, they revise the position of the gap and repeat the same procedure. When they read the theta-role assigner (*buy* in (1)), they build a filler-gap dependency to postulate the gap as early as possible (known as the active filler strategy, e.g., Frazier and Clifton 1989).

        Filled-gap effects are psychological evidence of a gap and an active filler strategy; when a direct object appears, the reading time (RT) increases due to the processing burden. For instance, readers of (2) search for the gap corresponding to the filler *which car*.

    (2) Which car did the man buy the radio for?

When they reach the verb *buy*, which is usually transitive, they build a filler-gap dependency and then interpret the semantic relationship. However, when the direct object *the radio* appears and the anticipated gap position is already filled, they revise the anticipation and continue searching for the gap. Consequently, a processing delay reflecting the original anticipation could be predicted, and has been observed (e.g., Stowe 1986).

Plausibility effects (e.g., Traxler and Pickering 1996) are another piece of evidence for a gap and an active filler strategy. It became apparent that filler-gap dependency processing is affected not only by syntactic structure but also by a semantic relationship between the filler and the verb in front of the gap. As an example, in (1), (2) and (3), below, a gap corresponding to the filler is first postulated immediately after *buy*.

(3) Which friend did the man buy the radio for?

The semantic relationship between *which car* and *buy* is plausible as in the sentence *the man buys a car*. On the other hand, in (3) that between *which friend* and *buy* is implausible as in the sentence *the man buys a friend*. Thus, the readers of (3) build a filler-gap dependency on reading the verb *buy*, but later recognize implausibility through the interpretation of the semantic relationship. As a result, they require additional RT to revise the position of the gap. By contrast, when they read the direct object *the radio*, no filled-gap effects occur because they have already revised the position of the gap (if they did not calculate the semantic relationship at the verb, no plausibility effects would be observed when they read *buy*, but instead filled-gap effects would occur when they read *the radio*).

Plausibility effects reflecting active gap filling are confirmed not only in native English speakers' but also in ESL learners' filler-gap dependency processing. Omaki and Schulz (2011) experimented on L1-Spanish L2-English learners, and identified plausibility effects immediately after reading verbs. They concluded that Spanish learners build the dependencies on reading the verbs and immediately calculate plausibility of the dependencies. Felser et al. (2012) confirmed that plausibility effects likewise apply to L1-German L2-English learners. However, Spanish and German are obligatory wh-movement languages,

whereas Japanese is not. L1-L2 syntactic similarity and difference affect L2 processing (Foucart and Frenck-Mestre 2011). Therefore, the present study investigates when L1-Japanese L2-English learners calculate the meaning of a sentence in real-time processing. Specifically, two research questions were investigated:

i. Do L1-Japanese L2-English learners build filler-gap dependencies immediately after they read verbs (*buy* in (3)), causing plausibility effects at verb regions?
ii. Do L1-Japanese L2-English learners interpret semantic relationship of the dependencies as soon as they build the dependencies? Is there no filled-gap effects at direct objects (*the radio* in (3)) in sentences with semantically implausible dependencies?

2. Experiment

2.1. Materials

The target sentences for the experiment were designed as shown in example (4). The sentences are divided into seven or eight regions (abbreviated as R) by slashes.

(4)
Plausible-Gap Condition

	R1	R2	R3	R4	R5

(a) I wonder / which car / the man / bought / the radio /

	R6	R7

for / two months ago.

Control for the Plausible-Gap Condition

	R1	R2	R3	R4	R5

(b) I wonder / whether / the man / bought / the radio /

	R6	R7	R8

for / the car / two months ago.

Implausible-Gap Condition

	R1	R2	R3	R4	R5

(c) I wonder / which friend / the man / bought / the radio

	R6	R7

/ for / two months ago.

Control for the Implausible-Gap Condition

R1	R2	R3	R4	R5

(d) I wonder / whether / the man / bought / the radio /

R6	R7	R8

for / the friend / two months ago.

In (4a) and (4c), the filler (*which car* / *friend*) is in Region 2 and the corresponding gap is between Regions 6 and 7. Nonetheless, in (4a) the semantic relationship between Regions 2 and 4 (*bought*) is plausible, while in (4c) it is not. Sentences (4a) and (4c) are consequently labeled as Plausible-Gap and Implausible-Gap respectively. In order to provide a baseline for comparison, non-gap counterparts, (4b) for (4a) and (4d) for (4c), were added, making a set of four sentences. In these control sentences, *whether* is used in Region 2 (antecedent) instead of the filler to eliminate the gap, and thus the object (*the car* / *friend*) is in Region 7 (the original position).

Twenty-four sets of the quadruplet sentences (a total of 96 target sentences) were prepared. (The complete set of the target sentences can be found in the appendix.) Distractor sentences (filler sentences) were also included to add variation to the items which the participants read. In addition, nine example sentences were prepared as practice before the experiment. The target and distractor sentences were divided into four lists using Latin square design and presented in pseudo-random order. Yes/no comprehension questions were presented after these sentences in which subjects had a 50% chance of randomly selecting the correct answer. An example question for (4a) is shown in (5).

(5) Did the man buy the radio?

2.2. Participants

Twenty-six advanced Japanese-speaking learners of English (mean age 19.1, range 18–21), all of them undergraduate students at the University of Tokyo, participated in this experiment. All participants had good vision and were ignorant of the exact purpose of the study. Twenty-four of the participants began studying English grammar at the age of 12, one at the age of 10, and for the other the age is unknown. Fourteen of the participants reported the age of their first exposure to English (mean

age 9, range 2–12). The participants' proficiency in English was assessed after the main experiment using a standardized proficiency test which measures acquisition of grammar and vocabulary (the Oxford Quick Placement Test, OQPT). In this test, all participants' scores were in the range 68–93%, corresponding to B1-C2 levels in the CEFR, showing that they are at least upper-intermediate to highly advanced learners of English.

2.3. Procedure

In order to investigate the online parsing strategies of the participants, a nonaccumulative, moving-window self-paced reading task was conducted using Linger. Each participant was asked to sit in front of a computer screen and read sentences in a segment-by-segment fashion. The participants were instructed to read the sentences at a normal speed while understanding them, since the task was not a competition. Dotted lines indicating the number and length of each word in the sentence were shown on the screen before the actual words appeared. By pressing the space key, the participants could see the actual words replacing the dotted lines segment by segment (a "+" mark appeared before each sentence to direct the participants' attention to the part of the sentence that was about to appear). To ensure that the target sentences were correctly understood, about half of the sentences were followed by comprehension questions, and the participants were asked to press the F key for yes, and the J key for no. The F and J keys were labeled with a circle and a cross respectively, for convenience. Each participant read the example sentences as practice, and then the target and distractor sentences. After the participants went through about half the sentences, a message recommending a short break appeared so that the participants could rest as long as they needed. Following the break, the participants worked on the rest of the self-paced reading task and then moved on to taking the OQPT. The two tasks were finished within an hour.

3. Predictions

If L1-Japanese L2-English learners calculate semantic relation between the filler and the verb in front of the gap as soon as they determine that the gap is located immediately after the verb, the

results are predicted as shown below.

   i. An interaction between plausibility and sentence types will be observed, reflecting longer RTs for Region 4 (verb) in the Implausible-Gap condition than in its control condition, and no significant difference in RTs between the Plausible conditions.
   ii. In the Plausible-Gap condition RTs will increase due to filled-gap effects at Region 5 (direct object), whereas in the Implausible-Gap condition they will not.

The above predictions will be discussed in the results section.

4. Results

The experimental data were analyzed according to the linear mixed-effects (LME) model (Baayen 2008) with plausibility and sentence type as fixed effects, and participants and target stimuli sets as random effects. This analysis was conducted by using R, a statistical software program for data calculation. The RT for each region in the target sentences is shown in Figure 1.
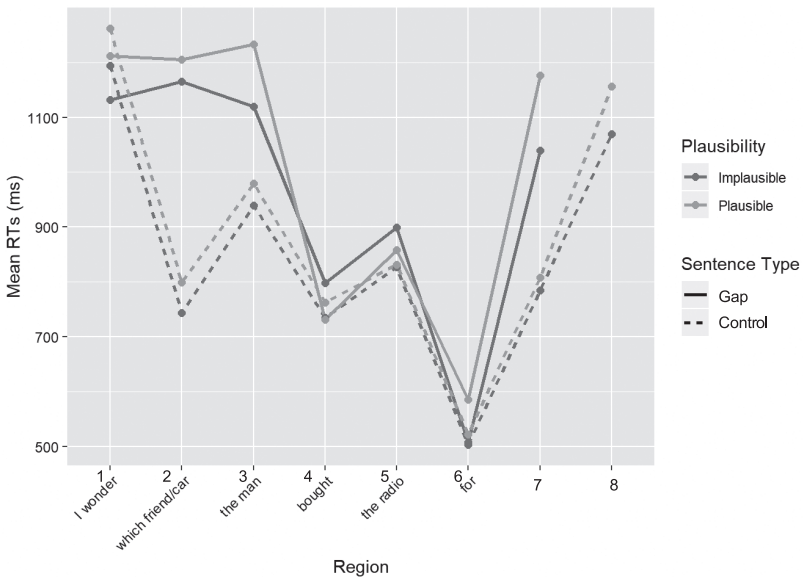

Figure 1: Reading time for each region in the target sentences

The average percentage of correct answers for the comprehension questions was 88% or higher for all sentence conditions, indicating that the participants paid attention while reading the target sentences. If a participant wrongly answered a question about a sentence, the participant's RT for the sentence was excluded from the analysis to improve its precision. The RTs for one of the 24 sentence sets with a missing word was also excluded. Detailed results for Regions 4–6 will be presented in order, below.

4.1. Region 4

As for Region 4, unnatural RTs (RT>4000 ms or RT<100 ms) were removed before the formula was applied (an exclusion of approximately 0.7% of the total data), and by adopting a backward stepwise selection (following Baayen 2008), the final formula for analysis was determined as lmer(rt ~ c.(f1)*c.(f2)+(1|subj)+(1+c.(f1)||set), REML=F). Data trimming was also done after formula selection (sd=2.5). The two factors, c.(f1) and c.(f2), represent sentence type (Gap / Control) and plausibility (Plausible / Implausible) respectively.
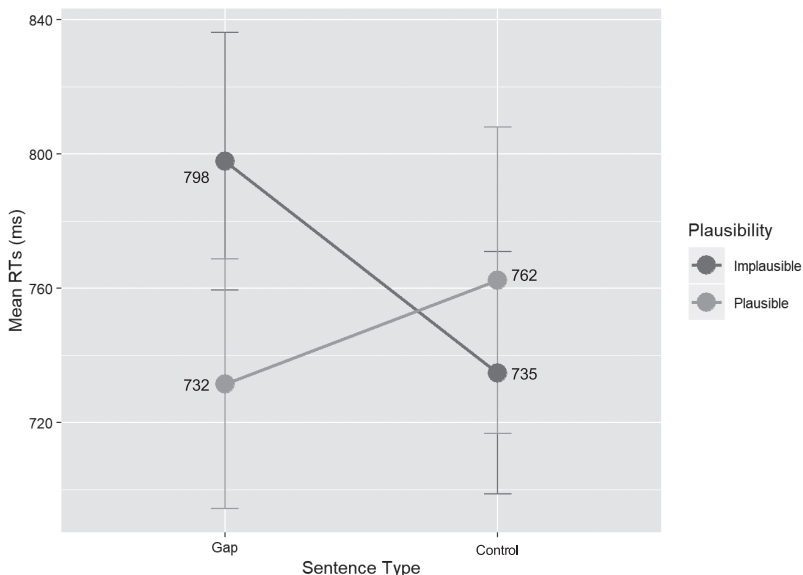

Figure 2: Estimated average mean reading times of all the participants in Region 4

Figure 2 shows the mean RTs for Region 4 in each sentence condition. The error bars indicate the standard error of the mean. The RT in the Implausible-Gap condition was the longest. In contrast, the RT in the Control for the Implausible-Gap condition was the shortest, almost as short as that in the Plausible-Gap condition.

Table 1: Fixed effects of Region 4

	Estimate	SD	df	t-value	p-value	
(Intercept)	757.05	41.25	38.63	18.351	<2e-16	***
Sentence type	−17.01	30.56	20.14	−0.557	0.584	
Plausibility	−16.46	24.75	469.11	−0.665	0.507	
Sentence type: Plausibility	100.5	49.77	469.02	2.019	0.044	*

Table 1 shows the fixed effects of Region 4. Since the focus is on the average RTs of the participants, the values in the fixed effects are the object of interest. SD and df stand for standard deviation and degrees of freedom respectively. Significance is expressed with asterisks in the p-value slot: *=P<0.05; **=P<0.01; ***=P<0.001. There were no main effects of either sentence type or plausibility, but the interaction was significant; the two lines intersect in Figure 2.

4.2. Region 5

As for Region 5, unnatural RTs (RT>4000 ms or RT<100 ms) were removed before the formula was applied (an exclusion of approximately 1.5% of the total data), and by adopting a backward stepwise selection, the final formula for analysis was determined as lmer(rt~c.(f1)*c.(f2)+(1+c.(f1):c.(f2)||subj)+(1+c.(f2)||set), REML=F). Data trimming was also done after formula selection (sd=2.5). As in the case of Region 4, the two factors, c.(f1) and c.(f2), represent sentence type and plausibility respectively.

Figure 3 shows the mean RTs for Region 5 in each sentence condition. The error bars indicate the standard error of the mean. The RTs in both the Gap conditions were longer than their controls. Additionally, the RTs in the Control conditions were nearly the same.
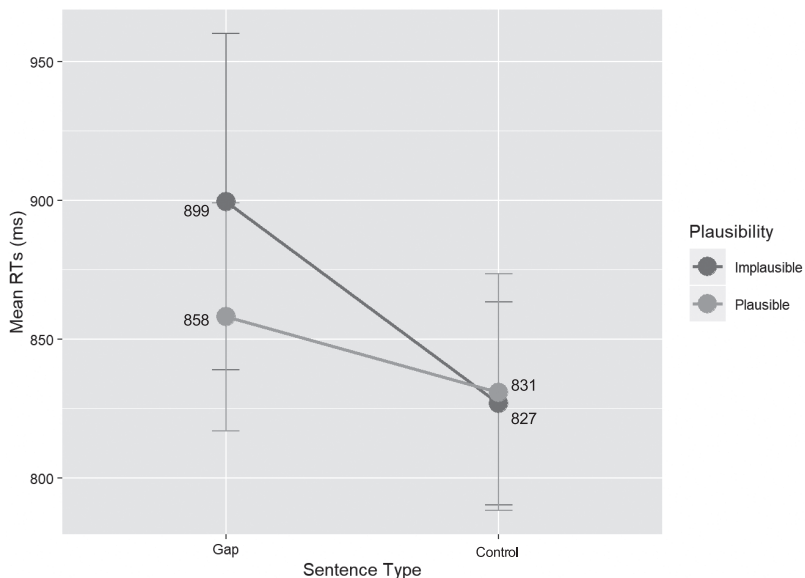
Figure 3: Estimated average mean reading times of all the participants in Region 5

Table 2: Fixed effects of Region 5

	Estimate	SD	df	t-value	p-value	
(Intercept)	858.21	41.91	34.06	20.476	<2e-16	***
Sentence type	−46.57	29.05	434.93	−1.603	0.11	
Plausibility	−10.05	42.1	23.1	−0.239	0.813	
Sentence type: Plausibility	40.67	63.63	22.95	0.639	0.529	

Table 2 shows the fixed effects of Region 5. There were no main effects of either sentence type or plausibility, and the interaction was not seen as well. Filled-gap effects were unidentifiable from the RTs for the critical region. However, there are cases in which the anticipated reaction is not seen immediately in the target region, but in the following regions (spillover regions). Therefore, an analysis of Region 6 was also done to search for a spillover effect.

4.3. Region 6

As for Region 6, unnatural RTs (RT>4000 ms or RT<100 ms) were removed before the formula was applied (an exclusion of approximately 0.3% of the total data), and by adopting a back-
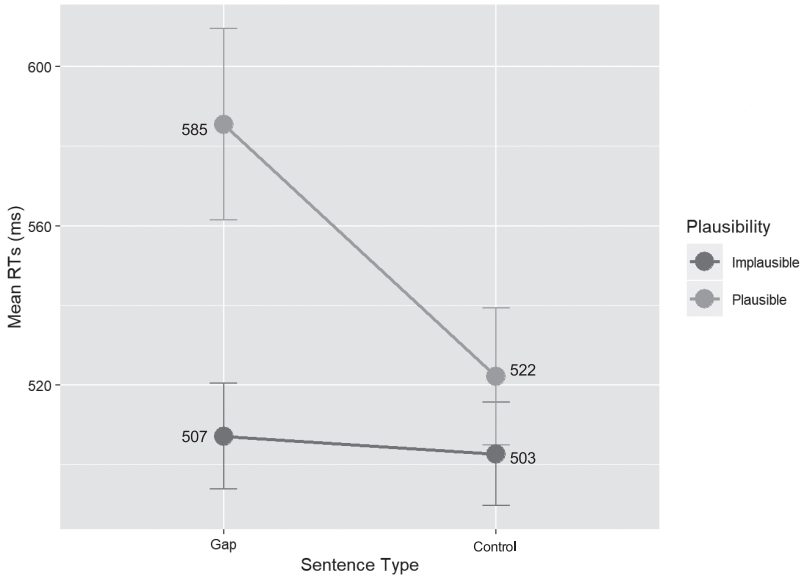
Figure 4: Estimated average mean reading times of all the participants in Region 6

ward stepwise selection, the final formula for analysis was determined as lmer(rt ~ c.(f1)*c.(f2)+(1|subj)+(1|set), REML=F). Data trimming was also done after formula selection (sd=2.5). As in the cases of Regions 4 and 5, the two factors, c.(f1) and c.(f2), represent sentence type and plausibility respectively.

Figure 4 shows the mean RTs for Region 6 in each sentence condition. The error bars indicate the standard error of the mean. The RT in the Plausible-Gap condition was the longest. The RTs in the other conditions were almost the same, but that in the Control for the Implausible-Gap condition was the shortest.

Table 3: Fixed effects of Region 6

	Estimate	SD	df	t-value	p-value	
(Intercept)	528.56	14.79	32.51	35.727	<2e-16	***
Sentence type	−29.82	11.09	483.02	−2.688	0.00743	**
Plausibility	46.74	11.09	482.66	4.215	2.98e-5	***
Sentence type: Plausibility	−49.57	22.22	482.7	−2.231	0.02612	*

Table 3 shows the fixed effects of Region 6. Both main effects were significant: Gap>Control, Plausible>Implausible. Signifi-

cant interaction was found as well; the two lines in Figure 4 are obviously not parallel. A greater filled-gap effect was observed in the Plausible conditions than in the Implausible conditions.

5. Discussion

As mentioned above, the interaction was marginally significant in Region 4, and the RTs for the verbs were longer in the Implausible-Gap condition than in the Plausible-Gap condition. This shows that Japanese learners build filler-gap dependencies as soon as they reach the verbs, and they interpret the semantic relationship immediately after the verbs. On the other hand, the RTs were longer in the Control for the Plausible-Gap condition than in the Plausible-Gap condition, contrary to the prediction. This difference may be attributed to the processing burden; *I wonder which car the man bought* in (4a) is a complete imperative sentence, whereas *I wonder whether the man bought* in (4b) is probably not, since there is no object, for instance.

Moreover, no filled-gap effects were observed in Region 5 (direct object). The effects might be neutralized by the spillover of the plausibility effects at the verb region. In fact, interaction was significant in Region 6. In this region, filled-gap effects were observed only in the Plausible-Gap condition. This supports the prediction; in the Implausible-Gap condition, the participants realized the implausibility of placing the gap at the object position in Region 4, and thus a filled-gap effect was not observed in Region 6. By contrast, in the Plausible-Gap condition, postulating the gap at the object position was valid until they read noun phrases in Region 5, so the object gap analysis was retained until then, and hence in Region 6 a greater filled-gap effect was observed than in the Implausible-Gap condition.

6. Conclusion

Previous studies identified plausibility effects in the filler-gap dependency processing not only by native English speakers but also by Spanish and German ESL learners, whose L1s are obligatory wh-movement languages. Instead, the present study performed an experiment on Japanese ESL learners, whose L1 is not an obligatory wh-movement language, and revealed the following:

   i. L1-Japanese L2-English learners build filler-gap dependencies as soon as they read verbs.

   ii. L1-Japanese L2-English learners calculate semantic plausibility of filler-gap dependencies immediately after they build the dependencies. Furthermore, they can revise the dependencies (the gap positions) by making use of semantic plausibility of the dependencies.

Future research should also focus on such factors as the number of years learning English to further investigate the processing mechanisms of Japanese ESL learners and contribute to research on English education.

Acknowledgements

Note

  * An earlier version of this paper was presented at the 19th Annual Conference of the Japan Second Language Association (Fujii and Minemi 2019).

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Appendix

1. Example sentences

This is an example sentence.

This is a practice for the experiment.

David has been to Tokyo.

The brother likes sushi but his sister doesn't like it.

I can not believe that Mary said such a rude thing to John.

The old woman gave lemmon (*sic*) candies to the child and told an old story.

Unemployment rates remain high in many countries but some economists say that the global economy is being recovered.

According to the reference materials, the racer that the engineer supports insists on the reduction of environment loads.

The leader of the delegation assumed that the idea is great, but it was not accepted by the other members of the delegation.

2. Target sentences

I wonder which car the man bought the radio for two months ago.

I wonder whether the man bought the radio for the car two months ago.

I wonder which friend the man bought the radio for two months ago.

I wonder whether the man bought the radio for the friend two months ago.

They will ask which girl the man pushed the bike towards late last night.

They will ask whether the man pushed the bike towards the girl late last night.

They will ask which river the man pushed the bike towards late last night.

They will ask whether the man pushed the bike towards the river late last night.

We know which machine the mechanic fixed the motorbike with two weeks ago.

We know whether the mechanic fixed the motorbike with the machine two weeks ago.

We know which customer the mechanic fixed the motorbike for two weeks ago.

We know whether the mechanic fixed the motorbike for the customer two weeks ago.

The question is which parcel the secretary found the bomb in early this morning.

The question is whether the secretary found the bomb in the parcel early this morning.

The question is which floor the secretary found the bomb on early this morning.

The question is whether the secretary found the bomb on the floor early this morning.

It is unknown which relative the farmer killed the chicken for two weeks ago.

It is unknown whether the farmer killed the chicken for the relative two weeks ago.

It is unknown which stick the farmer killed the chicken with two weeks ago.

It is unknown whether the farmer killed the chicken with the stick two weeks ago.

Tell me which ladder the man repaired the roof with during the holidays.

Tell me whether the man repaired the roof with the ladder during the holidays.

Tell me which friend the man repaired the roof for during the holidays.

Tell me whether the man repaired the roof for the friend during the holidays.

It doesn't matter which businessman the gangster shot the woman for late last night.

It doesn't matter whether the gangster shot the woman for the businessman late last night.

It doesn't matter which cave the gangster shot the woman in late last night.

It doesn't matter whether the gangster shot the woman in the cave late last night.

Please look into which dog the farmer chased the sheep with early this morning.

Please look into whether the farmer chased the sheep with the dog early this morning.

Please look into which hill the farmer chased the sheep up early this morning.

Please look into whether the farmer chased the sheep up the hill early this morning.

I am not certain which station the architect built the hotel beside during the summer.
I am not certain whether the architect built the hotel beside the station during the summer.
I am not certain which mountain the architect built the hotel on during the summer.
I am not certain whether the architect built the hotel on the mountain during the summer.

I can't tell which meal the chef cooked the meat for during the afternoon.
I can't tell whether the chef cooked the meat for the meal during the afternoon.
I can't tell which pot the chef cooked the meat in during the afternoon.
I can't tell (*sic*) the chef cooked the meat in the pot during the afternoon.

It's of no interest to me which bucket the lady washed the shirt in early this morning.
It's of no interest to me whether the lady washed the shirt in the bucket early this morning.
It's of no interest to me which soap the lady washed the shirt with early this morning.
It's of no interest to me whether the lady washed the shirt with the soap early this morning.

We should discuss which woman the doctor lifted the child for early this morning.
We should discuss whether the doctor lifted the child for the woman early this morning.
We should discuss which lab the doctor lifted the child in early this morning.
We should discuss whether the doctor lifted the child in the lab early this morning.

She is not sure which baby the boy dropped the toy on just after lunch.
She is not sure whether the boy dropped the toy on the baby just after lunch.
She is not sure which hole the boy dropped the toy in just after lunch.
She is not sure whether the boy dropped the toy in the hole just after lunch.

Do you know which lorry the thief crashed the car into late last night?
Do you know whether the thief crashed the car into the lorry late last night?

Do you know which wall the thief crashed the car into late last night?
Do you know whether the thief crashed the car into the wall late last night?

We have no idea which ball the boy broke the window with in the afternoon.
We have no idea whether the boy broke the window with the ball in the afternoon.
We have no idea which cat the boy broke the window for in the afternoon.
We have no idea whether the boy broke the window for the cat in the afternoon.

Tell him which machine the woman polished the floors with last night.
Tell him whether the woman polished the floors with the machine last night.
Tell him which wax the woman polished the floors with last night.
Tell him whether the woman polished the floors with the wax last night.

It makes no difference which book the author wrote the article about in 1998.
It makes no difference whether the author wrote the article about the book in 1998.
It makes no difference which war the author wrote the article about in 1998.
It makes no difference whether the author wrote the article about the war in 1998.

I'm interested in which sauce the guy boiled the meat in last week.
I'm interested in whether the guy boiled the meat in the sauce last week.
I'm interested in which party the guy boiled the meat for last week.
I'm interested in whether the guy boiled the meat for the party last week.

I will inquire which meal the housemaid prepared the drink for yesterday.
I will inquire whether the housemaid prepared the drink for the meal yesterday.
I will inquire which lady the housemaid prepared the drink for yesterday.
I will inquire whether the housemaid prepared the drink for the lady yesterday.

Please notify me which board the carpenter cut the cake with this morning.
Please notify me whether the carpenter cut the cake with the board this morning.
Please notify me which knife the carpenter cut the cake with this morning.
Please notify me whether the carpenter cut the cake with the knife this morning.

You already know which stone the girl threw the egg at last Tuesday.

You already know whether the girl threw the egg at the stone last Tuesday.
You already know which boy the girl threw the egg at last Tuesday.
You already know whether the girl threw the egg at the boy last Tuesday.

Can you guess which letter the tourist sent the money with last year?
Can you guess whether the tourist sent the money with the letter last year?
Can you guess which bank the tourist sent the money to last year?
Can you guess whether the tourist sent the money to the bank last year?

It is a secret which street the woman ran a store by in the 1980s.
It is a secret whether the woman ran a store by the street in the 1980s.
It is a secret which building the woman ran a store in in the 1980s.
It is a secret whether the woman ran a store in the building in the 1980s.

Let's discuss which town the terrorist visited his fellow in last Saturday.
Let's discuss whether the terrorist visited his fellow in the town last Saturday.
Let's discuss which purpose the terrorist visited his fellow for last Saturday.
Let's discuss whether the terrorist visited his fellow for the purpose last Saturday.

3. **Distractor sentences** (Partial data. These are the stimuli for other experiments which were conducted in combination with the present study.)
The police found the fingerprint of the criminal that was wiped from the jewel box.
The city that the author wrote regularly about was very famous.
The woman hid behind the door yesterday.
The man realized the goal in his life would be far out of reach.
The recent steep rise in prices prohibited the manager from building his factory.