Semantic Processing of Escher Sentences
Arriving at an Interpretation

Abstract

This project investigates Escher Sentences using experimental linguistic paradigms. These sentences have anecdotally been observed to have no possible interpretation but are judged as acceptable sentences by readers. Three experiments, including a survey, self-paced reading experiment, and event related potential (ERP) experiment are discussed, with results collected from the survey. The survey looks at what interpretation is derived from Eschers, the self-paced reading experiment is designed to establish a target area for when during online processing we arrive at an interpretation, and the ERP experiment examines what neural mechanisms are responsible for this interpretation. The survey results indicate that we arrive at an individual-comparison interpretation of Escher Sentences via a syntactic reanalysis model.

1. Introduction

Escher Sentences, also known as comparative illusions, have become a subject of interest in linguistics in the past few years. However, while some linguists have highlighted the problems that Escher Sentences (Eschers) present for our linguistic model, there is a lack of thorough exploration (Phillips et al. 2011 and Wellwood et al. 2012). By anecdotal observation, Eschers are sentences that seem to lack an interpretation, but are deemed acceptable sentences such as *more people have been to Russia than I have*. In an attempt to explain why this is, they have been grouped together with grammatical illusions, which are instances of the parser failing to recognize grammatical constraints[1] or rules (Phillips et al. 2011 and Wellwood et al. 2012). A classic example of a sentence that would lead to a grammatical illusion would be a subject attraction error as shown in (1)

(1)   a. The keys to the cabinet are on the table.
       b. *The key to the cabinets are on the table.

In (1b), the embedded NP is attracting the verb *to be* to agree with it. When grammatical constraints like subject-verb agreement are overlooked by the parser such that there is an increased delay in processing, an instance of a grammatical illusion is elicited (Phillips et al. 2011). In comparison, a sentence that is simply acceptable obeys all of the grammatical constraints in the language, while an example of an illusion is when one (or more) of these constraints is overlooked. Moreover, instances such as the second sentence of (1) are not consistently judged acceptable or unacceptable, a feature coined selective fallibility i.e. some people recognize that the sentence is an illusion and judge it unacceptable while others judge it acceptable. Additionally, sentences that fall into the grammatical illusion category are also more likely to be judged acceptable than other kinds of linguistic errors e.g. *the jumped bacon pan in* (Bock & Miller 1991).

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[1] A grammatical constraint is a rule that exists in our mental grammar that defines certain properties of our linguistic model. For example, one grammatical constraint in English is subject-verb agreement, where the verb must agree with the subject e.g. "Bill walks to school" as opposed to "*Bill walk to school."

The features of grammatical illusions, namely ignoring grammatical constraints, selective fallibility, and the likelihood of being judged acceptable have drawn linguists to group Eschers into this category. From observation, Eschers ignore a major grammatical constraint with usage of *more*[2], they are selectively fallible, and they are often judged to be acceptable even though no interpretation seems available. This project, however, aims to look at these claims through an experimental lens in order to substantiate or negate them. First, I will present an experiment that looks at the meta-linguistic understanding of Eschers and conclude that we do arrive at an interpretation for these sentences when we accept them. Secondly, I will present the design of a second experiment that examines when we arrive at this interpretation during sentence processing. Finally, I will discuss a third experiment that seeks to determine what neural mechanisms are at play when we are processing an Escher. I will then conclude with ideas on how to further proceed experimentally.

II. Escher Sentences

Eschers are sentences that have been observationally judged as non-interpretable but acceptable sentences of English that ignore the grammatical constraints of English comparative *more*. Consider below the well-known example from the introduction.

(2)   More people have been to Russia than I have [been to Russia][3].

Comparative sentences with *more* compare two compatible sets e.g. a comparison of individuals or events. We have a grammatical constraint that says that these sets must match, in that we must compare individuals to individuals, events to events, etc. With (2), there is a comparison of a set of individual people having gone to Russia versus a proposition that I have been to Russia. Comparing a set of individuals to a proposition does not elicit a meaning, therefore, we should not arrive at an interpretation, just as we arrive at no interpretation for *Six frogs Mary that left had* (Heim and Kratzer 1998).

Anecdotally, linguists have observed that because readers find Eschers acceptable sentences that they must be arriving at some interpretation, but articulating what that interpretation is has been a challenge. The literature has discussed two possibilities for arriving at an Escher interpretation. First, an Escher could undergo syntactic reanalysis, meaning that when we process an Escher in a bottom-up parsing procedure, the syntax then looks at the structure and rejects it due to its ungrammaticality. The syntax then reconstructs another structure that is grammatical. This is similar to the claims made about reanalysis being a re-parsing of a structure that is first judged unacceptable and then adjusted by the syntax and re-parsed, yielding an acceptable sentence (Sturt 2000). Moreover, according to Wellwood et al. 2012, this syntactic reanalysis can result in a new syntactic structure that the semantics would process as either a comparison between sets of individuals or between sets of events.

The other possibility is a coercion[4] account. Here, the semantics would examine the input and realize that there is no available comparison i.e. a set of individuals compared to a proposition. Using (2) as an example, a semantic coercion account would mean that the set of individuals who have been to Russia would be assigned an *event* type, and the proposition would

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[2] *More* requires a comparison between two compatible sets, and Eschers fail to have two comparable sets.
[3] Brackets indicate elision.
[4] See Section III.i for further discussion.

be changed into a singular event of *me* going to Russia (Wellwood et al. 2012). Therefore, we would end up with an event comparison interpretation after semantic coercion. Speculatively, coercion may also account for an individual comparison interpretation. However, this is less likely than an event comparison interpretation because the verbs of Eschers often require event-type arguments (going to Russia), so it seems plausible for coercion to only account for event comparisons. However, for the scope of this project, we will assume that coercion accounts for only event type comparisons. Nevertheless, whether reanalysis or coercion is the mechanism by which we arrive at an interpretation, (3) below spells out the two possible interpretations discussed – event comparison, or individual comparison.

(3)   More (|events of people going to Russia|, |events of me going to Russia|)
        More (|individuals that have gone to Russia|=x, |myself having gone to Russia|=1)

        The first portion of (3) is an illustration of what a coerced or reanalyzed event comparison would look like, in that we are comparing the events of others going to Russia versus the number of times I have gone to Russia. Likewise, another interpretation brought from syntactic reanalysis is comparing a number of individuals having gone to Russia (with a cardinality of x) compared to *myself* with a cardinality of one.
        Wellwood et al. 2012 conducted a study with the goal in mind of separating these two interpretations. In their study, they manipulate select semantic properties such as repeatability of an event and predicate type, and they found varying levels of acceptability based on these manipulations (2012). The study showed that singular NPs will lead to lowered acceptability, as they postulate that the reader is forced to make an individual comparison to an event (Wellwood et al. 2012). Furthermore, NPs that were repeatable were statistically more acceptable than non-repeatable events, and that if the non-repeatable event had plurality added to it, then it was more acceptable for the reader. According to Wellwood's study, the non-repeatable events, or events that have a denotation of only being performed once (e.g. *he ate the cake*) should help expose the comparative illusion. For instance, the sentence, *more workers were laid off from the plant than the manager was* was rated less acceptable than a repeatable counterpart e.g. *more students get involved with team sports than the teacher does* (Wellwood 2012). Here, workers can only be fired once, but students can repeatedly get involved with team sports, and their data show that these repeatable sentences were rated more acceptable than the non-repeatable ones. They conclude that because their manipulations were semantic in nature, semantic coercion was the best option. They further make the claim that because coercion is a semantic process, participants must be arriving at an event comparison interpretation.
        While Wellwood et al. suggest a coercion account for explaining why we may deem Eschers acceptable, there is little experimental evidence probing at the meta-linguistic understanding of Eschers. If we were to poll the participants in the Wellwood et al. study, would people respond that they understood that there were more events of X happening than Y, or would they be arriving at a different meaning than what a semantic coercion account would entail? Furthermore, if probing into the understanding of these Eschers reveals that readers and listeners arrive at a consistent meaning, then this would be evidence against classifying an Escher as a grammatical illusion.

III. Experiment One

The goal of experiment one is to determine what interpretation participants arrive at when encountering Eschers. The survey was designed to explore the meta-linguistic judgments of meaning by presenting a series of contexts and follow-up statements that would either be true or false based on the context given. With this survey, I hope to accurately represent a consensus of what interpretation is derived from Escher sentences. Before discussing the actual design of the experiments, the following sections will talk about the hypotheses and predictions associated with experiment one.

While the literature posits two possible interpretations, a comparison of individuals or events, I propose instead three potential interpretations for Eschers: event comparison, individual comparison, and underspecification. Underspecification means that we create an incomplete interpretation of the sentence because we have not been tasked with having to fully understand it. To explicate, this is similar to a claim about sentence meaning by Pickering et al. 2006. They set up two self-paced reading and two eye-tracking experiments with sentences with mismatching telicity[5]. Participants were asked basic comprehension questions of these sentences, and they found that participants were underspecifying instead of committing to a non-telic or telic reading (see Underspecification section). Unless these participants were asked to provide a meaning for these sentences, they would create and underspecified interpretation with no commitment to a full meaning.

Below is a brief summary of the models that are tested for Experiment 1.

Model	Interpretation
Coercion	Event Comparison
Syntactic Reanalysis "Just Me"	Individual Comparison
Syntactic Reanalysis "More Movement"	Event Comparison
Underspecification	Underspecified

i. The Coercion Account

As previously discussed from findings by Wellwood et al. 2012, this model predicts that Eschers undergo semantic coercion to force an event comparison interpretation. Coercion itself is a process where additional computations are made on syntactic structures in order for the listener or reader to arrive at an interpretation (Kuperberg et al. 2010) (4) below provides a well-known example of this process.

(4) The journalist began the book.

The verb *begin* requires an argument that denotes an event, and in this case, the argument is *the book* which refers to an entity. Readers, however, arrive at a perfectly reasonable interpretation of this sentence e.g. *the journalist began [writing/reading] the book.* To account for this interpretation, we say that coercion has occurred, where we satisfy the argument

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[5] Telicity describes an event that is completed e.g. I hit the car, while an event that is non-telic would be an event that is continuous e.g. I brushed my dog (Pickering et al. 2006).

denotation requirement by making *book* into an event (reading or writing a book). Studies have repeatedly shown that there is extra processing lag (self-paced reading, eye tracking, and neuroimaging studies) when readers encounter *began the book*, meaning that the extra computations create extra work and thusly extra processing time (Baggio et al. 2010, Kuperberg et al. 2010, McElree et al. 2001, Traxler et al. 2002).

In the case of Eschers, we have comparative sentences with incompatible sets. This model predicts that coercion is the process that forces an event interpretation for both sets being compared e.g. number of events of people going to Russia vs. number of events of me going to Russia. This is done by assigning *people that have been to Russia* an event type and changing the proposition of *I have been to Russia* into an event. However, no electrophysiology studies have been done to back this claim up, which helped to further motivate the second and third experiments in this project.

ii. The "Just Me" Model

The Just Me model utilizes syntactic reanalysis as the mechanism by which we arrive at an interpretation for Eschers. Specifically, when the syntax recognizes the structure is ungrammatical, the syntax reorganizes the structure and inserts *just me* which is shown in (5).

(5)   More knights have seen the queen than I have → More knights have seen the queen than **just me**.

With the string now ending in *just me*, we now have a comparison of individuals, the knights, to the set of individuals *just me*. While *than I have [seen the queen]* seems synonymous with *than just me, than I have seen the queen* denotes a proposition while *just me* denotes a set with a cardinality of one. By altering the syntax through a syntactic reanalysis process, we arrive at an interpretation.

iii. The "More Movement" Model

Another way to utilize the syntactic reanalysis mechanism is by moving the position of *more* in an Escher comparison as shown in (6).

(6)   More knights have seen the queen that I have → Knights have seen the queen **more** than I have [seen the queen].

With *more* in this new position, *more* now takes scope over *than I have seen the queen.* We then syntactically will compare this constituent which denotes an event with *Knights (that) have seen the queen* which also denotes an event. Now, the sentence becomes a comparison of the number of times knights have seen the queen versus the number of the times I have seen the queen. By yielding an event comparison, though, this model predicts the same result as semantic coercion, which will be addressed later this section.

iv. The Underspecification Model

The final model involves arriving at an underspecified interpretation of an Escher sentence. The basic concept is that as we parse Eschers, we construct an interpretation that is sufficient enough for us to judge it an acceptable sentence of English but not complete enough to elicit a concrete explanation of what the meaning is. In Pickering et al. 2006, participants were given sentences ambiguous to whether the event described was telic or non-telic such as *the insect hopped effortlessly until it reached the garden.* If we interpret *hop* as being telic, then it is impossible to think of a single hop reaching the garden as in this example, but it is much easier to understand if instead *hop* implies multiple hops instead of one hop. Note that their study did not actually test what interpretations were derived from readers, but that there was no online difference when these telic or non-telic events were compared. However, if we assume that *hop* denotes a single hopping event, then coercion is required to arrive at an iterative meaning with *until it reached the garden.* Thus, their studies suggest that instead of simply committing immediately to *hop* and other similar instances as telic, we instead have an underspecified understanding of the sentence and only commit to telicity if tasked to answer what the sentence means or make decisions about the sentence—we will arrive at that decision via coercion into an iterative or non-telic meaning (2006). We can apply this same logic to the interpretation of Eschers. Instead of committing to a logically sound comparison, we instead arrive at an incomplete interpretation and pass it off as acceptable until we are required to reflect upon the meaning.

v. The Design

The goal of experiment one is to tease apart which of the four models best describes the data through a series of survey batches conducted via Mechanical Turk (MTurk), a program for crowdsourcing data tasks designed by amazon.com. The very nature of crowdsourcing can fall victim to many confounding variables such as false identities, programs filling out surveys instead of humans, etc. However, several previous linguistic studies have found that data collected from MTurk is as viable and reliable as other kinds of surveying methodologies (Gibson 2011 and Sprouse 2011). In addition to using MTurk to gather participants and preliminary data, Qualtics Software was used to design the survey itself, which is linked through MTurk. The participants on MTurk can access this survey through an internet link and are rewarded upon completion of the Qualtrics survey.

Participants

Participants in the survey were all workers through Mechanical Turk both male and female ranging from ages 19 to 66. Each worker was asked if they had lived in the United States from birth until (at least) age 13, if both parents spoke English during those years, their gender, age, and current residency. The first two questions help to establish if participants are native speakers of English, and if they answer no to either one, their data is collected by excluded from later analysis.

Stimuli

The survey[6] contained forty possible scenarios with each scenario having three possible statements, totaling to 120 combinations[7]. Using Qualtrics Software, these combinations are broken down into six smaller surveys, each with 20/120 of these combinations. Participants were randomly assigned one of these six smaller surveys with randomized statements and contexts. A Latin Square was used to create possible scenario and statement combinations while Qualtrics software randomized the order with which they were presented to participants.

Each scenario was broken down into two separate parts, **a** and **b**. The **a** scenario had an example where *you* performed some task more than other people present in the given scenario, and **b** had an example where these other people performed some task more than you. This split was done in order to differentiate whether participants answer true or false for the possible statements, which included the following—S1 was an individual comparison comparative sentence ("just me" model), S2 was an event comparison comparative sentence ("more movement" or coercion model), and S3 was an Escher sentence. Below is an example of what one set of stimuli looked like.

(7)   Scenario 1a

You are among a group of three knights, and you are discussing at dinner how many times you have seen the queen today. The knights have seen the queen once, where you have seen her six times, due to her need for sweets and wine that you must bring to her.

Scenario 1b

You are among a group of three knights, and you are discussing at dinner how many times you have seen the queen today. The knights have seen the queen six times, where you have seen her only once, due to the fact that she does not like squires very much.

Possible Statements:

S1 - More knights have seen the queen than just me.
S2 - The knights have seen the queen more than I have.
S3 - More knights have seen the queen than I have.

Looking at this example, scenarios 1a and 1b involve a situation where there are three knights in total and yourself, the reader. We make a distinction between 1a and 1b by having the reader perform the task of seeing the queen more times than the knights in 1a (me > other), and having the knights perform the task of seeing the queen more times than the reader in 1b (other >me). Differentiating the amount of times the reader vs. the other party performs a certain task allows me to have S1 and S2 be true or false given the context. For instance, S2 would be false if the knights have seen the queen more than I have but true in the same case. However, S1 will always be true because there will always be more knights, hence why two scenarios

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[6] http://umichlsa.qualtrics.com/SE/?SID=SV_87jm03cHQhN4brf
[7] To see a complete list of contexts and statements used, please see Appendix 1.

manipulating the activities performed were created for the survey. Having only one true or false to compare with would not help differentiate between the possible interpretation models.

The **a** and **b** scenarios also control for several confounding factors that could affect judgment. Participants are left ambiguous as to whether they are a member of the group (in 1a a knight) or not, which allows for each possible statement to interact with each other e.g. in S1, you can either be a knight or not and find the sentence acceptable, but with S2 you must not be a knight for the sentence to be acceptable. Keeping this ambiguity is important in order to prevent the reader from locking himself or herself into a member of each group of each context they read. This could alter their overall judgment of the sentences and lock them into S1s or S2s being always true or false.

Additionally, another problem is to control for collective vs. distributive readings for situations such as *the knights have seen the queen once.* Given that the scenario gives the reader three knights, he or she could read that sentence in two ways. The reader could have a distributive interpretation, which would mean that there are three events of each knight seeing the queen once, or the reader could have a collective interpretation of this sentence, where there is only one event of three knights seeing the queen. To correct for this, there will always be a greater number of others than yourself regardless of the scenario, and for **a** scenarios, the action you perform will always outnumber the potential amount of times the others can perform it. This way, whether readers interpret *the knights have seen the queen once* as either three separate events or one event, it will not affect their judgment of S1, S2, or S3.

A final issue is controlling for a bare-subject reading of these sentences. *Knights have seen the queen* and *the knights have seen the queen* have two different interpretation. The bare-subject sentence, or the sentence without an article, implies that the set of knights in general have seen the queen, while the sentence with *the knights* will denote a certain set of knights. This can affect the judgment of readers because it could confuse whether *knights* refers to the three knights in the context or some other group of knights. To control for this, we add determiners to each S2 sentence across the board which helps to indicate that the group of people indicated come from the previous context as opposed to some general set of people. In addition, S2 controls for a bare-subject reading by inserting a determiner before the subject to prevent variability in judgments.

The participant is asked to read a scenario and respond to a follow-up statement with either *true*, *false*, or *not sure*. *Not sure* is included to test whether the participant is sure of their answer or not, or if they cannot access an arrived at interpretation. (8) exemplifies an answer key to what participants are expected to answer with explanation with what we want to see with answering S3 statements.

(8)   "A" Scenario (Me > Others)
         S1   True
         S2   False
         S3   ?

       "B" Scenario (Others > Me)
         S1   True
         S2   True
         S3   ?

If participants answer *true* for S3 in both scenarios **a** and **b**, this would pattern with the expected answers with S1s, indicating that participants are interpreting Eschers with individual comparisons, directly supporting the "Just Me" model. Likewise, if participants answer with the same expected response pattern as S2s, this would indicate an event comparison interpretation of Eschers, supporting either the coercion model or the "more movement" model. Finally, if we find no significant patterning for answering the Escher sentences, this would offer some support for an Underspecification model, as people are not arriving at a consistent meaning or any meaning at all. This will be especially true if we find an overwhelming amount of *not sure* responses to these Eschers.

Procedure

97 participants from MTurk were asked to fill out a preliminary questionnaire containing demographic info on the MTurk interface, followed by instructions to click on a link and complete the survey on an outside website[8]. The link took the workers to the Qualtrics survey, where they were presented with forty scenarios, twenty measureable scenarios and twenty fillers, one webpage at a time. The ordering of these forty scenarios was randomized with Qualtrics software, and the survey set they received was evenly and randomly distributed amongst the participants.

Each participant was asked to input their MTurk worker ID in Qualtrics to keep track of which participant took each survey and to verify that the participant was human. In the Qualtrics survey, each response is forced, and Qualtrics did not record incomplete surveys. At the end of the survey, a keyword ("Chocolate, Vanilla, Strawberry, Mind, Raspberry, Orange") was provided to ensure payment for the worker. We utilized the criteria in (9) to filter out participant data.

(9)   Data was thrown out if:
      1. Participant was a non-native speaker of English
      2. Not a resident of the United States
   3. Did not follow instructions
      4. 75% or less accuracy

Regarding payment, even if a participant's data was thrown out, every worker was compensated $3.00, following the approach that Gibson took with his MTurk experimentation—"Note that because we pay people no matter whether they indicate that they are native English speakers or not, participants have no motivation to pretend to be native English speakers if they are not" (2011). This prevented any non-native speakers thinking that they must pretend to be a speaker of English to receive payment. The amount of payment was decided upon a MTurk suggestion that for every minute of work, a typical MTurk worker desires $0.10 to total up to a $6.00/hr job (https://www.mturk.com/mturk/welcome). However, due to the nature of the survey and its length, we extended this to $3.00 for a roughly twenty minute task to offer greater incentive and quicker data collection.

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[8] Some HTML code was used from Sprouse 2011 available at http://www.socsci.uci.edu/~jsprouse/#tools.

IV – Experiment One: Results

Data was filtered and processed using R and Microsoft Excel. Figure 1 below represents a raw count of responses from the 97 participants that passed through the filters described in section III.

Figure 1 – Raw Count
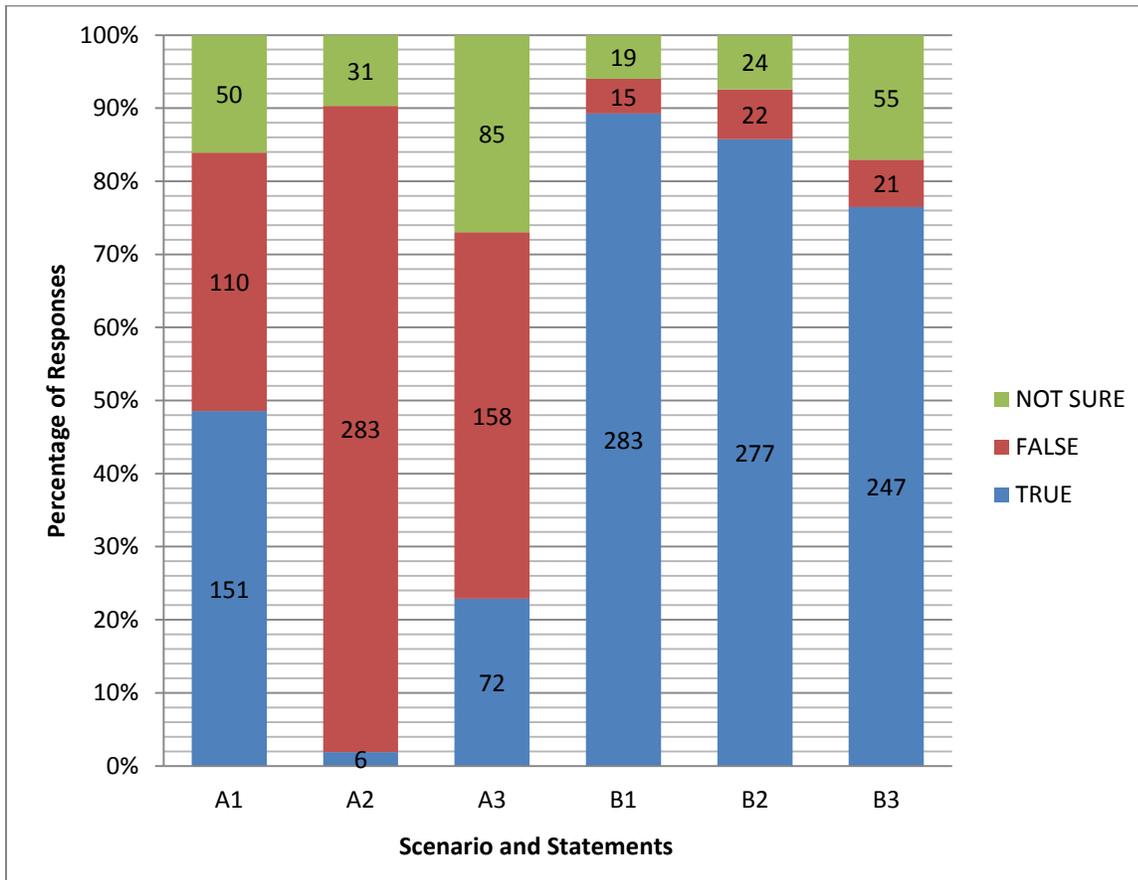
Out of the three choices participants were given to respond to statements (true, false, or not sure), participants were sure of their responses, answering 87% of all responses as true or false. Overall, participants were more sure than unsure of their answers across the board. Additionally, there appears to be a consistent difference between how sure participants were when answering statements **1** and **3** between scenario **a** and **b**. This suggests that scenario **b** is more easily interpretable than scenario **a** regarding these statements. This may be due to the *other* > *me* comparison being made: scenario **b** has the other people in the context performing the task more than the reader while additionally there are more of them. This could make understanding each statement easier for the participant. Nevertheless, participants are arriving at some interpretation for Eschers and are not underspecifying. Figure 2 then removes not sure responses and looks only at a raw count for true and false response.

Figure 2 – Raw count of "Sure" data
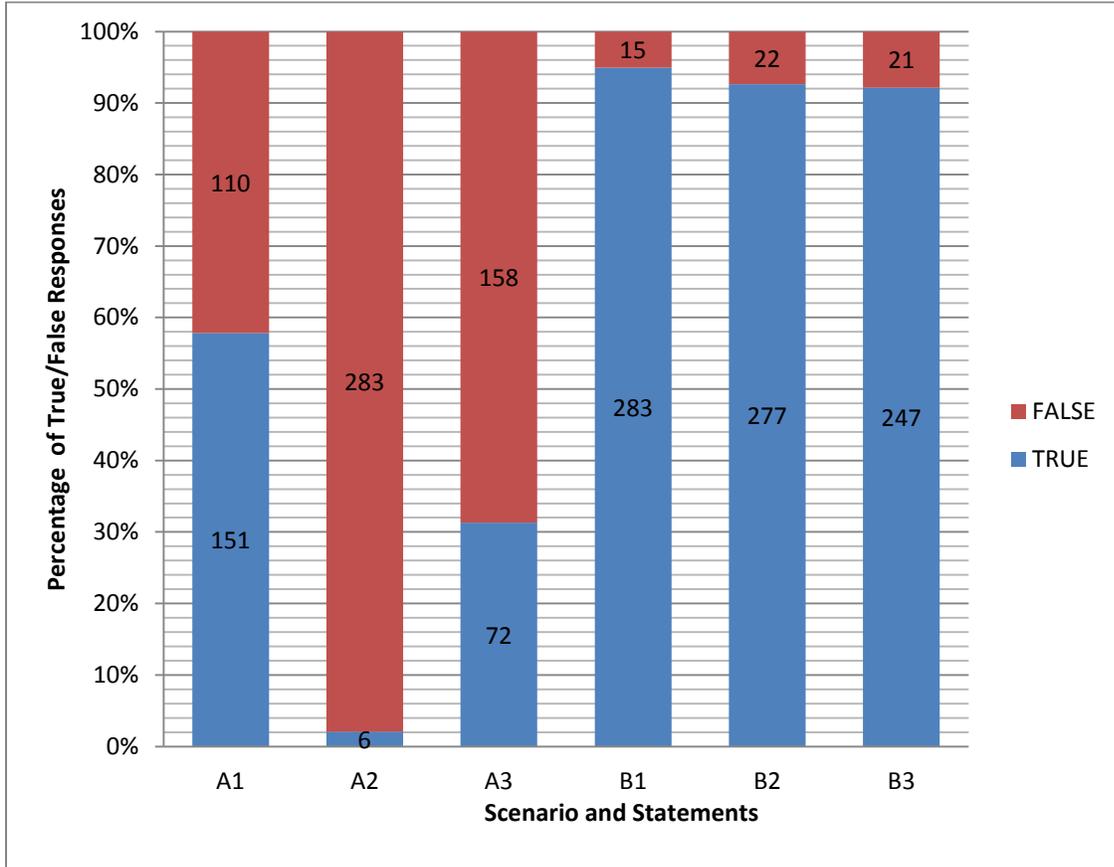
Looking at the data, if we take each category and take the majority (>50%) responses, we end up with the following—

"A" Scenario (Me > Others)
    S1   True
    S2   False
    S3   **False**

    "B" Scenario (Others > Me)
    S1   True
    S2   True
    S3   **True**

The responses for S3 pattern False and True for scenarios **a** and **b** respectively, just as we predicted would occur with an event comparison interpretation of Eschers from either a syntactic reanalysis "more movement" model or a semantic coercion model. This, however, is only a heuristic approach to the raw overall data and does not indicate individual computations on Escher sentences. I include this data to show the general responses from a large survey, but the data that will help determine which interpretation readers arrive at should be looking at how each participant responded individually.

For each individual, we computed the average values of the proportion for each statement they rated as *true* and averaged this across participants. We then compared these averages using bivariate correlations i.e. we compared how individual participants rated their S1s and S3s and their S2s and S3s.

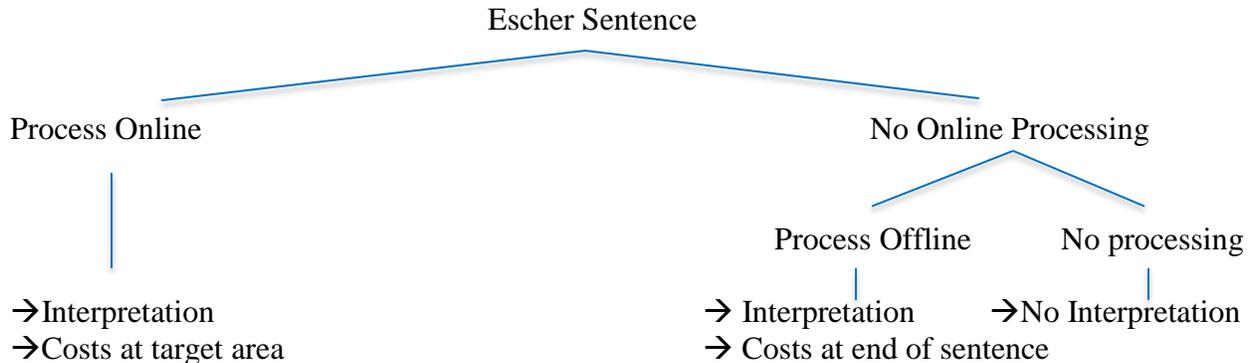|	aS1 and aS3	aS2 and aS3	bS1 and bS3	bS2 and bS3
r(95)=	0.511	0.075	0.358	-.116
p=	.001*	.486**	.001*	.282**

*=significant
**=insignificant

If the statements we provide for participants have similar representations, then this should be reflected in participant judgments for each statement. For example, if participants judge S1s as **true**, then if S3s have the same representation, they should also be consistently judged as **true**. As expected, we see a difference in correlations between scenarios, and we see significant (where p=.01) and highly correlated relationships between 1 and 3 scenarios in both A and B, while the correlations between 2 and 3 scenarios are highly insignificant. By looking at these relationships, we see a clear pattern between 1 and 3 scenarios, suggesting that a "just me" syntactic reanalysis and individual comparison interpretation are derived from Eschers.

With the data insofar, it appears that we have a divide between two models. On one hand, when looking at the raw count of data across participants, Eschers appear to pattern with an event comparison interpretation. However, looking at individual judgments across participants shows a strong correlation between selecting S1s and Eschers (S3s) as both true. These correlations suggest that Escher judgments track individual comparisons if Eschers have an individual comparison interpretation to offer. These data suggest that this is indeed the case, and that Eschers offer an individual comparison interpretation and evidence towards supporting a "more movement" model. Moreover, we will conclude with the correlation data as opposed to the raw overall data because we are looking for how individuals interpret these sentences and the bivariate correlations help determine this aspect of answering the question better than looking at a raw count of how many true or false responses elicited in a survey.
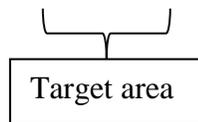
V. Experiment Two

To recapitulate, the motivation for experiment one was to find evidence for what kind of interpretation people have of Eschers. Experiment Two of this project explores the parser and processing of Eschers. The question remains of *where and when* we arrive at an interpretation, given that we do not underspecify an interpretation. Using well-established self-paced reading paradigms, we can start to look at when we arrive at an interpretation for Eschers (Traxler 2002). (10) offers a visual model for the background of this experiment.

(10)

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                          Escher Sentence
                 _____/           _____
                /                             \
        Process Online                   No Online Processing
              |                            ____/        \____
              |                           /                  \
              |                    Process Offline      No processing
              |                           |                   |
→Interpretation                    → Interpretation    →No Interpretation
→Costs at target area              → Costs at end of sentence
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For an Escher, we either have a process (syntactic reanalysis or semantic coercion) that triggers an interpretation online or not. If we do, then we will arrive at an interpretation for the sentence and a processing cost at the target area. The "target area" will be immediately before the VP elision of an Escher, and to account for end of sentence processing costs, we will add a neutral spill-over to the end of the sentence such as (11).

(11)   More people have been to Russia than I have, and it is pretty cold there.

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                            ┌─────────────┐
                            │  Target area │
                            └─────────────┘
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With Experiment Two, we expect additional computation and thus processing lag at the target area, which would provide evidence for online processing of Eschers. Alternatively, if we find no processing lag at this target area, then there are a few conclusions we can draw. First, if we have processing of the Escher offline, the participant will arrive at an interpretation but will have additional processing costs at the very end of the sentence (after the spill-over). Secondly, a lack of processing costs at the target area or sentence finally would not indicate that they never form an interpretation, rather, they may only build an interpretation offline when tasked to e.g. asking what this sentence means to them.

i. The Design

I propose a self-paced reading experiment in order to see if there is processing costs at the target area, end of the sentence, or alternatively no processing costs at all. We expect to find processing costs at either the target area or end of the sentence. The stimuli will involve reading a background and follow-up statement, very similar to Experiment One, and the participant will be given a makes sense task, essentially surveying if they believe the statement makes sense or not based on the previous context. (12) provides an example of 1/50 stimuli designed for Experiment Two.

(12)   **Background**: Two ranchers are talking about their work, referring to their fellow cowboys and the neighboring farmers (they) down the road.

Control 1: The cowboys have lassoed the horse more than you have, and the cows are happy.

Control 2: More cowboys have lassoed the horse than they have, and the cows are happy.

Escher: More cowboys have lassoed the horse than you have, and the cows are happy.

Participants will be randomly given an assortment of backgrounds paired with one of three possible statements and asked if the statement makes sense. The purpose of the background is to make the statements seem more natural given a context also to provide two groups of people to compare with, important for making Control 2 seem natural. Control 1 sentences have a forced individual comparison, accomplished by using more movement syntactic reanalysis as discussed in Section III. Control 2 sentences have a forced event comparison. These controls are in place to control not only for what kind of interpretation to force on the participants, but they are also designed to be as similar as possible to the Escher sentence in regards to a target area.
Moreover, having a background context for Control 2 is imperative, as we need a pronoun to be present in our target area for consistency while simultaneously providing an event comparison interpretation. This is accomplished by giving concrete plurality to the comparative NP, forcing an event comparison (see Wellwood 2012). Finally, the Escher is the interest in this experiment, where we will compare processing costs with our controls and establish when and where processing of Eschers occurs.

VI. Experiment Three – Future Directions

In Experiment One, we established how people interpret Eschers, experiment Two explored when we process Eschers, and finally, the goal of Experiment Three is to see which neural mechanisms are being elicited at the area where we found processing costs. We want to focus on two possible ERPs that could be elicited—the N400 or P600. The N400 ERP is commonly associated with processing semantic errors, while the P600 is commonly associated with processing syntactic errors. (Kuperberg et al. 2010 and Lau 2008).

In previous studies, while N400s have been generally associated with semantic errors, they can also be extended to cases of pseudowords[9], pictures, and even human faces. (Lau et al. 2008). More importantly for this study, this N400 has also been elicited in cases of semantic coercion e.g. *The journalist began the book* cf. *The journalist wrote the book*. (Kuperberg et al. 2010). When *book* undergoes a type-shift to match with a verb that requires an event type *begin* (coercion)*, we have seen processing lag at this target area, but studies have also shown N400 ERPs to be elicited here (Kuperberg et al. 2010). In cases where there is no coercion (*the journalist wrote the book*), this N400 is absent. Likewise, P600s have occurred in cases of syntactic anomalies such as **The woman persuaded to answer the door* (Osterhaut and Holcomb 1992). They have also occurred in cases where syntactic reanalysis is required. As Osterhaut and Holcomb pointed out, Garden Path sentences such as *The broker persuaded to sell the stock was sent to jail* elicits a P600 at the *to* (1992). Garden Paths are sentences that require a re-parsing after an initial reading due to an error in creating a syntactic structure. In this case, when readers arrive at *to* from *to sell the stock*, they interpret it as the broker is persuading someone to sell the stock, but when *was sent to jail* comes next, it does not make sense, so they are forced to reanalyze the sentence.

We concluded in experiment one that a "just me" model is responsible for the individual comparison interpretation readers arrive at for Eschers. Experiment two proposes an experiment to investigate when this process would occur in the sentence. Finally, upon further study and investigation, experiment three would hope to distinguish between which process is occurring by looking at the neural mechanisms that are elicited at the target area. The next question is understanding why the N400/P600 signals would be relevant to looking at Eschers.

The stimuli used for Experiment Three would be the same stimuli from Experiment Two, but instead of a self-paced reading paradigm, I would propose using a serial visual presentation protocol and focusing on the target area established from Experiment Two, assuming that there are costs at the target area of the Escher sentence (immediately before the spill-over). Regarding ERPs, finding an N400 signal would indicate that a semantic anomaly is present, while a P600 would indicate a syntactic anomaly. Following claims made by previous studies, then, because P600s have been found with syntactic reanalysis instances e.g. Garden Path Sentences, the P600 would suggest a similar syntactic reanalysis occurring at the Escher target area. Moreover, since N400 semantic anomalies have also been indicated with coercion accounts, then likewise, an N400 at this target area would suggest a semantic coercion occurring at the Escher target area. However, data insofar suggest that Eschers require syntactic reanalysis, and finding an N400 would be an issue with the claims made so far based on previous studies.

Because this experiment requires further research and resources, pinpointing exactly how the N400/P600 paradigm would operate with Eschers is difficult due to the lack of experimental work. We may find that Eschers have a combination of semantic and syntactic processes affecting their judgments and interpretations, which may not be reflected in an N400 or P600. However, based on previous claims about these ERPs, we can at least speculate that the N400 would provide evidence for semantic anomaly processing when we process an Escher, while a P600 would provide evidence for syntactic anomaly processing.

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[9] These are false words that have pronounceable English phonology e.g. "Trukent" (Lau et al. 2008)

VII. Conclusion

From anecdotal observation, Eschers are sentences that appear to have no available interpretation, yet we often find them acceptable more than other kinds of sentences where no meaning can be ascertained. This project takes these observations and puts an experimental lens to them to see how we are processing these sentences. From experimentation insofar, we have concluded that Eschers have an available and consistent interpretation of an individual comparison through syntactic reanalysis. Once the proper resources are allocated, experiment two's design aims to answer the question of when either coercion or reanalysis occurs during parsing, and experiment three will observe ERPs elicited at the target area established a priori and conclude whether this is a syntactic or semantic process that elicits an interpretation.

This project, however, is only a starting point for looking at Eschers. After completion of this project, there are still several questions remaining about Escher Sentences. One, if we consider Eschers to not fit into the category of grammatical illusions, how should we properly categorize them? Are there other sentences in English, or any other language, that behave in a similar pattern, and if so, will they have similar processing effects? If not, should we be modifying our model of grammar in order to account for the interpretation derived from Escher sentences? Further experimentation and research is needed to answer these kinds of questions. Nevertheless, Eschers have been heavily discussed anecdotally in linguistic literature and in the general public. They have yet to undergo much experimental observation, so I hope that this project can help to improve our linguistic knowledge of these sentences and press forward with continuing to utilize experimental linguistics to help better understand how we process language.

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Appendix 1 – Stimuli for Experiment 1

Scenario 1a

You are among a group of three knights, and you are discussing at dinner how many times you have seen the queen today. The knights have seen the queen once, where you have seen her six times, due to her need for sweets and wine that you must bring to her.

Scenario 1b

You are among a group of three knights, and you are discussing at dinner how many times you have seen the queen today. The knights have seen the queen six times, where you have seen her only once, due to the fact that she does not like squires very much.

Possible Statements:

1) More knights have seen the queen than just me.
2) The knights have seen the queen more than I have.
3) More knights have seen the queen than I have.

Scenario 2a

A professor and two other students are talking about a seminar that you have also taken. The professor comments that you have taken the seminar four times because of your interest in the subject matter, while the other students have only taken the seminar once.

Scenario 2b

A professor and several students are talking about a seminar that you have mutually taken. The professor comments that you have only taken the seminar once because of your lack in interest, while the other students have taken the seminar three times for easy credit.

Possible Statements:

1) More students have taken the seminar than just me.

2) The students have taken the seminar more than I have.
3) More students have taken the seminar than I have.

Scenario 3a

There are two ranchers talking about the cowboys down the road, and you are talking with them about how many times they have ridden a bull. You have ridden a bull seven times, while the cowboys are a bit afraid of the bull and have only ridden it twice.

Statement 3b
There are two ranchers talking about the cowboys down the road, and you are talking with them about how many times they have ridden a bull. You have only done it once, but the two cowboys have ridden the bull several times just this week.

Possible Statements:

1) More cowboys have ridden the bull than just me.
2) The cowboys have ridden the bull more than I have.
3) More cowboys have ridden the bull than I have.

Scenario 4a

You are talking with the owner of a mansion and two workers about who does more cleaning. Just today, you have cleaned the living room four times because the owner's son is such a slob, and the workers have only cleaned it once.

Scenario 4b

You are talking with the owner of a mansion and two workers about who does more cleaning. You have only cleaned the living room once today, but the workers have done it six times because of the mess the owner's son causes.

Possible Statements:

1) More workers have cleaned the room than just me.
2) The workers have cleaned the room more than I have.
3) More workers have ridden the bull than I have.

Scenario 5a

You and three nerdy friends are talking about who has seen the movie *Star Wars* more. You have seen it twelve times, as you are a big fan, and your friends have only seen it once.

Scenario 5b

You and three nerdy friends are talking about who has seen the movie *Star Wars* more. You have only seen it once, but your friends have seen it over a dozen times.

Possible Statements:

1) More nerds have seen *Star Wars* than just me.
2) The nerds have seen *Star Wars* more than I have.
3) More nerds have seen *Star Wars* than I have.

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Scenario 6a

You are talking with your two friends about who has driven to Austin, Texas more times. You have driven there fourteen times, while your friends have only driven there twice.

Scenario 6b

You are talking with your two friends about who has driven to Austin, Texas more times. You have driven there only once, while your friends pass through there so often that they have lost count.

Possible Statements:

1) More truckers have driven to Austin than just me.
2) The truckers have driven to Austin more than I have.
3) More truckers have driven to Austin than I have.

_____

Scenario 7a

You are working at a restaurant, and you are talking to two waiters about dealing with bad customers. Just today, you had to deal with seven bad customers, while they have only dealt with two today. It just is not your day.

Scenario 7b

You are working at a restaurant, and you are talking to two waiters about dealing with bad customers. You have only interacted with a single bad customer, while your co-workers have dealt with twelve bad customers. It is just not their day.

Possible Statements:

1) More waiters have dealt with bad customers than just me.
2) The waiters have dealt with bad customers more than I have.
3) More waiters have dealt with bad customers than I have.

Scenario 8a

You are attending a party with three actors, and you are talking about recent shows. You say that you have gone to see *The Book of Mormon* four times because you find it very funny, while your actor friends have only seen it once.

Scenario 8b

You are attending a party with three actors, and you are talking about recent shows. You say that you have seen *The Book of Mormon* once, but your actor friends have seen it twelve times because they know some of the people in the show.

Possible Statements:

1) More actors have seen *The Book of Mormon* than just me.
2) The actors have seen *The Book of Mormon* more than I have.
3) More actors have seen *The Book of Mormon* than I have.

Scenario 9a

Inside of the classroom, you and your two math friends are working on an equation. You have tried to solve the problem six times because are really struggling with this class, and even your friends have tried to solve it twice because of its complexity.

Scenario 9b

Inside of the classroom, you and your two math friends are working on an equation. You have tried to solve the problem twice because you are really struggling with this class, and, much to your chagrin, your math friends have tried to solve it six times because of its complexity.

Possible Statements:

1) More math students have tried to solve the equation than just me.
2) The math students have tried to solve the equation more than I have.
3) More math students have tried to solve the equation than I have.

Scenario 10a

A visit with your three friends leads to a heated argument about video games. You say that you have beaten *Super Mario* twelve times because of your skills, while your three gamer friends have only beaten it twice.

Scenario 10b

A visit with your three friends leads to a heated argument about video games. You say that you have beaten *Super Mario* only once because of your lack of interest, while your three gamer friends have beaten it twenty-six times, claiming it to be the best video games ever.

Possible Statements:

1) More gamers have beaten Super Mario than just me.
2) The gamers have beaten Super Mario more than I have.
3) More gamers have beaten Super Mario than I have.

Scenario 11a

You walk into a classroom where there are two ballerinas practicing. As you get to talking, you find out that you have seen Swan Lake over a dozen times because of your love of Tchaikovsky, while the ballerinas have only seen it once.

Scenario 11b

You walk into a classroom where there are two ballerinas practicing. As you get to talking, you find out that you have seen Swan Lake only once, compared to the ballerinas who have seen it six times because they wanted to improve their skills.

Possible Statements:

1) More ballerinas have seen Swan Lake than just me.
2) The ballerinas have seen Swan Lake more than I have.
3) More ballerinas have seen Swan Lake than I have.

Scenario 12a

While walking to class one day, you run across a couple of football players. You start to talk about workout routines, and you find out that you have run a marathon six times, while the football players have only ran a marathon once.

Scenario 12b

While walking to class one day, you run across a couple of football players. You start to talk about workout routines, and while you have run a marathon a few times, the football players have run marathons over a dozen times to keep in shape.

Possible Statements:

1) More football players have run a marathon than just me.
2) The football players have run a marathon more than I have.
3) More football players have run a marathon than I have.

Scenario 13a

You are at a local bar for trivia night with your friends, and they invite three girls over to play at the table. After some discussion, you say that you have won trivia night twelve times and are a reigning champion, while the girls have only won once.

Scenario 13b

You are at a local bar for trivia night with your friends, and they invite three girls over to play at the table. After some discussion, you say that you have won trivia night twelve times and are a reigning champion, while the girls have only won once.

Possible Statements:

1) More girls have won trivia night than just me.
2) The girls have won trivia night more than I have.
3) More girls have won trivia night than I have.

Scenario 14a

At the local library, you start talking with two of the librarians. You claim to have read *Harry Potter* seventeen times, while the librarians have only read it once. They then suggest other books for you.

Scenario 14b

At the local library, you start talking with two of the librarians. You tell them that you have read *Harry Potter* once, but they then comment that they have read it twelve times because they love the writing so much. You think that they should probably try reading different books once in a while.

Possible Statements:

1) More librarians have read *Harry Potter* than just me.
2) The librarians have read *Harry Potter* than I have.
3) More librarians have read *Harry Potter* than I have.

_____

Scenario 15a

You are at a monastery and start to converse with three monks. The conversation turns to great books, and you say that you have read Augustine six times, while they have only read him once.

Scenario 15b

You are at a monastery and start to converse with three monks. The conversation turns to great books, and you say that you have read Augustine only once, while they have read his books on several occasions.

Possible Statements:

1) More monks have studied Augustine than just me.
2) The monks have studied Augustine more than I have.
3) More monks have studied Augustine than I have.

_____

Scenario 16a

You are talking with two trainers at a gym. You say you have lifted weights six times this week, and they have only lifted weights once this week.

Scenario 16b

You are talking with two trainers at a gym. You say to have lifted weights only once this week in preparation. They themselves have lifted six times this week.

Possible Statements:

1) More trainers have lifted weights than just me.
2) The trainers have lifted weights more than I have.
3) More trainers have lifted weights than I have.

_____

Scenario 17a

You are talking with two skiers about how you skied today. You fell down six times, while they admit that they both fell once.

Scenario 17b

You are talking with two skiers about how you skied today. You only fell down once, but the skiers both admit to falling down four times.

Possible Statements:

1) More skiers have fallen down than just me.
2) The skiers have fallen down more than I have.
3) More skiers have fallen down than I have.
_____

Scenario 18a

You are talking with two carnival workers. You have ridden the rollercoaster twelve times today because you love the thrill, and the workers comment that they had to ride it once today to test it.

Scenario 18b

You are talking with two carnival workers. You have ridden the rollercoaster only once today, but you find out that the workers have ridden it six times to make sure it worked before the crowd arrived.

Possible Statements:

1) More carnival workers have ridden the rollercoaster than just me.
2) The carnival workers have ridden the rollercoaster more than I have.
3) More carnival workers have ridden the rollercoaster than I have.

_____

Scenario 19a

You are working backstage at a theater and begin talking to two stagehands. You mention that you had missed an important cue seven times during rehearsal, while the two stagehands had only missed one cue.

Scenario 19b

You are working backstage at a theater and begin talking to two stagehands. You mention that you had missed one cue during rehearsal, while the two stagehands had missed several.

Possible Statements:

1) More stagehands have missed cues than just me.
2) The stagehands have missed cues more than I have.
3) More stagehands have missed cues than I have.

_____

Scenario 20a

You are visiting the Napa Valley and attend a wine tasting event. There, you start talking with two wine connoisseurs. You mention that you have tasted the chardonnay three times, while the wine connoisseurs have only had it once today.

Scenario 20b

You are visiting the Napa Valley and attend a wine tasting event. There, you start talking with two wine connoisseurs. You mention that you have only tasted the chardonnay once today, while the wine connoisseurs have tasted it three times today, and they found it full bodied with an oaky note.

Possible Statements:

1) More wine connoisseurs have tasted the chardonnay than just me.
2) The wine connoisseurs have tasted the chardonnay more than I have.
3) More wine connoisseurs have tasted the chardonnay than I have.

_____

Please read the following contexts followed by a statement made immediately afterwards. Decide if the statement is true or false based on the context, and if you are not sure, please mark "not sure." Please answer each question to the best of your abilities.

Filler Questions

F1

You are in a group of friends talking about the latest video games. Some of your friends think that older games are better, but you feel that the newer ones have better graphics.

More people think older games are better.

F2

Someone spilled the milk in the refrigerator at work. A little annoyed, you decide to find the culprit. No one will fess up to the misdeed, though Dennis was the last person seen in the kitchen.

I think Dennis spilled the milk in the refrigerator a lot more than my coworkers.

F3

While on vacation in Florida, you find a group of beachgoers talking about a local restaurant. They say that the best crab legs are at The Crab Shack, but you think that the neighboring Lobster Lunch-in has the best shellfish in the county.

The Lobster Lunch-in has more variety than The Crab Shack.

F4

You notice that your roommate loves to leave dirty dishes in the sink. Frustrated, you confront him, but he ignores you. You start to leave sticky notes all over the dirty dishes, but you soon realize that this only exacerbates the tension.

There are more sticky notes on the dishes than I care to comment on.

F5

While writing your final paper for a class, you realize that you are missing almost 1,000 words. You also realize that the paper is due in an hour, so you are faced with a troubling situation.

You are missing more than 2,000 words for your final paper.

F6

Your friend and you are walking to the movie theatre, when you run into a stray husky by the side of the road. You both decide to skip the movie and take the dog home.

The dog was more of a husky than a Labrador.

F7

Listening to your favorite music, you decide that you need a little snack. You go into the kitchen and get some crackers and cheese dip. Unfortunately, on the way back to your room, you spill the cheese dip all over the new carpeting.

The rug ate more of the cheese dip than I did.

F8

You see a frog trying to cross the street one morning on your way to work. Even though you are in a rush, you decide to pick the frog up and carry it across the street. Feeling good about your deed, you then decide to give your employees a raise.

There was a pond across the street.

F9

After a long night of working, you decide to take a break in front of the television. Your partner, however, wants you to clean the living room. A bit annoyed that your TV time is cut short, you decide to do it anyway, though you only got to watch TV for 10 minutes.

There should be a lot more TV time after work is over.

F10

On your way to the gym one day, you see a couple of food carts that are selling freshly fried pickles. Having never tried one, you decide to visit one of the stands, considering you are about to work out anyway. Turns out that they are so good, you never make it to the gym.

More pickles were consumed than weights lifted on that day.

F11

Making dinner one evening, you realize that you have run out of garlic for your garlic mashed potatoes. As a substitute, you find a very old container of garlic salt, and though it said "Expires 2004," you desperately want those mashed potatoes.

Garlic salt offers a fine alternative to fresh garlic.

F12

At your favorite restaurant, you are torn between ordering the chicken or the steak. The waitress claims that the chicken is a better choice, but you look around and notice that a lot of people have steaks on their plates.

There are more steaks in the dining room than chicken dishes.

F13

At the Laundromat, you see a couple of friends doing some laundry. However, one of them forgot their quarters, but thankfully you brought some extra. Your friends were very grateful for the gift.

You didn't give your friends any quarters.

F14

You are in the mood to eat fresh-baked bread, so you head down to the local bakery. Disappointed at their hours, you leave empty handed and instead head to bed.

The bakery is open late at night.

F15

Watching the football game, you decide to go out and buy some more snacks. You ask your friends what they want, and they give you a variety of answers, but hot wings seems to be the winner.

Most of your friends like hot wings.

F16

You are out at the mall with some of your friends and you see a really cool jacket in the window. It costs well beyond what you can afford, yet you still really want it. Your friends offer a decent alternative, but it still is not the same.

Friends would prefer that you buy the expensive jacket more than the cheap one.

F17

You are visiting the zoo one day, and you notice that one of the rhinos has a top hat on. As you are setting up your camera to take a picture of the odd sight, the rhino bows down and tips his hat at you. Going to the zoo was a great idea.

The aquarium has the best exhibits.

F18

You are looking in to buying a new car. After finding the car that has the features you need at a good price, you are now thinking of the best color to match your personality. Green seems to fit you, but there is something special that you love about a red car.

You decided to buy a blue car at the dealership.

F19

Sitting at your work desk, you notice a strange bug near the corner that appears to be a walking stick. Excited, you run to find and show your coworkers, but by the time you get back, you see that it is a cockroach and Janet starts to scream. Deborah, on the other hand, tries to catch it in a bottle.

The cockroach on the corner of your desk scared Deborah more than Janet.

F20

Your friends are trying to decide which board game to play before heading out to dinner that evening. You recommend something simple like a card game, but Enrico wants to play a very complex board game. Though the reservations were at six thirty, you don't arrive at the restaurant until seven.

You played a board game with Enrico instead of a card game.