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A Small Wolf Eats a Large Apple: An Experimental Investigation of the Temporal Processing of Conceptual Magnitudes

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A SMALL WOLF EATS A LARGE APPLE: AN EXPERIMENTAL INVESTIGATION OF THE TEMPORAL PROCESSING OF CONCEPTUAL MAGNITUDES

A Thesis

by

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ABSTRACT

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When individuals are presented with two options and are asked to select the conceptually larger item, a size congruity effect is usually observed. A size congruity effect is present in comparison tasks when congruent stimuli, whose physical size and conceptual size match, are compared much faster than incongruent stimuli, whose physical size and conceptual size do not match. The current study used images and words as stimuli to investigate the two competing hypotheses for the size congruity effect using delta plots. Positive delta plots were observed when response time for incongruent items was compared to congruent items, providing evidence of a late competition effect between the conceptual and physical size dimensions. These results were not replicated when the response time for incongruent items was compared to neutral items, possibly showing that the competition effect might be modulated by the specific manipulation of the task.

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CHAPTER I

INTRODUCTION

When asked to compare the sizes of two objects, one has to wonder what is meant by that. The comparison that is being requested might pertain to either the physical size or the conceptual size of an object. The relative physical size of an object is found by comparing it to another object that might be displayed as larger or smaller. The conceptual size of an object refers to how big or small it is in the real-world, and one does not necessarily have to be looking at those objects to make the comparison (Gliksman et al., 2016). The objects that have been used to make these types of comparisons include numbers, images, and words (Gliksman et al. 2016, Henik & Tzelgov, 1982; Rubinsten & Henik, 2002).

One size dimension cannot be ignored by participants when it is asked of them to focus on the other size dimension. For example, if a task requests participants to choose which of the two objects displayed is physically larger, the conceptual size of the object would not be ignored. The same happens when the relevant dimension is conceptual size. Participants cannot ignore the physical size dimension even when they are told to solely focus on the conceptual size of an object (Henik et al., 2017).

A size congruity effect has been observed in various studies focusing on these types of judgment tasks. For a size congruity effect to be present, the congruent stimuli must be compared faster than the incongruent stimuli (Henik & Tzelgov, 1982; Konkle & Oliva, 2012; Rubinsten &

Henik, 2016). Congruent stimuli are those objects whose physical size matches their conceptual size. An example of a congruent pair would be a large image of a wolf shown next to a small image of an apple. Incongruent stimuli are those objects whose physical size and conceptual size do not match (Gliksman et al., 2016). An example of an incongruent pair would be a small image of a wolf next to a large image of an apple. Although a wolf is larger than the apple in the real world, it is shown to be physically smaller.

Statement of the Problem

There are two competing theoretical models that can account for the time course of the size congruity effect that appears in comparison tasks. In the early competition model, the physical size and numerical size are associated together onto an integrated analog representation. As the name implies, the size congruity effect occurs early. In the late competition model, the physical magnitude and numerical magnitude each have their own representation and do not interact until the time to make a decision is reached, therefore, the size congruity effects occurs at a later stage (Faulkenberry et al., 2016; see Santens & Verguts, 2010 for detailed model specification). Delta plot analysis of total response time is one method that can be used to address this debate concerning the time course of congruity effect. Analyzing the shape of total response time distributions via different delta plots can investigate the size congruity effect that is observed in conflict tasks.

One of the current conflict models, such as Diffusion Model for Conflict Tasks (DMC) developed by Ulrich et al. (2015), can be used to explain the reaction time and error rate data as it can account for both positive and negative delta functions and assumes that there are two separate processes involved, the controlled processes that control task-relevant information and automatic processes that control task-irrelevant information. Delta plots show the reaction time difference between two experimental conditions. For example, it allows one to compare the incongruent condition against the congruent condition, or against the neutral condition. Reaction times are ranked ordered and divided into an equal number of bins for each condition. The x-axis shows the difference between the mean reaction times of the two conditions chosen for the analysis, and the y-axis shows the mean reaction time of both conditions. Evidence of a late competition effect is typically provided by a positive delta plot. The irrelevant information is accumulated slowly over time, so interference does not occur right away. This indicates that the response time difference between the two conditions is greater for relatively slow than for relatively fast responses. Negative delta plots represent the opposite and provide evidence of an early competition effect. This shows that irrelevant information is accumulated very fast and as a result, it interferes with the relevant information early in the time course (Ellinghaus & Miller, 2018; Pratte, 2020; Ulrich et al., 2015).

Currently, there are no experimental studies that have investigated whether there is an early competition effect or late competition effect between a target and a distractor when conceptual size comparisons (i.e., real world size comparisons) are made using images and words. Past studies have only focused on the type of interaction found when numerical comparisons are made (Faulkenberry et al., 2016; Santens & Verguts, 2010; Sobel et al., 2017). It is important to investigate the size congruity effect and the early and late competition effect using other types of stimuli aside from numbers. This can help one determine if there are any significant differences when different stimuli are compared.

Statement of the Purpose

The current study used a Stroop-like paradigm to investigate if a size congruity effect would be observed when making comparisons based on the conceptual size of an object by analyzing total response time to determine the type of competition effect found using delta functions. If a positive delta function is observed, then this indicates that there was competition between the relevant and irrelevant dimension late in the time course. The opposite would be true for a negative delta plot (Ulrich et al. 2015).

In addition to total response time, the eye fixation proportions towards a distractor were also analyzed in the current study to determine the level of attraction of a competitor during the decision-making stage. Eye fixation proportions can provide confirmation of the size congruity effect as they can tell one where the visual attention was directed to the target and the competitor (Schulte-Mecklenbeck et al., 2019).

CHAPTER II

REVIEW OF LITERATURE

There have been a number of studies that have used a Stroop-like paradigm to examine the response time of participants when making comparisons about the physical or conceptual size of an object. Henik and Tzelgov (1982) attempted to describe the interaction between physical and semantic information by assigning these two dimensions as relevant or irrelevant to the task. They had two sessions, one where the relevant dimension was physical size and the other where it was numerical size. The level of congruency was also manipulated as well as the order of sessions. The participants in their study had to choose which of the two numbers displayed was larger either physically or numerically. A size congruity effect was observed, meaning that participants compared the numbers whose size was physically and numerically congruent much faster than when they were incongruent. It was also concluded that physical size comparisons were made faster than numerical size comparisons. Additionally, it was found that physical and semantic information is processed in parallel when numerical comparisons are made.

A similar effect was observed by Gilksman et al. (2016) when making size comparisons using images. On one session, participants were asked to select the image that was physically larger. On the other session, they were instructed to select the image that was conceptually larger. The response times for physical size judgments were faster than in the conceptual size judgments. A size congruity effect was present for the physical size comparisons and the conceptual size comparisons, indicating that the processing of both is automatic. Konkle and

Oliva (2012) also presented two images to participants and asked them to pick the one that was bigger on the screen. They were also asked to choose the image that was smaller on the screen in another session. The response time for the congruent stimuli was shorter than for the incongruent stimuli. Both of these studies used colored images. It has been well-documented that certain colors have particular effects on an individual’s attention. For example, Elliot and Niesta (2008) discovered that the color red tends to attract the attention of males. To avoid color becoming a confounding variable, black-and-white images were used in the first experiment of the current study.

Rubinsten and Henik (2002) demonstrated that the size congruity effect is not only present when comparing numbers and images. It can also be observed when words are used. In their experiment, participants had to choose which of the two animal names looked larger on the screen on one session, while on the other session they were instructed to choose the animal name that represented the larger animal in the real-world. There was an equal number of congruent, incongruent, and neutral stimuli. A size congruity effect was found for both types of comparisons. In addition, the response times for physical judgments were faster than for semantic judgments.

A study by S. Sereno et al. (2009) employed a standard lexical decision task in order to determine the effect the real-world size of a word has on response time. The stimuli used were concrete nouns representing big or small objects. There was a total of 90 words and 90 nonwords. Participants were asked to decide if the word shown on the screen was a word or a nonword. It was concluded that participants identified words describing big objects much faster than they did the words denoting small objects. The results indicate that when reading a printed word, the real-world size of it is automatically activated.

Much of the studies focusing on choices use off-line methods that simply record the response of a participant without going further into investigating what could potentially shed more light into the real-time process of decision-making. Koop and Johnson (2013) demonstrated the validity and usefulness of methods such as eye-tracking for preferential choices. They began by monitoring hand movement using mouse tracking and moved on to use the eye-tracker to show the process that occurs when making a choice. Olk (2013) used an eye-tracker to measure the allocation of attention in a Stroop task that used numbers, providing more evidence of the vast array of information monitoring eye movements brings. This was accomplished by analyzing fixations and saccades. The congruent condition consisted of two arrays of numbers, one which contained more numbers with higher value and another that contained fewer numbers of lower value. The incongruent condition consisted of an array that had more numbers of lower value and another that had fewer numbers of higher value. The instructions specified that the participants choose the array that contained more numbers.

Their eye movements while they did this indicated that in both the congruent and incongruent conditions there were more first saccades directed to the array that contained more numbers. However, there was a higher percentage of first saccades to the array that had more numbers in the congruent condition. There were more first saccades directed to the array that had less numbers and numbers of higher value. When the fixations were analyzed, it was found that in both the congruent and incongruent conditions the participants spent more time fixating on the array that had more numbers. It was concluded that more time was spent on the array that had more items in the two conditions, and that the percentage of fixations of arrays with more or less items was similar when the fixation location and its duration were analyzed. These results are in line with previous studies about attention and size perception (Olk, 2013).

Previous studies examining numerical comparisons have found evidence for the early and late competition effect hypotheses (Faulkenberry et al., 2015; Krause et al., 2017; Santens & Verguts, 2010; Sobel et al., 2017). Neuroimaging studies, for example, have provided support for both models (Kadosh et al., 2007; Szücs & Soltész, 2008). In a study by Kadosh (2007), functional magnetic resonance imaging (fMRI) and event-related potentials (ERPs) were combined with a size comparison task. It was determined that the type of interaction found was dependent on the type of task requirements. In contrast to the neuroimaging studies, a visual search study conducted by Krause et al. (2017) provided support solely for the early interaction hypothesis. Participants in this study were required to identify the physically larger target number among physically small distractors. Participants were quicker to detect the physically larger target number when the numerical size matched the physical size.

Santens and Verguts (2010) identified the shared representation account and the shared decisions account. In the former, it is thought that numerical and physical size overlap and the interaction between both size dimensions occurs early on. In the latter, both dimensions do not interact until the decision stage. They conducted four behavioral experiments and four simulations that provided support for the late interaction account. In the first experiment, two numbers were presented on a screen. Participants were instructed to select the number that was smaller or larger and to ignore the number's physical size. They were quicker to select the appropriate number when its physical size and numerical size were congruent than when they were incongruent. The first simulation was implemented in a computational model with a dual route design. The model replicated the significant effects that were found in the behavioral experiment.

In the second experiment by Santens and Verguts (2010), participants were required to decide if the number that was shown on the screen was smaller or larger than the average numerical size. This was the magnitude judgment task. The other was the parity judgment task that consisted of having participants decide if the number displayed was even or odd. The size congruity effect only appeared in the first task. The third experiment required the participants to indicate if the number that was shown was numerically close or far to the number five. They had to press the left button for a number that was far from five and the right button for the number that was near to five. In the second half of the experiment, they were told to do the opposite.

Unlike the past three experiments, in the fourth one the focus of the task was physical size. The procedure was the same as the one from the third experiment, however, the participants had to decide if the physical distance between the physical size of the number presented, and the mean physical size was close or far. Once again, more support for the shared representation account was found. All the simulations managed to replicate the significant results of the behavioral experiments (Santens & Verguts, 2010).

Faulkenberry et al. (2016) used mouse tracking to investigate the size congruity effect in a series of three experiments. Participants were asked to choose which of the two numbers displayed was physically larger in the first experiment. They had to click the start button to begin each trial and were instructed to move the computer mouse as soon as they did this. It was found that in incongruent trials the hand trajectories tended to move towards the distractor. Area under the curve (AUC) was used to verify the later interaction account by analyzing the distribution of the trajectories on these trials which proved to be unimodal. The bimodality coefficient, which was less than the 0.555 value that is indicative of a bimodal distribution, and the Hartigan dip statistic were used to identify the distribution of trajectories as unimodal. If the distribution of trajectories on incongruent trials was found to be multimodal, then this would have provided support for the early competition hypothesis. To confirm these results, the numerical distance of the numbers was manipulated in a second experiment. Again, the hand trajectories in incongruent trials moved more towards the distractor. As numerical distance increased, the size congruity effect also increased.

A third experiment by Faulkenberry et al. (2016) was completed to test whether the instructions of requiring the participants to move the computer mouse as soon as they clicked the start button were biased towards any of the models. Participants were then asked to make a decision as quickly and accurately as they could, but they were not told to move the computer mouse as soon as possible. Results were similar to the first and second experiments. When completing incongruent trials, the mouse trajectories were found to be attracted to the distractor, lending support to the late competition effect model.

In the current study, it was expected that when making conceptual size comparisons, a size congruity effect would be observed. Additionally, there would be higher eye fixation proportions at the distractor in the incongruent condition than in the neutral and congruent conditions. It was also hypothesized that the delta plot would show a positive slope, indicative of a late competition effect.

CHAPTER III

EXPERIMENT I

The purpose of this experiment was to determine if a size congruity effect was present, and to identify the type of competition between a target and distractor when making size comparisons. The stimuli used were black-and-white images that were manipulated based on three conditions: congruent, incongruent, and neutral. Participants were instructed to select the one that was conceptually larger, the image that depicted an object as larger in the real world.

Based on previous studies that have used images as stimuli, high accuracy was expected. Furthermore, total response times were expected to be slower in the incongruent condition than in the congruent condition (Gliksman et al., 2016). Higher eye fixation proportions at the distractor in the incongruent condition were expected. Evidence of a late competition effect was also expected.

Norming Task

The images used as stimuli in the experiments were selected after a norming task was conducted using the Qualtrics Survey software. In the first part of the study, a total of 81 participants (63 females; 18 males) from the University of Texas Rio Grande Valley were recruited through SONA Systems. Most had English or Spanish as their native language, except for three participants. A total of 326 picture stimuli were selected from the International Picture

Naming Project (IPNP) and past studies (Bates et al., 2000; Bonin et al., 2002; Nishimoto et al., 2012; Snodgrass & Vanderwart, 1980).

The task was divided into two sections to allow participants to take a break. The participants were asked to provide a name for each image. Similarly to Paivio (1975), they also rated the size of each object depicted in the image on a scale of 1 to 9, with 1 being the smallest and 9 being the largest. An additional 161 (125 females; 35 males; 1 other) participants were recruited to name and rate the size of a different set of images. Only four participants did not have English or Spanish as their native language.

A total of 158 images with 85% name agreement and above were selected for the second part of the study. Fifty participants for this second part were recruited and were asked to rate the familiarity, visual complexity, object agreement, and viewpoint agreement of each of the images in addition to selecting a category each object belonged to as was done in the study by Bordeur et al. (2010). From this set of images, 120 were selected to form the pairs used in the study. The results are provided in Table 1. The images were paired based on their size difference, complexity, and familiarity. The name of each object was determined to be an English-Spanish cognate or noncognate word using two cognate dictionaries (Academic Learning Company, n.d.; Nash, 1997). Cognate words were paired with each other and noncognates were also paired together to neutralize the effects cognates would have on the results. Table 2 shows all the possible pairings.

CHAPTER IV

EXPERIMENT I METHODOLOGY AND FINDINGS

Participants

Thirty-five participants (26 females; 9 males) from the University of Texas Rio Grande Valley with normal or corrected-to-normal vision were recruited through SONA Systems. Their mean age was 19.17 (*SD* = 1.72). They were given extra credit in one of their psychology classes as an incentive. Thirty participants were right-handed, 1 left-handed, and 4 ambidextrous. A total of 19 participants reported English as their native language (L1) and 16 Spanish as their L1, while 16 participants reported English as their second language (L2) and 14 reported Spanish as their L2. Five participants reported no L2. Participants rated their proficiency level in speaking, listening, reading, writing on both their L1 and L2 on a scale from 1 (very low) to 10 (perfect). Table 3 provides the mean proficiency level for those self-reported measures.

Apparatus

The eye-tracker used was the desktop EyeLink 1000 Plus desktop mount Version 5.09 with a sampling rate of 1000 Hz (SR Research, Mississauga, Ontario, Canada). A host laptop was in charge of processing and recording eye movements. The images were shown on the display computer (1920 X 1080 pixel resolution with a 60 Hz refresh rate) with a Microsoft Windows 10 operating system. A chinrest was placed in the middle of the table facing the monitor and was clamped tightly to the edge of the table. The distance from the participant’s eye to the top and bottom of the display monitor was measured as well as the height and width of the display monitor. This was done to ensure that the distance from the eye to the display monitor was at least 1.75 times the width of the monitor, which was 20 inches, since the range of the eye-tracker is 32 degrees horizontally and 25 degrees vertically.

Stimuli

For the image physical size and conceptual size tasks, there was a total of 60 black-and-white image pairs that consisted of 20 congruent, 20 incongruent, and 20 neutral pairs. Black-and-white-images were chosen because color may affect attention and, as a result, can become a confounding variable (Elliot & Niesta, 2008). In the congruent condition, one of the images was both larger conceptually and physically. In the incongruent condition, one of the images was conceptually larger and physically smaller. In the neutral condition, both images were the same physical size. Figure 1 provides examples of the type of stimuli that was used in the experiment. The physically large images were fit into a 6 × 6 inch square outline centered on a slide on Microsoft PowerPoint 2016, while the physically small images were fit into a 3 × 3 inch square outline. The outline was removed, and each slide was saved as a JPEG image. The graphics editor program GIMP (The GIMP Development Team, 2019) was used to resize all the images to be 1200 × 900 with a resolution of 146 dpi. The images were shown on the upper left and upper right corner of the screen. The target images appeared an equal number of times on the left and right side of the screen.

Design

The level of congruity was manipulated, resulting in a congruent, incongruent, and neutral condition. The dependent variables investigated were accuracy, total response time, and eye fixation proportions. Accuracy referred to the percentage of correct trials. Total response time referred to the time from the onset of the stimulus to the time the participant made a response. Eye fixation proportions toward the distractor were calculated by dividing the total number of fixations made to the distractor by the total number of fixations made toward the screen.

Procedure

In the eye tracking tasks created with SR Research Experiment Builder Version 2.3.38, participants had to select which image or word was either physically or conceptually larger. Participants were led to a well-lit room. After signing the consent form, they were asked to stand in the middle of the room and were shown how to position their hands to create a hole into which they could look through to see the black '×' that was displayed on the door. Next, the participants were told to bring their hands towards their face. The direction the participants brought their hands to indicated which eye was their dominant eye, the eye that was tracked. The participants were asked to take a seat on a chair with adjustable height and to place their head on the chinrest located at the middle of the table. The chinrest and the forehead rest were adjusted until the participants were in a comfortable position. The camera of the eye tracker was pointed in the direction of the dominant eye. After making sure the image of the eye was not blurry, calibration was done by asking the participants to follow the black dot that appeared on the screen without moving their heads. Validation was performed by again telling the participants to look at the black dot on the monitor. Once this was completed, the instructions for the experiment were shown on the screen, followed by six practice trials to familiarize them with the procedure. The instructions, which carefully explained what was meant by conceptual size, remained on the screen until the participants pressed the spacebar to move on. Each trial began by a fixation cross located at the bottom of the screen that the participants had to look at. After that, the word “START” appeared on the bottom of the screen. Once the participants clicked on the word “START” the two images or words appeared on the screen. Participants used the computer mouse to select the image that was conceptually larger. Figure 3 shows this process.

The Language Experience and Proficiency Questionnaire (LEAP-Q), a self-report measure containing questions about language proficiency level, was given next (Marian et al., 2007). Lastly, they were given the short version of the Edinburgh Handedness Inventory (EHI), developed by Oldfield (1971), to determine their dominant hand (Veale, 2014).

Data Analysis

The linear mixed model (LMM) using the statistical programming language R (R Core Team, 2021) and R Studio (RStudio Team, 2021) was used to analyze response time with the lme4 package (Bates et al., 2015), and the generalized linear mixed model (GLMM) was used to analyze accuracy if the error rate was above 5%. The condition (i.e., congruent, incongruent, and neutral) was entered as a fixed factor with sum coding. The random factors were by-subject and by-item intercept as well as by-item slope of condition. Log transformations were conducted on response times to correct for distribution skews. The syntax for the final model was lgRT ~ (1+Condition|Subject) + (1| Trial). To obtain delta plots, the DMCfun package was used (Mackenzie & Dudschig, 2021). Total reaction times for the two conditions being compared (i.e., incongruent vs. congruent and incongruent vs. neutral) were ranked ordered and divided into three equal sized bins with equal number of trials. For the delta plot analysis of total response time, one participant was excluded as they had 100% error rate on the incongruent condition.

The fixation proportions (from the time the participant clicked on “START” to the time they made a response) were modeled by Growth curve analysis (GCA, Mirman, 2014) using a two-order orthogonal polynomial with fixed effects of condition and random effects of participants and participants-by-condition. The syntax of the model used was fixp~(poly1+poly2)*Condition+(poly1+poly2|Subject) + (poly1+poly2|Trial). The package GazeR (Geller et al., 2020) was used to analyze the data. The time window was restricted from 0 ms to 2400 ms[1]. The time window was chosen based on the grand average reaction time across conditions.

Ten participants were excluded from the eye tracking analysis because of calibration issues. Only the dominant eye was tracked. The right eye was tracked for 21 participants and the left for 4 participants. Data was trimmed to only those fixations that fell into the target and distractor interest areas of 600 × 450 using SR Research Data Viewer Version 4.2.1. The fixations that fell into the target and distractor interest areas were coded binomially (1 = fixated, 0 = not fixated) for the 20 ms bins relative to the stimulus onset. A model was fit with only random effects and data points with residuals that exceeded 2.5 standard deviations were excluded.

Results

Accuracy was high (*M* = 97%, *SD* = 17%). There was no error rate analysis conducted with GLMM as the error rate of 2.98% was too low. Table 4 shows the mean accuracy, response time, and error rate for all conditions. In the response time analysis, there was a significant main effect on condition, $X^2(2) = 4360.2$, $p < .0001$, indicating that there was a significant difference

[1] The mean response time for the correct trials was 2,399 milliseconds (*SD* = 94.93 ms).

between the conditions. Post hoc comparisons revealed a significant difference in response time between the neutral and incongruent condition (β = -.0801, SE = .00196, z = -40.948, $p < .0001$), neutral and congruent condition (β = .0481, SE = .00201, z = 24.005, $p < .0001$), and the incongruent and congruent condition (β = .1282, SE = .00197, z = 65.081, $p < .0001$). The marginal R^2 was 0.021, indicating that the fixed effects of the model accounted for 2.1% variance of the data. The conditional R^2 was 0.465, indicating that both the fixed effects and random effects of the model accounted for 46.5% of the data.

There was a main effect on condition ($X^2(2) = 828.4218$, $p < .0001$) for eye fixation proportions to a competitor. A significant condition effect was found on the cubic terms ($X^2(2) = 9.6864$, $p < .007$) and linear terms ($X^2(2) = 352.4030$, $p < .0001$). Post hoc analysis confirmed a significant difference in eye fixation proportions in the neutral condition compared to the incongruent condition (β = .0813, SE = .00430, z = 18.899, $p < .0001$), the neutral condition and the congruent condition (β = -.0401, SE = .00432, z = -9.267, $p < .0001$), and the incongruent and congruent condition (β = -.1214, SE = .00431, z = -28.168, $p < .0001$). Table 4 shows the mean and standard deviation of eye fixation proportions to a distractor. The marginal R^2 was 0.035, indicating that the fixed effects of the model accounted for 3.5% variance of the fixation proportion data. The conditional R^2 was 0.13, indicating that the fixed effects and random effects accounted for 13% variance of the fixation proportion data.

The distribution of total response time analysis revealed a late interaction effect between the incongruent and congruent condition for the conceptual size comparison task. Figure 5 shows the positive delta plot of the incongruent and congruent comparison. However, when the incongruent condition was compared with the neutral condition, an early interaction effect was observed shown by the negative slope of the plot. Figure 6 shows the delta plot of the incongruent and neutral comparison.

CHAPTER V

EXPERIMENT I SUMMARY AND CONCLUSION

Discussion

As was expected, accuracy was above 90%. Responses were also found to be made faster in the congruent condition compared to the incongruent condition. The results were in line with the study conducted by Gliksman et al. (2016) where they also reported high accuracy and faster response times in the congruent condition compared to the incongruent, providing evidence for the size congruity effect.

There were more fixations made towards the competitor in the congruent condition compared to the incongruent and neutral condition. This was not expected as it was hypothesized that there would be higher eye fixation proportions at the distractor in the incongruent condition compared to the other conditions since incongruent items are processed slower than congruent items. As a result, it was expected that participants would spend more time viewing the distractor in the incongruent condition. Image quality might have influenced eye fixations since some images had darker outlines and shadings than others. An alternative explanation for this discrepancy of results based on attention studies might be caused by an error in the data preparation process and analysis of the eye fixation data.

The evidence of an early competition effect in the delta plot when the incongruent condition was compared to the neutral condition brought forth the question of whether the competition effect is modulated by the specific manipulations of the task when images are compared. Even if confound variables affected the results of the current study causing a negative. slope in the delta plot of the incongruent and neutral comparison, the experiment manipulations would be an interesting factor to investigate since most conflict tasks that have used delta analysis have mainly focused on the incongruent versus congruent comparison, stimulus effect, and task type (Ellinghaus & Miller, 2018; Pratte, 2020).

CHAPTER VI

EXPERIMENT II

Much like in the first experiment, participants were asked to compare the stimuli, in this case printed words, and to select the one that was conceptually larger. The goal was to investigate if participants would have a shorter response time when comparing congruent stimuli than when comparing incongruent stimuli. The objective was to gather evidence of either a later competition or early competition effect between a target and a competitor.

Accuracy was expected to be in line with the results of previous studies that have used words as stimuli in comparative judgment tasks The response times for incongruent trials were expected to be slower than the response times for congruent trials (Rubinsten & Henik, 2002). It was also hypothesized that there would be longer total response times and higher eye fixation proportions at the distractor in the incongruent condition than in the congruent and/or neutral conditions. Delta plots for the comparisons were predicted to show evidence of a late competition effect.

CHAPTER VII

EXPERIMENT II METHODOLOGY AND FINDINGS

Participants

Twenty participants (13 females; 7 males) from the University of Texas Rio Grande with normal or corrected-to-normal vision were recruited through SONA Systems. Their mean age was 19.23 (*SD* = 1.51). The participants were different from the ones who completed the first experiment. They were given extra credit in one of their psychology classes as an incentive. Only one participant was left-handed while 19 were right-handed. For their L1, 9 participants reported English, 10 Spanish, and 1 Marathi. For their L2, 11 reported English, 8 Spanish, and 1 reported none. They self-rated their proficiency level in four measures: speaking, listening, reading, and writing. Table 5 shows the mean proficiency level for those measures.

Apparatus

As in the first experiment, a desktop EyeLink 1000 Plus Version 5.09 eye-tracker with a sampling rate of 1000 Hz (SR Research, Mississauga, Ontario, Canada) was used. The host computer processed and recorded eye movements. The stimuli were shown on the display computer.

Stimuli

A total of 60-word pairs typed in Courier New font, as was done in the study by Sereno et al. (2009), were used in each session. The font size for the large words was 140 and 70 for the small words. There was a total of 20-word pairs for each of the three experimental conditions (i.e., congruent, incongruent, and neutral). In the congruent condition, one word was larger both physically and conceptually. The incongruent condition consisted of one word being conceptually larger and physically smaller. In the neutral condition, both words were presented in the same font size. Table 2 shows examples of the stimuli used. Microsoft PowerPoint 2016 was used to prepare the images for the experiment. The physically large images were fit into a 6 × 6 inch square outline that was centered on a slide, while the physically small images were fit into a 4 × 4 inch square outline. After removing the outline, the slides were saved as JPEG images and resized on GIMP to be 1200 × 900 with a resolution of 146 dpi. The location the target word appeared on the screen was counterbalanced.

Design

As in the first experiment, the three experimental conditions were congruent, incongruent, and neutral. Accuracy, total response time, and eye fixation proportions were the dependent variables.

Procedure

The procedure for this second experiment was the same as the one in the first, with the only difference being the type of stimuli used. Participants were directed to go to a well-lit room where they were given a consent form to read and sign. Once this was done, they were asked to stand in the middle of the room facing the door that had a black '×' on it. They were instructed to move their hands away from their body and to position their hands in a way that they could create a hole to see through and look at the '×'. Then they were directed to move their hands towards their face to identify their dominant eye. Next, the participants were asked to take a seat on a chair with adjustable height and to place their head on the chinrest. Once the chinrest and forehead rest were adjusted, calibration and validation were done. The instructions appeared on the screen until the participants were ready to move on by pressing the spacebar. A black fixation cross at the bottom of the screen indicated the beginning of each trial. Participants were required to use the computer mouse to click on the word “START” before the two words appeared on the screen. After this, they made their response by clicking on the word that was conceptually larger. Figure 4 depicts this process. Participants then completed the LEAP-Q (Marian et al., 2007) and the EHI (Veale, 2014).

Data Analysis

Data was analyzed the same way as in the first experiment. Calibration issues resulted in the exclusion of two participants from the eye tracking analysis. The right eye was tracked for 12 participants and the left for 5 participants. To calculate the mean response time, the incorrect trials were removed. Once again, a model was fit with only random effects and data points with residuals that exceeded 2.5 standard deviations were excluded.

Results

Mean accuracy was 95% (*SD* = 21%). GLMM was not used to analyze error rate as the error rate of 4.58% was small. When analyzing response time, there was a main effect on condition, $X^2(2) = 828.93$, $p < .0001$. Post hoc analysis revealed a statistically significant difference between the neutral and incongruent condition ($\beta = .0107$, $SE = .00191$, $z = 5.592$, $p < .0001$), indicating that participants responded slower in the neutral condition compared to the incongruent condition. There was also a statistically significant effect between the neutral and congruent condition ($\beta = .0524$, $SE = .00191$, $z = 27.411$, $p < .0001$), and the incongruent and congruent condition (β = .0417, *SE* = .00194, z = 21.53, p < .0001). The marginal R^2 was 0.005 and the conditional R^2 was 0.497. Table 6 shows the mean accuracy, response time, and error rate for all conditions.

Growth curve analysis for eye fixation proportions revealed a main effect on condition ($X^2(2) = 172.2650$, $p < .0001$). A condition effect was observed on both the cubic ($X^2(2) = 110.3983$, $p < .0001$) and linear terms ($X^2(2) = 18.0067$, $p < .0001$). The marginal R^2 was 0.045, indicating that the fixed effects of the model accounted for 4.5% variance of the fixation proportion data. The conditional R^2 was 0.10, indicating that the fixed effects and random effects accounted for 10% variance of the fixation proportion data. Since a main effect was observed, a post hoc test was administered. It was found that comparing the neutral condition with the incongruent condition (β = .0329, *SE* = 0.00535, z = 6.136, p < .0001) and to the congruent condition (β = -.0370, *SE* = 0.00533, z = -6.953, p < .0001) led to a statistically significant difference. The difference in fixation proportions toward the distractor was also significant when the incongruent condition was compared to the congruent condition (β = -.0699, *SE* = .00539, z = -12.979, p < .0001).

The delta plot analysis for the comparison of response time in the incongruent and congruent condition revealed a late competition effect as shown by the positive slope in Figure 7. In contrast, a negative slope was observed for the comparison between the incongruent and neutral condition, indicative of an early competition effect. This is shown in Figure 8.

CHAPTER VIII

EXPERIMENT II SUMMARY AND CONCLUSION

Discussion

Accuracy was in line with other size judgment studies (Henik & Tzelgov,1982; Rubinsten & Henik, 2002). Response time was found to be slower in the incongruent condition compared to the congruent condition. However, response time was found to be faster in the incongruent condition compared to the neutral condition. This conclusion was also different from the observations found in the first experiment since in the first one, the response time in the incongruent condition was slower than in the neutral condition. Additionally, distractor eye fixation proportions were higher in the congruent and neutral conditions compared to the incongruent condition. As in the first experiment, this was not expected since based on the competition effect typically found in conflict tasks in the incongruent condition, one would expect to find higher fixations on the distractor. Results of the eye fixation proportions data could have been affected by an error in the data preparation and analysis process.

Another possible explanation for this discrepancy could be that other factors that were not controlled might have affected the results. In this experiment, the printed words were gathered from the images used in the first experiment. The names of the objects being depicted in the images were used as stimuli. When the image norming task was conducted, only the name agreement, size, category, familiarity, visual complexity, object agreement, and viewpoint agreement were assessed for each item. The number of phenomes, the orthographic neighborhood size, frequency, among other lexical characteristics were not assessed.

The delta plots were the same as in the first experiment. When the response times of the incongruent condition were compared to those of the congruent condition, the delta plot that resulted was positive. This demonstrated that competition occurred late in the time course. When the response times of the incongruent condition were compared to the response times of the neutral condition, evidence that competition occurred early in the time course was provided by the negative slope of the delta plot.

CHAPTER IX

GENERAL SUMMARY AND CONCLUSION

General Discussion

The two experiments only allowed one to observe the automatic processes of the competition effect from the physical size dimension, not the automatic conceptual size dimension. Response time analysis provided evidence of a size congruity effect in the first experiment as there was a facilitation effect in the congruent condition. An inhibitory effect was present in the incongruent condition. This is consistent with previous findings on image, word, and numerical comparisons (Gliksman et al., 2016; Henik & Tzelgov, 1982; Rubinsten & Henik, 2002). Eye fixation proportions were higher to the distractor in the congruent condition and even the neutral condition compared to the incongruent condition. This finding did not support the hypothesis that there would be more fixations to the distractor in the incongruent condition compared to the congruent condition and neutral condition.

In the second experiment, the congruent condition was processed faster than the incongruent, but the neutral condition was processed slower than the incongruent condition. This effect in the neutral condition and incongruent condition differed from the first experiment. The higher fixation proportions to the distractor in the congruent condition compared to the incongruent condition observed in the first experiment were also present in the congruent condition of the second experiment.

Both experiments provided evidence of a late competition effect with delta plots when the response times of the conditions being compared were incongruent and congruent. When the comparison of response times involved the incongruent and neutral trials, this effect was reversed. This might mean that manipulation of the task affects the competition effect in decision making tasks. Future studies using delta plots to compare two conditions could explore these differences.

Limitations

Time constraints caused by technical issues in the program used to run the image and word tasks resulted in few participants. Calibration issues limited the sample size further. This is a problem because the lack of a large sample size affects the generalizability of the results. A large sample size is needed to report Chi-square test results otherwise the Chi-square will be large and inaccurate compared to the F-test and the t-test. Aside from a limited sample size, there was also a limited number of trials. Each condition only contained 20 trials, for a total of 60 trials.

There was also no physical size comparison of images and words. Participants were only asked to select the object that was conceptually larger. Previous studies have conducted both types of comparisons in size judgment tasks. In those studies, there is a difference in the response time of the physical size comparisons and the conceptual size comparisons. Participants typically respond faster in the physical size comparisons (Gliksman et al., 2016; Rubinsten & Henik, 2002). Conducting a session where the relevant dimension is physical size could allow one to observe the automatic processes of the competition effect from the conceptual size dimension.

For the word comparison task, the lexical characteristics of each word pair were not assessed. This could have been one of the confounding variables as similar, unfamiliar, or complex words could affect attention and response time. For example, an infrequent word might attract the attention of a participant as they will take longer to recognize it. This would affect response time. Databases such as SUBTLEX-EN database, the CLEARPOND database, or the MRC Psycholinguistic database could be used to determine characteristics like word frequency and orthographic neighborhood size (Brysbaert & New, 2009; Marian et al., 2012; Wilson, 1988).

Future Directions

The participants for the experiments were mainly college students aged 18-35. The study could be replicated in children and elders to see if there is a significant change in the way the information is processed in the different age groups. Additionally, those with learning disabilities such as dyslexia could also be examined, and those with neurodevelopmental disorders like attention-deficit/hyperactivity disorder (ADHD).

Aside from examining eye fixation proportions to measure attention, pupil size can also be used. Pupil dilation has been found to be associated with mental effort. The pupil size is affected by task difficulty, so one can observe when there is an inhibitory effect or facilitation effect present (Wierda et al., 2012; Schulte-Mecklenbeck et al., 2019). It is an adequate addition to response times to confirm the size congruity effect and may provide evidence for a late or early competition effect.

The information learned from this type of conflict task studies can be beneficial for the development of interventions that might increase math performance, especially if there is evidence of a strong association between performance in size judgment tasks and math achievement. A comparison between male and female participants could also be done since previous studies have found that females display a higher level of math anxiety compared to males even though they have the same potential to perform well on math tasks (Casanova et al., 2021; Goetz et al., 2013; Maloney & Beilock, 2012). The conclusions derived from this study could be beneficial in future studies that examine the cognitive processes involved in more complex decision-making tasks, such as those that are influenced by outside factors.

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APPENDIX A

APPENDIX A

NORMING TASK DATA

Table 1

Norms

Object Number	Object	Category	Name Agreement	Size Rank	Familiarity	Visual Complexity	Object Agreement	Viewpoint Agreement	Cognate/Noncognate
1	Anchor	Others	0.86	6.56	6.39	5.38	7.82	7.52	NC
2	Ant	Animals	0.92	2.26	8.2	5.8	7.39	7.79	NC
3	Apple	Food	0.96	3.35	8.37	5.18	8	8	NC
4	Arm	Others	0.87	4.16	8.37	5.44	7.86	7.98	NC
5	Baby	Others	0.86	3.81	7.87	6.31	7.75	7.9	C
6	Banana	Food	0.92	2.77	8.5	5.42	7.77	7.74	C
7	Barrel	Others	0.87	5.29	6.41	5.8	7.77	7.57	C
8	Bed	Furniture	0.91	5.87	8.52	5.89	7.89	7.79	NC
9	Bell	Musical instruments	0.94	3.12	7.91	5.22	7.77	7.71	NC
10	Binoculars	Outdoor activity and sport items	0.87	2.9	7.57	6.31	7.67	7.71	NC
11	Broom	Household articles and cleaners	0.92	5.26	8.41	5.77	7.68	7.83	NC
12	Butterfly	Animals	0.89	2.25	8.35	6.4	7.86	7.64	NC
13	Button	Clothing	0.92	2.27	8.11	5.11	7.91	7.98	C
14	Calculator	Electronic devices and accessories	0.92	2.86	8.42	6.29	7.91	7.85	C
15	Camel	Animals	0.91	6.48	6.52	6.13	7.8	7.95	C
16	Camera	Electronic devices and accessories	0.95	3.14	8.11	6.36	7.7	7.62	C
17	Car	Others	0.91	6.95	8.43	6.04	7.56	7.81	C
18	Carrot	Food	0.96	2.55	8.5	5.48	7.86	7.88	NC
19	Castle	Others	0.91	7.69	6.43	6.49	7.68	7.86	C

Table 1, cont.

20	Cat	Animals	0.89	3.38	8.17	5.78	7.74	7.67	C
21	Chair	Furniture	0.92	4.19	8.54	5.69	7.73	8	NC
22	Cherry	Food	0.87	2.5	8.17	5	7.53	7.64	C
23	Cow	Animals	0.91	6.43	8.07	5.89	7.95	7.69	NC
24	Crab	Animals	0.94	2.77	7.48	6.4	7.55	7.8	NC
25	Crown	Jewels and money	0.92	3.29	7.04	6.32	7.64	7.76	C
26	Desk	Furniture	0.91	5.61	8.3	6.22	8.05	7.74	NC
27	Diamond	Jewels and money	0.89	2.58	7.22	5.98	7.64	7.85	C
28	Dog	Animals	0.87	4.21	8.43	5.67	7.79	7.48	NC
29	Domino	Games, toys, and entertainment	0.91	2.34	7.87	4.96	7.7	8.05	C
30	Door	Building materials	0.95	5.44	8.41	5.31	8.07	7.86	NC
31	Dress	Clothing	0.9	3.99	8.19	5.87	7.79	7.9	NC
32	Ear	Others	0.9	2.7	8.41	5.96	7.95	8.12	NC
33	Egg	Food	0.86	2.34	8.39	5.32	7.61	8	NC
34	Eraser	Stationery and school supplies	0.89	2.3	8.39	4.4	7.61	7.69	NC
35	Eye	Others	0.87	2.83	8.42	6.09	7.91	7.86	NC
36	Flashlight	Outdoor activity and sport items	0.86	2.78	8.15	5.53	8.09	7.93	NC
37	Flower	Nature elements and vegetation	0.86	2.61	8.3	5.51	8.02	7.74	C
38	Foot	Others	0.86	3.11	8.41	5.58	8	7.95	NC
39	Football	Outdoor activity and sport items /Games, toys, and entertainment	0.91	3.16	8.32	5.31	7.98	7.83	NC
40	Fork	Kitchen utensils	0.89	2.32	8.35	4.69	8.09	8.05	NC
41	Giraffe	Animals	0.92	7.26	7.48	6.4	7.89	7.9	C
42	Glasses	Medical instruments and accessories	0.87	2.74	8.28	5.27	7.91	7.88	NC
43	Goat	Animals	0.9	5.07	8	5.75	7.84	7.88	NC
44	Gorilla	Animals	0.86	6.5	7.39	5.78	7.75	7.93	C
45	Grapes	Food	0.89	2.61	8.43	5.58	8.11	7.86	NC
46	Hammer	Hand labor tools and accessories	0.92	2.92	8.17	5.07	8.07	7.93	NC
47	Helicopter	Others	0.91	7.07	6.87	6.69	8.05	7.86	C
48	Horse	Animals	0.94	6.8	7.7	5.89	8	7.98	NC
49	Hot Dog	Food	0.94	2.51	8.26	5.09	8.11	7.95	NC
50	House	Others	0.87	7.39	8.38	6.2	8.02	7.81	NC
51	Iron	Household articles and cleaners	0.86	3.87	8.2	5.82	8.02	7.93	NC
52	Key	Others	0.94	2.07	8.41	5.58	8.14	7.83	NC
53	Kite	Games, toys, and entertainment	0.95	3.36	7.96	4.93	7.91	8	NC

Table 1, cont.

54	Lighter	Others	0.9	2.39	7.91	5.56	7.8	7.86	NC
55	Lion	Animals	0.94	6.2	7.46	6.47	7.7	7.83	C
56	Lock	Others	0.97	2.62	8.3	5	8.07	7.74	NC
57	Magnet	Others	0.86	2.72	7.43	5.38	7.68	7.83	NC
58	Mirror	Decoration and gift accessories	0.95	3.9	8.43	5.56	8.16	7.86	NC
59	Monkey	Animals	0.92	4.61	7.63	6.09	7.91	7.98	NC
60	Mop	Household articles and cleaners	0.87	4.88	8.35	5.49	8	7.68	NC
61	Mosquito	Animals	0.85	1.62	8.17	6.16	7.89	8.03	C
62	Mountain	Nature elements and vegetation	0.92	7.82	7.41	6.2	7.89	7.85	C
63	Nail	Hand labor tools and accessories	0.87	1.75	8.24	4.69	7.89	7.95	NC
64	Necklace	Jewels and money	0.94	2.72	8.26	5.67	8	7.63	NC
65	Nose	Others	0.95	2.59	8.33	5.27	8.07	7.95	NC
66	Octopus	Animals	0.95	6.41	7.35	6.64	8.11	7.78	NC
67	Owl	Animals	0.97	4.03	7.3	6.4	8.25	8	NC
68	Panda	Animals	0.89	6.46	7.41	6.18	7.84	7.93	C
69	Paper Clip	Stationery and school supplies	0.85	2.36	8.33	4.67	8.3	7.93	NC
70	Peach	Food	0.85	2.39	8.37	5.04	8.05	7.82	NC
71	Peanut	Food	0.92	2.11	8.33	5.59	8.07	8.03	NC
72	Pear	Food	0.9	2.44	8.26	4.51	7.91	7.79	C
73	Pen	Stationery and school supplies	0.9	2.08	8.41	4.96	7.88	7.9	NC
74	Pencil	Stationery and school supplies	0.89	2.59	8.42	5.18	7.89	7.98	NC
75	Penguin	Animals	0.94	4.46	7.5	5.57	7.89	7.75	C
76	Piano	Musical instruments	0.89	6.23	7.76	6.67	7.82	7.85	C
77	Pig	Animals	0.9	4.23	8.02	5.8	7.81	7.79	NC
78	Pillow	Household articles and cleaners	0.89	3.41	8.39	4.69	7.86	7.97	NC
79	Pineapple	Food	0.92	3.03	8.26	5.91	8.02	7.85	C
80	Plate	Kitchen utensils	0.92	2.8	8.41	4.66	7.84	7.83	C
81	Pumpkin	Food	0.97	4.13	8.15	5.02	8.05	7.95	NC
82	Pyramid	Others	0.9	7.41	6.72	6.76	7.93	7.88	C
83	Raccoon	Animals	0.9	3.36	7.48	5.89	8.11	8.08	NC
84	Ring	Jewels and money	0.9	2.51	8.39	4.84	7.8	7.8	NC
85	Sandwich	Food	0.94	2.62	8.42	5.27	7.84	7.88	C
86	Scissors	Stationery and school supplies	0.97	2.54	8.39	4.89	8.02	7.88	NC
87	Scorpion	Animals	0.89	2.6	7.24	6.5	8.02	7.9	NC
88	Seal	Animals	0.85	5.33	7.26	6.11	7.86	7.82	NC

Table 1, cont.

89	Shark	Animals	0.95	6.21	7.43	5.53	7.8	7.95	NC
90	Shovel	Hand labor tools and accessories	0.87	4.05	8.18	5.09	8.09	7.78	NC
91	Skull	Others	0.89	3.52	7.87	6.31	8.07	7.85	NC
92	Snail	Animals	0.85	1.92	8.02	5.33	8	8.05	NC
93	Snake	Animals	0.91	4.83	7.93	6.02	8.12	7.9	NC
94	Snowflake	Nature elements and vegetation	0.92	1.7	7.24	5.75	7.98	8.03	NC
95	Spider	Animals	0.9	2.05	8.15	6.02	7.74	8.03	NC
96	Stamp	Stationery and school supplies	0.86	2.11	8.27	4.6	7.67	8.1	C
97	Strawberry	Food	0.89	2.59	8.35	4.89	7.77	7.9	NC
98	Stroller	Others	0.89	4.57	8.2	5.38	8	8	NC
99	Sword	Weapons and items related to war	0.88	4.88	7.07	5.16	8	8.08	NC
100	Table	Furniture	0.9	4.9	8.48	4.3	7.98	8.08	NC
101	Telescope	Outdoor activity and sport items	0.9	5.93	7.7	5.98	8.14	7.97	C
102	Tiger	Animals	0.95	6.48	7.59	6.02	7.91	7.95	C
103	Toaster	Electronic devices and accessories	0.9	3.31	8.28	5.11	8.05	8	NC
104	Toilet	Skin care and bathroom items	0.94	4.43	8.43	5.27	7.81	7.9	NC
105	Tomato	Food	0.98	2.74	8.33	4.4	7.84	8.03	C
106	Tooth	Others	0.89	2.1	8.41	4.71	7.74	7.92	NC
107	Tractor	Others	0.89	6.18	7.82	6.04	8.07	8.08	C
108	Train	Others	0.89	7.18	7.46	6.42	7.98	7.77	C
109	Tree	Nature elements and vegetation	0.92	6.34	8.3	5.29	7.95	7.84	NC
110	Turkey	Animals	0.97	3.85	7.83	5.67	7.93	7.97	NC
111	Umbrella	Others	0.9	4.51	8.39	5.38	8.02	8	NC
112	Vase	Decoration and gift accessories	0.89	3.49	8.13	5.36	7.91	7.87	C
113	Violin	Musical instruments	0.9	3.77	7.67	5.91	8.07	7.95	C
114	Volcano	Nature elements and vegetation	0.92	7.64	6.8	6.42	7.95	7.87	C
115	Wallet	Jewels and money /Others	0.89	2.7	8.41	4.76	7.9	7.9	NC
116	Whale	Animals	0.86	7.76	7.09	5.6	8.21	8.03	NC
117	Whistle	Outdoor activity and sport items	0.89	2.32	8.3	4.91	7.98	8	NC
118	Wolf	Animals	0.91	6.22	7.02	5.4	8.02	7.95	NC
119	Yo-Yo	Games, toys, and entertainment	0.95	2.42	8.16	4.96	7.98	7.89	C

Table 1, cont.

120	Zebra	Animals	0.95	6.16	7.72	6.16	7.88	8.13	C

Note. Means of Name Agreement, Size Rank, Familiarity, Visual Complexity, Object Agreement, and Viewpoint Agreement are shown.

Table 2

List of All Possible Pairing Combinations

Pairs	Object A	Object B	Size_Diff	Familiarity_Diff	Complexity_Diff
1	Wolf	Apple	2.87	1.35	1.35
2	Umbrella	Pencil	1.92	0.03	0.03
3	Whale	Lighter	5.36	0.83	0.83
4	Anchor	Bell	3.45	1.52	1.52
5	House	Snail	5.48	0.36	0.36
6	Broom	Carrot	2.7	0.09	0.09
7	Cow	Tooth	4.33	0.35	0.35
8	Bed	Ant	3.61	0.33	0.33
9	Pig	Lock	1.61	0.28	0.28
10	Dog	Eraser	1.91	0.04	0.04
11	Horse	Snowflake	5.1	0.46	0.46
12	Octopus	Binoculars	3.51	0.22	0.22
13	Desk	Butterfly	3.36	0.04	0.04
14	Monkey	Skull	1.08	0.24	0.24
15	Goat	Key	3	0.41	0.41
16	Shark	Magnet	3.49	0	0
17	Owl	Ear	1.33	1.11	1.11
18	Iron	Strawberry	1.28	0.15	0.15
19	Arm	Grapes	1.55	0.07	0.07
20	Chair	Glasses	1.46	0.26	0.26
21	Door	Hot dog	2.93	0.15	0.15
22	Pumpkin	Nose	1.54	0.18	0.18
23	Stroller	Peach	2.18	0.17	0.17
24	Tree	Necklace	3.62	0.04	0.04
25	Toilet	Pen	2.34	0.02	0.02
26	Shovel	Peanut	1.93	0.15	0.15
27	Mop	Eye	2.05	0.07	0.07
28	Snake	Flashlight	2.05	0.22	0.22
29	Sword	Ring	2.37	1.33	1.33
30	Seal	Hammer	2.41	0.91	0.91

Table 2, cont.

31	Table	Paper clip	2.54	0.15	0.15
32	Mirror	Wallet	1.2	0.02	0.02
33	Turkey	Whistle	1.54	0.48	0.48
34	Pillow	Nail	1.66	0.15	0.15
35	Foot	Spider	1.06	0.26	0.26
36	Toaster	Crab	0.55	0.8	0.8
37	Kite	Egg	1.02	0.43	0.43
38	Football	Scorpion	0.56	1.07	1.07
39	Dress	Fork	1.67	0.16	0.16
40	Raccoon	Scissors	0.82	0.91	0.91
41	Gorilla	Cherry	4	0.78	0.78
42	Telescope	Diamond	3.34	0.48	0.48
43	Castle	Domino	5.35	1.43	1.43
44	Barrel	Cat	1.92	1.76	1.76
45	Camel	Stamp	4.38	1.74	1.74
46	Car	Mosquito	5.33	0.26	0.26
47	Pineapple	Yo-Yo	0.62	0.11	0.11
48	Baby	Plate	1	0.54	0.54
49	Giraffe	Sandwich	4.64	0.94	0.94
50	Helicopter	Camera	3.92	1.24	1.24
51	Lion	Vase	2.7	0.67	0.67
52	Panda	Calculator	3.6	1.01	1.01
53	Piano	Flower	3.62	0.54	0.54
54	Pyramid	Violin	3.64	0.96	0.96
55	Tiger	Pear	4.03	0.67	0.67
56	Tractor	Crown	2.89	0.78	0.78
57	Train	Banana	4.41	1.04	1.04
58	Volcano	Penguin	3.18	0.7	0.7
59	Zebra	Button	3.89	0.39	0.39
60	Mountain	Tomato	5.08	0.91	0.91

Note. Absolute value of the Size, Familiarity, and Complexity difference is shown.

APPENDIX B

APPENDIX B

EXAMPLES OF IMAGE PAIRS

Conceptual Size	
Congruent	 
Neutral	 
Incongruent	 

Figure 1. Examples of Image Pairs in Experiment I

EXAMPLES OF IMAGE PAIRS

Conceptual Size		
Congruent	WOLF	APPLE
Neutral	WOLF	APPLE
Incongruent	WOLF	APPLE

Figure 2. Examples of Image Pairs in Experiment II

APPENDIX C

APPENDIX C

EXAMPLES OF EXPERIMENT TRIALS

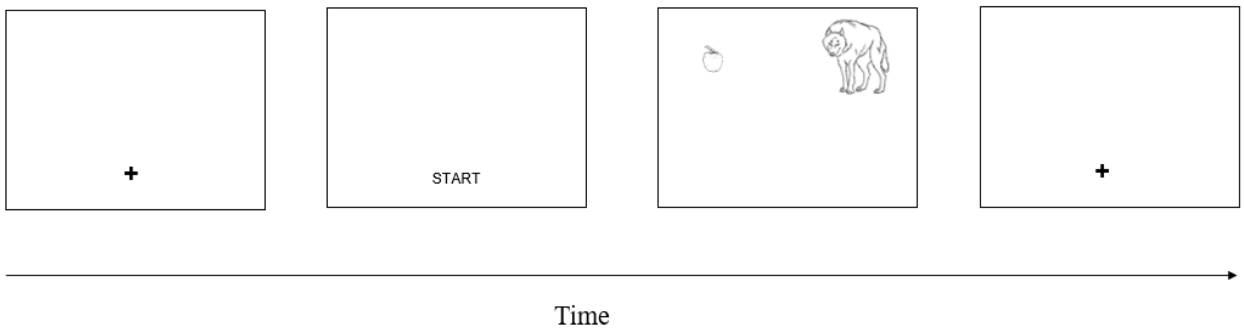

Figure 3. Example of a Congruent Trial in Experiment I. A fixation cross appeared at the beginning of each trial, followed by the word "START". The image pairs were displayed on the screen until the participant made a response.

EXAMPLES OF EXPERIMENT TRIALS

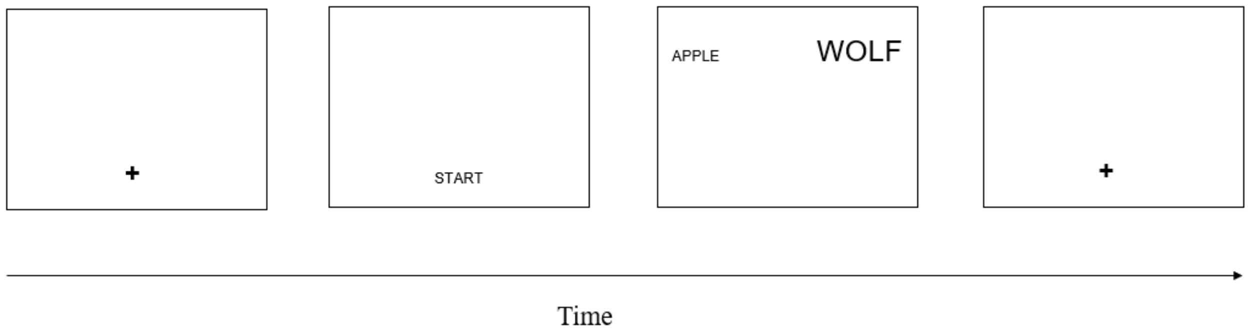

Figure 4. Example of a Congruent Trial in Experiment II. A fixation cross appeared at the beginning of each trial. The word pairs were shown on the screen until the participant made a response.

APPENDIX D

APPENDIX D

EXPERIMENT I DATA

Table 3

Experiment I LEAP-Q Measures

	L1		L2	
	English	Spanish	English	Spanish
Measure	Ratings			
Speaking	8.84(1.21)	7.88(1.31)	8.31(1.92)	6(2.35)
Listening	9.11(1.05)	8.81(1.05)	9(0.97)	7.71(1.82)
Reading	8.37(2.06)	7.69(2.06)	9.31(1.08)	5.71(2.67)
Writing	8.37(1.26)	6.44(2.19)	8.88(0.96)	4.29(2.46)

Note. LEAP-Q refers to the Language Experience and Proficiency Questionnaire. L1 refers to first language learned, and L2 refers to second language learned. The numbers inside the parentheses describe the standard deviation.

Table 4

Mean Accuracy, Error Rate, Response Time, and Fixation Proportions to the Distractor in Experiment I

Condition	Congruent	Incongruent	Neutral
Accuracy	100% (6%)	96% (20%)	96% (20%)
Error Rate	0% (5%)	4% (20%)	3% (19%)
Response Time	2222.21(836.76)	2595.77(973.6)	2357.24(987.55)
Fixp	0.32(0.46)	0.26(0.44)	0.3(0.45)

Note. Fixp = Fixation proportions. Numbers inside the parentheses represent the standard deviation. Accuracy and error rate are depicted as percentages. Response time is shown in milliseconds.

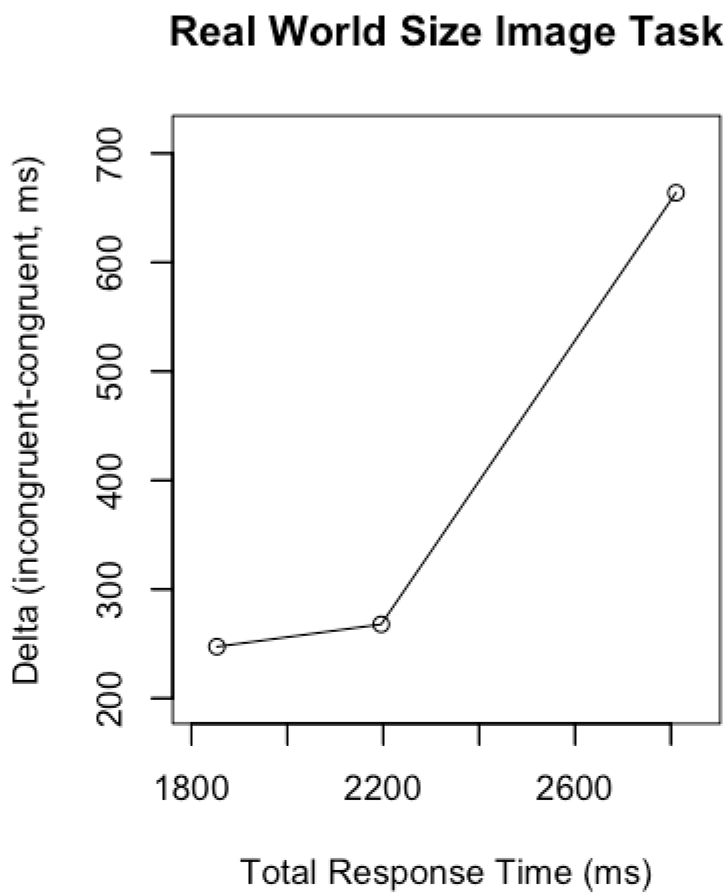

Figure 5. Delta Plot for the Incongruent-Congruent Comparison in the Real World Size Image Task in Experiment I

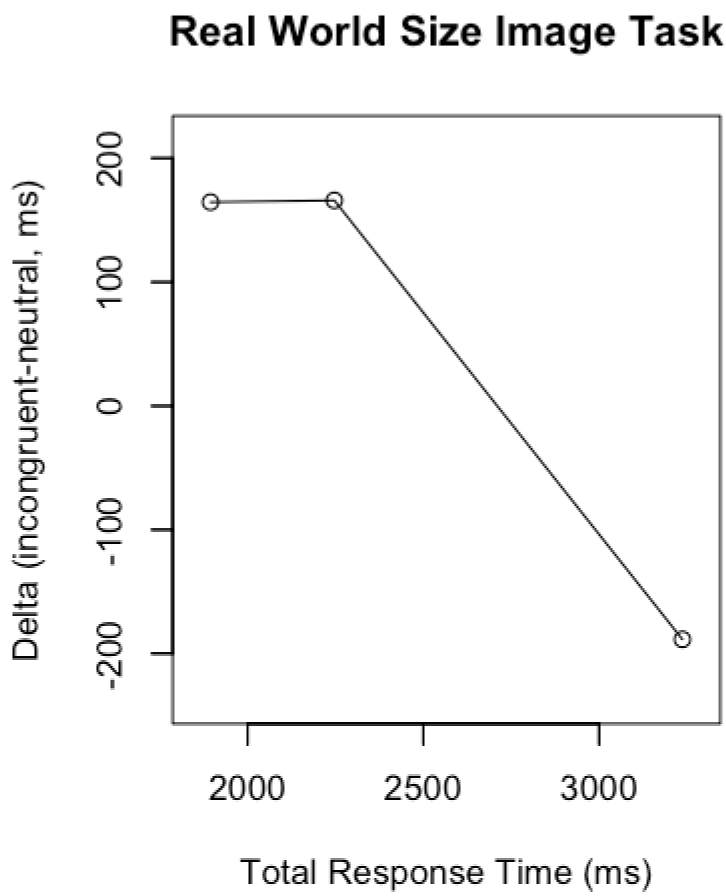

Figure 6. Delta Plot for the Incongruent-Neutral Comparison in the Real World Size Image Task in Experiment I

APPENDIX E

APPENDIX E

EXPERIMENT II DATA

Table 5

Experiment II LEAP-Q Measures

	L1		L2	
	English	Spanish	English	Spanish
Measure	Ratings			
Speaking	9.44(0.73)	7.9(1.45)	8.55(1.51)	5.25(2.25)
Listening	9.56(0.73)	8.9(1.29)	9.27(0.79)	7.25(1.17)
Reading	9.44(0.53)	8.1(1.66)	9(0.45)	6.13(1.46)
Writing	9.11(0.93)	6.9(1.85)	8.64(0.67)	3.75(2.38)

Note. LEAP-Q refers to the Language Experience and Proficiency Questionnaire. L1 refers to first language learned, and L2 refers to second language learned. The numbers inside the parentheses describe the standard deviation.

Table 6

Mean Accuracy, Error Rate, Response Time, and Fixation Proportions to the Distractor in Experiment II

Condition	Congruent	Incongruent	Neutral
Accuracy	99% (12%)	97% (18%)	91% (28%)
Error Rate	1% (11%)	3% (17%)	8% (27%)
Response Time	2383.73 (801.31)	2457.6 (714.74)	2536.81 (875.68)
Fixp	0.36 (0.47)	0.31 (0.46)	0.34 (0.47)

Note. Fixp = Fixation proportions. Numbers inside the parentheses represent the standard deviation. Accuracy and error rate are depicted as percentages. Response time is shown in milliseconds.

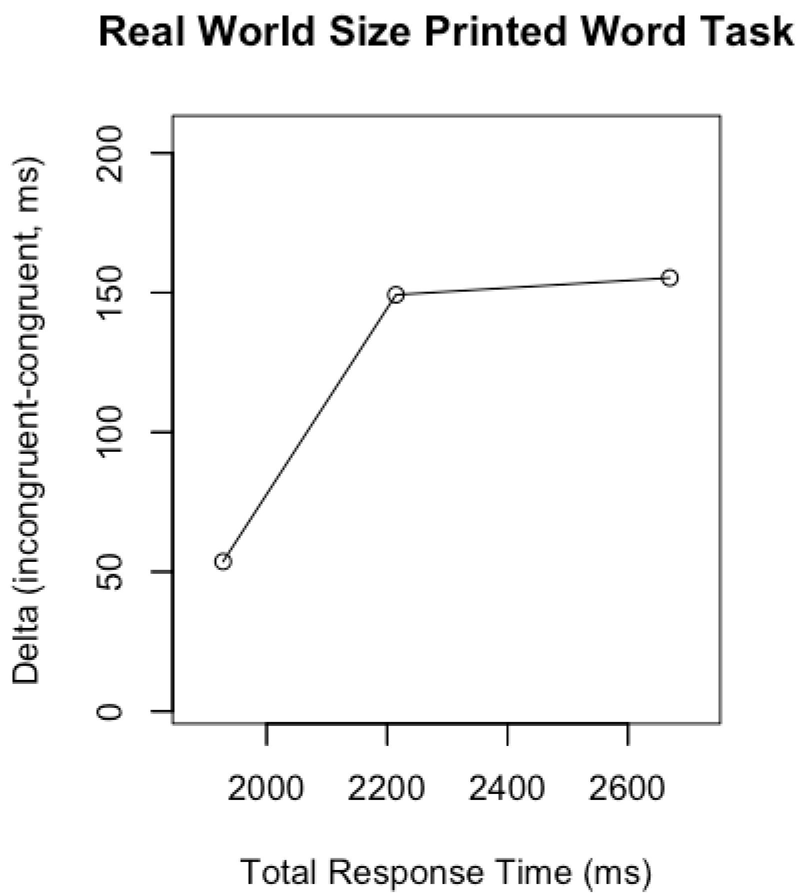

Figure 7. *Delta Plot for the Incongruent-Congruent Comparison in the Real World Size Printed Word Task in Experiment II*

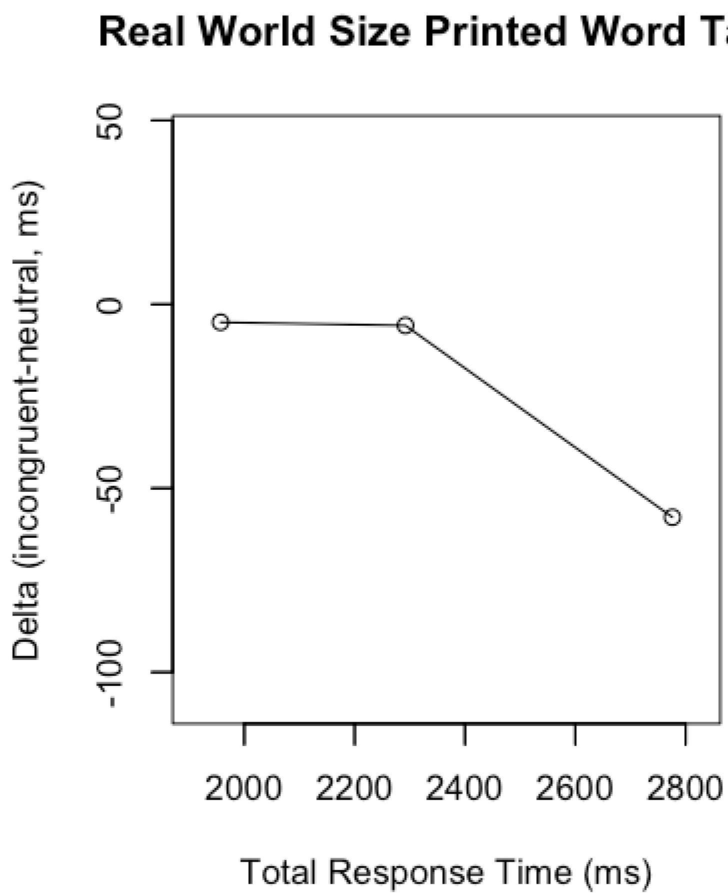

Figure 8. Delta Plot for the Incongruent-Neutral Comparison in the Real World Size Printed Word Task in Experiment II

BIOGRAPHICAL SKETCH

Carolina Alvarez graduated from Brownsville Early College High School in 2012 where she earned an Associate of Arts in General Studies. She entered the University of Texas at Brownsville/Texas Southmost College later that year and received a Bachelor of Arts in Psychology in 2016 from the University of Texas Rio Grande Valley. She graduated from the University of Texas Rio Grande Valley and earned a Master of Arts in Experimental Psychology in 2022. Carolina’s email is Carolina.alvarez02@utrgv.edu.