Semantic processing in bilingual people with aphasia: An eye-tracking study examining cross-language semantic facilitation and interference

Sophie Blankenheim[a], Claudia Peñaloza[b], Swathi Kiran[a], Maria Varkanitsa[a]

[a]Aphasia Research Laboratory/Center for Brain Recovery, Boston University, Boston, MA, USA; [b]Department of Cognition, Development, and Educational Psychology, University of Barcelona, Barcelona, Spain

Introduction

- Evidence from both monolingual and bilingual neurotypicals suggests that responses during naming (either blocked cyclic or continuous) are slowed down if a semantically related word is presented in close temporal proximity or simultaneously relative to an unrelated baseline. This phenomenon is known as **semantic interference**[1].
- People with aphasia are sensitive to semantic context and the semantic interference effect is exaggerated compared to neurotypicals[2].
  - Schnur et al (2006) hypothesized that patients show an exaggerated semantic interference effect due to an **inefficient executive selection mechanism**[2].
- Bilinguals with aphasia (BWA) have been shown to have a larger semantic interference effect during non-dominant language production in blocked cyclic naming tasks due to increased inhibition from their dominant language[3].

Aim & Hypotheses

Aim:
To investigate (a) the degree of semantic interference in English-Spanish bilingual people with aphasia and age-matched English-Spanish bilingual neurotypicals, and (b) whether individual differences in executive function may explain any differences observed between BWA and neurotypicals.

Hypotheses:
(a) Based on previous studies, we hypothesize that the presence of a semantically related word will result in longer reading times, indicating an interference effect. We further hypothesize that BWA will be slower than neurotypicals.
(b) We hypothesize that BWA will exhibit poorer executive function compared to neurotypicals.

Participants

Participants were 4 Spanish-English BWA and 7 Spanish-English healthy controls. All participants reported Spanish as their L1, language dominance was based on a Language Use Questionnaire[4] (LUQ). Aphasia type was determined via administration of the Western Aphasia Battery – Revised[5] (WAB-R) in their dominant language.

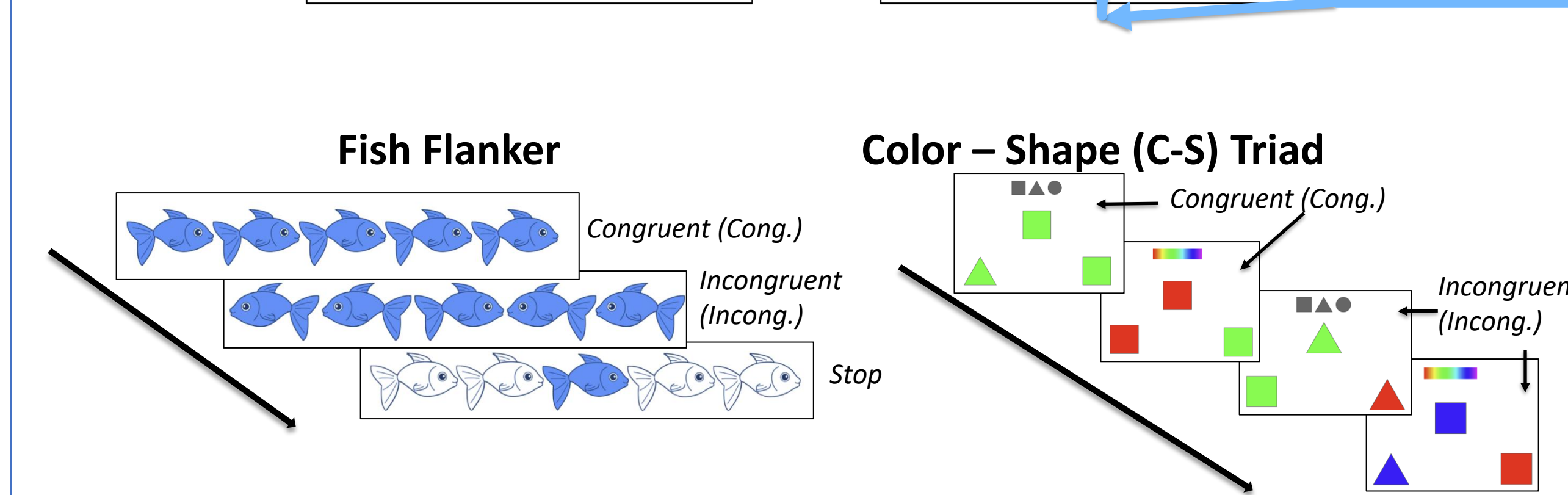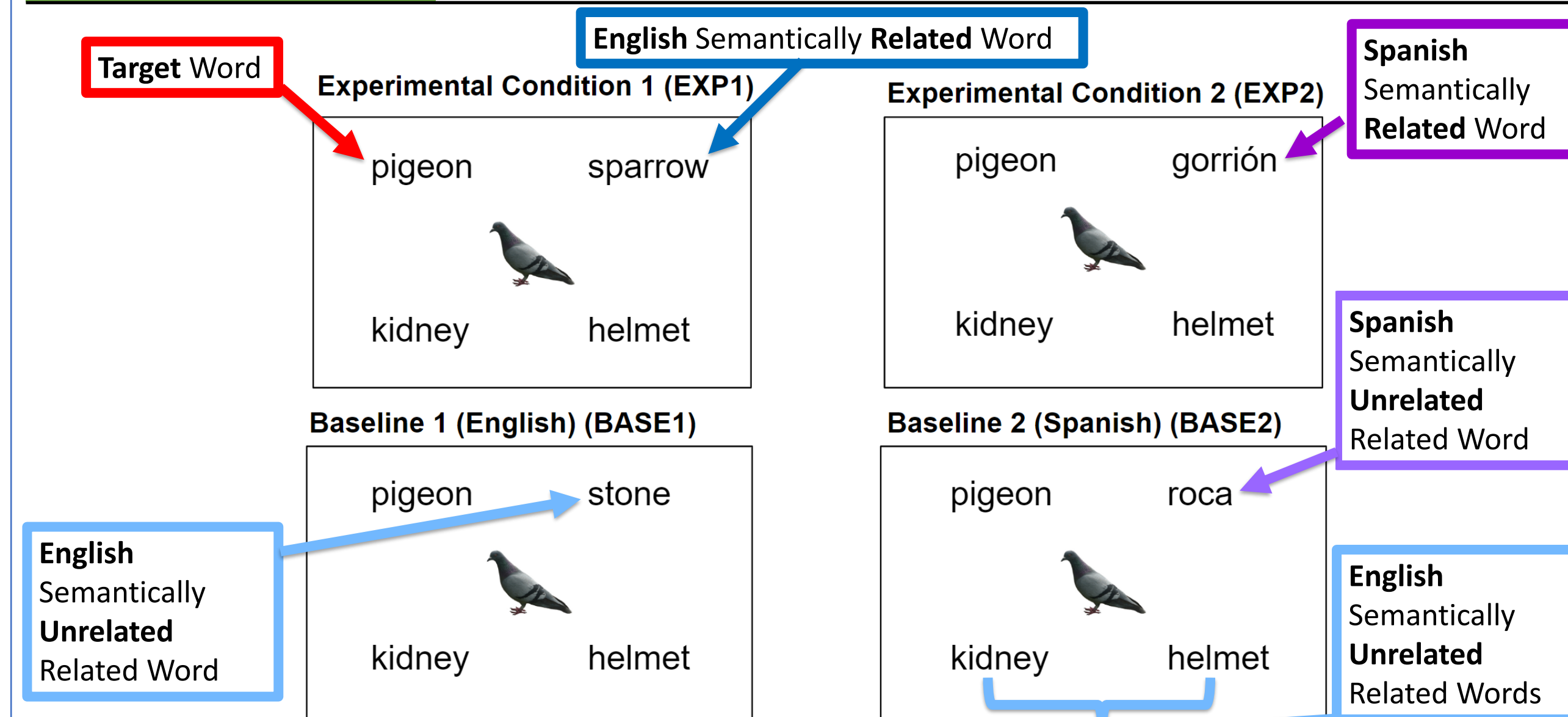| ID	Sex	Age	WAB-R AQ	Aphasia type	Dominant Language
P01	F	24	64.4	Broca's	English
P02	M	63	25.2	Anomic	English
P03	F	52	54.4	Conduction	Spanish
P04	M	54	54.9	Conduction	Spanish
C01	M	72	NA	NA	Spanish
C02	M	46	NA	NA	English
C03	F	38	NA	NA	English
C04	F	33	NA	NA	Both
C05	F	24	NA	NA	English
C06	F	47	NA	NA	Both
C07	M	21	NA	NA	English

Eye Tracking Apparatus

- Eye movements were recorded using a EyeLink II (SR Research, Toronto, ON, Canada).
- The sampling rate was 500 Hz and.
- Subjects were seated 55 cm from a CRT monitor.
- Although viewing was binocular, was only collected from the left eye to account for post stroke hemispheric weakness.
- Response keys were mapped to the visual field on the keyboard, all other keys were removed.
- The experiment was implemented in MatLab.
- A nine-point calibration was performed at the start of the experiment and repeated as needed.

Methods and Materials

Fixation Variable Name	Definition
Dwell Time	Cumulative time the participant spent looking at a particular area of interest (ms).
Fixation Count	Total number of discrete instances that a participant fixates on a particular area of interest.

Experimental Condition 1 (EXP1): Target Word — pigeon, English Semantically Related Word — sparrow, kidney, helmet

Experimental Condition 2 (EXP2): pigeon, Spanish Semantically Related Word — gorrión, kidney, helmet

Baseline 1 (English) (BASE1): pigeon, English Semantically Unrelated Related Word — stone, kidney, helmet

Baseline 2 (Spanish) (BASE2): pigeon, Spanish Semantically Unrelated Related Word — roca, kidney, helmet, English Semantically Unrelated Related Words

Fish Flanker — Congruent (Cong.), Incongruent (Incong.), Stop

Color – Shape (C-S) Triad — Congruent (Cong.), Incongruent (Incong.)

Results – Eye Tracking

*The Eye Tracking data was analyzed using a linear mixed-effects model looking at Target Fixation Variables as a function of the interaction between Condition and Group, with Participant and Item included as random variables.

Target Dwell Time per Condition
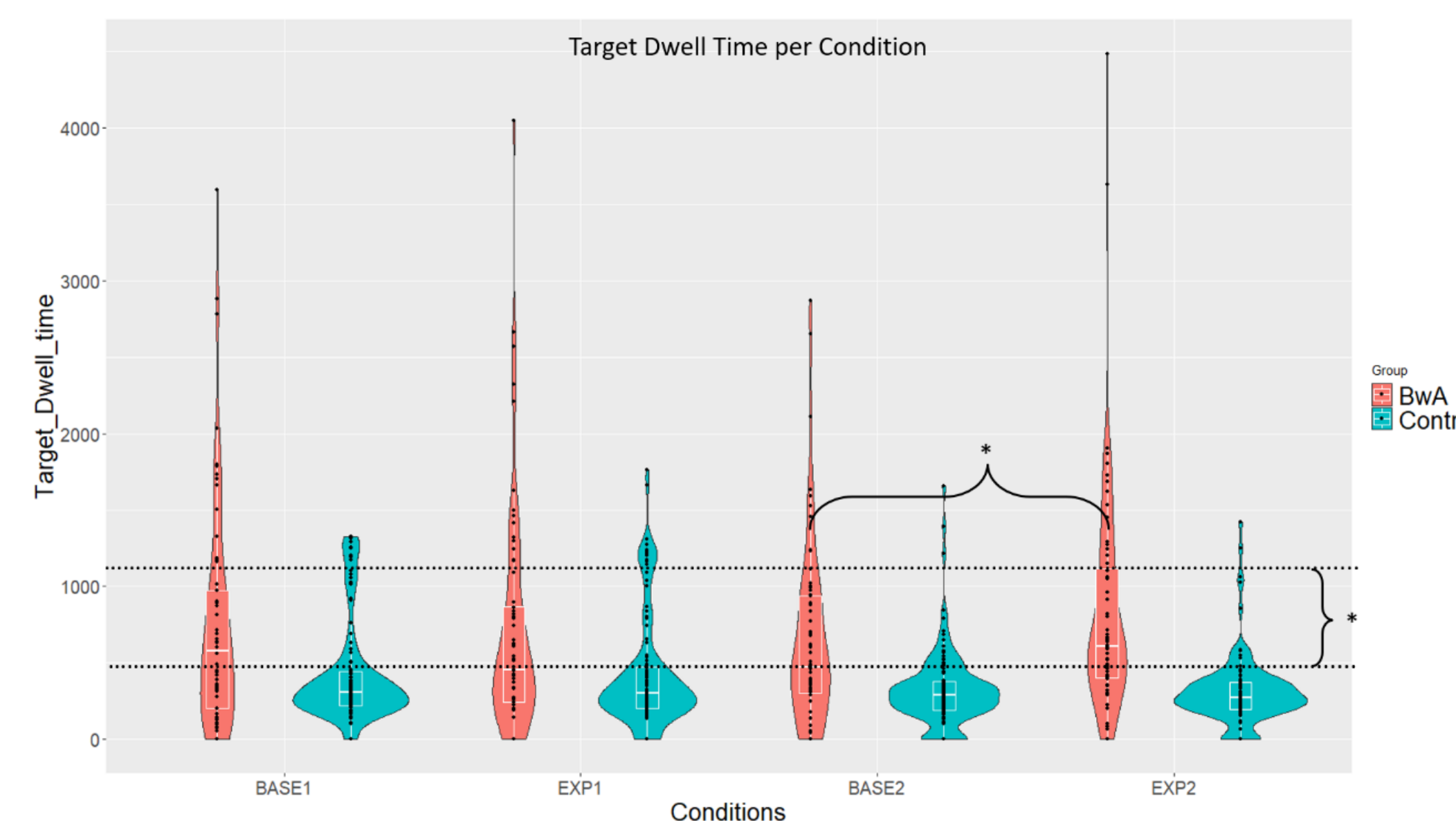
- Overall, BWA had longer reaction times at the target than controls did.
- BWA had longer Dwell Time in Experimental Condition 2, which included a Spanish semantically related distractor, compared to Baseline Condition 2, which included a Spanish unrelated distractor.
- This was not seen in Controls, or in BWA between Experimental Condition 1 and Baseline Condition 1 which only included English distractors.
- The same patterns were found when the same analysis was done one Fixation Count.

Results – Executive Functioning

*Accuracy and Reaction Time (RT) data were analyzed as a function of the interaction between condition and group with participant included as a random variable.
*Of note three healthy controls did not complete the executive functioning tasks due to time constraints.

ID	C-S (Cong.)	C-S (Incong.)	Flanker (Cong.)	Flanker (Incong.)	Flanker (Stop)	Cong. Effect C-S	Cong. Effect Flanker	Mean Flanker RT (ms)	Mean C-S RT (ms)
P01	39/40	23/40	48/48	12/48	37/48	16/40	36/48	1438	1087
P02	40/40	33/40	48/48	46/48	47/48	7/40	2/48	1350	793
P03	35/40	37/40	48/48	48/48	46/48	-2/40	0/48	1440	1701
P04	15/40	9/40	48/48	42/48	11/48	6/40	-1/48	1350	2091
C01	38/40	33/40	48/48	48/48	45/48	5/40	0/48	1386	1801
C02	40/40	39/40	48/48	48/48	48/48	1/40	0/48	1389	1381
C06	39/40	39/40	48/48	48/48	47/48	0/40	0/48	1279	816
C07	39/40	37/40	48/48	47/48	47/48	2/40	1/48	1358	1092

- Both Controls and BWA were less accurate in incongruent trials, BWA were less accurate overall.
- Both Controls and BWA were slower in incongruent trials.

Discussion

- The increased time BWA spent looking at the target word in the presence of a Spanish semantically related word, compared to in the presence of a Spanish semantically unrelated word suggests that they are experiencing a semantic interference effect.
- This, combined with the lack of significant difference in Dwell Times at the target in the presence or absence of an English semantically related distractor, suggests that BWA are experiencing semantic interference from L1 (Spanish) while performing a task in L2 (English), or cross-linguistic semantic interference. This confirms the claim made by Calabria et al (2019) that competitor inhibition is reduced in participant's non-dominant language[3].
- We did not see this pattern in the healthy controls to the same extent, suggesting that healthy bilinguals are not as sensitive to semantic interference as BWA. This confirms the findings from Patra et al (2021), which found that bilinguals were not sensitive to semantic context effects[8].
- The overall reduced accuracy of BWA in executive functioning tasks suggests that they are more susceptible to distraction than neurotypicals.

Future Directions

- Future work should consider :
  - Increasing the sample size of BWA to increase statistical power.
  - Inclusion of Spanish target words to account for differences in dominance.
  - Inclusion of participants with Spanish L2 to differentiate the impact of language dominance change over time as well as post-injury.
  - Inclusion of fMRI data to evaluate in detail the neurological processes involved in semantic processing.
  - Of note, this study was designed such that it is compatible with the current Boston University fMRI testing protocols.

Contact

Sophie Blankenheim, M.S.
Aphasia Research Laboratory
Dept. of Speech, Language, and Hearing Sciences
Boston University
sblankenheim@bu.edu

Funding

References

1. Damian M. F., & Als L. C. (2005). Long-lasting semantic context effects in the spoken production of object names. Journal of Experimental Psychology: Learning, Memory, and Cognition, 31(6), 1372–1384.
2. Schnur, TT., Schwartz, MF., Brecher, A., & Hodgson, C. (2006). Semantic interference during blocked-cyclic naming: Evidence from aphasia. Journal of Memory and Language, 54(2), 199-227.
3. Calabria, M., Grunden, N., Serra, M., García-Sánchez, C., and Costa, A. (2019). Semantic processing in bilingual aphasia: Evidence of language dependency. Frontiers in Human Neuroscience, 13.
4. Kastenbaum, J. G., Bedore, L. M., Peña, E. D., Sheng, L., Mavis, I., Sebastian-Vaytadden, A., Rangamani, G., Vallila-Rohter, S., & Kiran, S. (2018). The influence of proficiency and language combination on bilingual lexical access. Bilingualism: Language and Cognition, 1–31.
5. Kertesz, A. 92006). Western Aphasia Battery—Revised (WAB-R) [Database record]. APA PsychTests.
2. Eriksen, C. W. (1995). The flankers task and response competition: A useful tool for investigating a variety of cognitive problems.
3. Gray, Teresa & Kiran, Swathi. (2018). The effect of task complexity on linguistic and non-linguistic control mechanisms in bilingual aphasia. Bilingualism: Language and Cognition. 22. 1-19. 10.1017/S1366728917000712.
4. Patra, A., Bose, A., & Marinis, T. (2021). Semantic context effects in monolingual and bilingual speakers. Journal of Neurolinguistics. 57. 100942.