Adapting conflict across language comprehension and production using HD-tDCS

Erika Hussey
Nina Hsu, Nathan Ward
Arthur Kramer, Kiel Christianson
Language is rife with ambiguity.

Me ligue um táxi!

Soita minulle taksin!

Call me a cab!

OK, you're a cab!
Language is rife with ambiguity.

Resolving lexical (and cross-linguistic) ambiguities.

Engaging in conversational perspective taking.

Resolving syntactic ambiguity.

Selecting which word is best to produce.

(for a review: Hussey & Novick, 2012; Logačev & Vasishth, 2016; Brown-Schmidt, 2009; Novick et al., 2005; Snyder et al., 2010)
Resolving Conflict in Language

The role of inhibitory control.

The ability to ignore the first cognitive reaction that comes to mind

(Gray et al., 2003; Jonides et al., 1998; Milham et al., 2001; Miller & Cohen, 2001; Thompson-Schill et al., 2005)
Conflict in Comprehension: Syntactic Ambiguity

While the thief hid the jewelry that was elegant sparkled brightly.

Did the thief hide the jewelry?

(Christianson et al., 2001; 2006; Ferreira et al., 2001; Patson et al., 2009)
Conflict in Comprehension:
Syntactic Ambiguity

While the thief hid the jewelry that was elegant sparkled brightly.

thief hiding jewelry

(Christianson et al., 2001; 2006; Ferreira et al., 2001; Patson et al., 2009)
Conflict in Comprehension: Syntactic Ambiguity

While the thief hid the jewelry that was elegant sparkled brightly.

(Christianson et al., 2001; 2006; Ferreira et al., 2001; Patson et al., 2009)
Conflict in Comprehension: Syntactic Ambiguity

While the thief hid the jewelry that was elegant sparkled brightly.

- thief hiding himself
- thief hiding jewelry

(Christianson et al., 2001; 2006; Ferreira et al., 2001; Patson et al., 2009)
Conflict in Comprehension: Syntactic Ambiguity

While the thief hid the jewelry that was elegant sparkled brightly.

(Christianson et al., 2001; 2006; Ferreira et al., 2001; Patson et al., 2009)
Conflict in Comprehension: Syntactic Ambiguity

While the thief hid the jewelry that was elegant sparkled brightly.

Did the thief hide the jewelry?

(Christianson et al., 2001; 2006; Ferreira et al., 2001; Patson et al., 2009)
Conflict in Comprehension: Syntactic Ambiguity

While the thief hid the jewelry that was elegant sparkled brightly.
(High-Conflict Ambiguous Sentence)

The jewelry that was elegant sparkled brightly while the thief hid.
(Low-Conflict Unambiguous control)
Conflict in Production: Picture Naming

Low Agreement Pictures (High-Conflict)

- stove
- oven
- kiln
- range

High Agreement Pictures (Low-Conflict)

- owl

(Kan & Thompson-Schill, 2004; Thompson-Schill et al., 1997, 1999)
Conflict in Language

Comprehension

High Conflict

While the thief hid the jewelry sparkled brightly.

- thief hiding himself
- thief hiding jewelry

Low Conflict

The jewelry sparkled brightly while the thief hid.

- thief hiding himself

Production

- oven
- range
- stove
- owl
Left Lateral PFC for Linguistic Conflict

**BOOTSTRAPPED LEFT LPFC**

Brain Stimulation…
(Hussey, Ward, Christianson, & Kramer, 2015)

**Similar activation patterns in healthy brains**
(Hsu et al., 2014; January et al. 2009; Kan & Thompson-Schill, 2004)

**COMPROMISED LEFT LPFC**

Left LPFC Patients + Young Kids
(Patients: Novick et al., 2010; Schnur et al., 2009
Kids: Trueswell et al., 1999; Woodard et al., 2016)

While the thief…
Left Lateral PFC for Linguistic Conflict

1) To what extent do production and comprehension systems rely on common inhibitory control resources?

2) Can tDCS be used to test for this system overlap?
Design

Active Group (n=26):

2 mA anodal current over left LPFC (F3) in a high-definition 4x1 ring montage for 30 minutes (online/during tasks)

Control Group (n=23):

sham; ramp-up/ramp-down for 1 minute

Eye tracking with Eyelink 1000

Voice key responses

Predicted current flow model for active stimulation montage

96 sentences

120 pictures

96 sentences

120 pictures
Predictions

**Comprehension**

1. Comprehension Accuracy  
   (Did the thief hide himself?)
   
   Better comprehension for active tDCS group on only high-conflict ambiguous sentences.

2. Real-time recovery efforts  
   (second pass reading time)
   
   Faster recovery efforts for active tDCS group only on high-conflict ambiguous sentences.

**Production**

3. Voice Onset Time
   
   Faster naming times for active tDCS group on only high-conflict low-agreement pictures.
Comprehension Accuracy

![Bar chart showing comprehension accuracy for different sentence types.](image)

- **Unambiguous Sentence (Low-Conflict)**: Red bars for active and blue bars for sham conditions.
- **Ambiguous Sentence (High-Conflict)**: Red bars for active and blue bars for sham conditions, with a significance asterisk (*) indicating a difference between the conditions.
Predictions

1. Comprehension Accuracy
(Did the thief hide himself?)

Better comprehension for active tDCS group on only high-conflict ambiguous sentences.

2. Real-time recovery efforts
(second pass reading time)

Faster recovery efforts for active tDCS group only on high-conflict ambiguous sentences.

3. Voice Onset Time

Faster naming times for active tDCS group on only high-conflict low-agreement pictures.
Predictions

**Comprehension**

1. Comprehension Accuracy
   (Did the thief hide himself?)

   Better comprehension for active tDCS group on only high-conflict ambiguous sentences.

2. Real-time recovery efforts
   (second pass reading time)

   Faster recovery efforts for active tDCS group only on high-conflict low-agreement pictures.

**Production**

3. Voice Onset Time

   Faster naming times for active tDCS group on only high-conflict low-agreement pictures.
Rereading Time

Unambiguous Sentence (Low-Conflict)

Ambiguous Sentence (High-Conflict)
Predictions

**Comprehension**

1. Comprehension Accuracy (Did the thief hide himself?)
   Better comprehension for active tDCS group on only high-conflict ambiguous sentences.

2. Real-time recovery efforts (second pass reading time)
   *Slower recovery efforts for active tDCS group only on high-conflict ambiguous sentences.*

**Production**

3. Voice Onset Time
   Faster naming times for active tDCS group on only high-conflict low-agreement pictures.
Predictions

1. **Comprehension Accuracy**  
(Did the thief hide himself?)

Better comprehension for active tDCS group on only high-conflict ambiguous sentences.

2. **Real-time recovery efforts**  
(second pass reading time)

Faster recovery efforts for active tDCS group only on high-conflict ambiguous sentences.

3. **Voice Onset Time**

*Faster naming times for active tDCS group on only high-conflict low-agreement pictures.*
Predictions

1. **Comprehension**
   - **Comprehension Accuracy**
     - Did the thief hide himself?
   - Better comprehension for active tDCS group on only high-conflict ambiguous sentences.

2. **Production**
   - **Real-time recovery efforts**
     - (second pass reading time)
   - Faster recovery efforts for active tDCS group only on high-conflict ambiguous sentences.

   ![Voice Onset Time Diagram](image)
Voice Onset Time

The graph compares the average voice onset time (in ms) for Active and Sham conditions across Low-Conflict and High-Conflict picture types. There is a significant difference (*) between the Active and Sham conditions in the High-Conflict picture type compared to the Low-Conflict picture type.
Interim Summary

Comprehension

1. Comprehension Accuracy

Compared to sham, excitatory tDCS over left LPFC led to selective improvements in comprehension accuracy only to questions following ambiguous items.

2. Real-time recovery efforts (second pass reading time)

Compared to sham, excitatory tDCS over left LPFC led to slower rereading times on ambiguous sentences.

Production

3. Voice Onset Time

Compared to sham, excitatory tDCS over left LPFC induced no changes in naming times.
Interim Summary

Comprehension

1. Comprehension Accuracy
   Compared to sham, excitatory tDCS over left LPFC led to selective improvements in comprehension accuracy only to questions following ambiguous items.

2. Real-time recovery efforts (second pass reading time)
   Compared to sham, excitatory tDCS over left LPFC led to slower rereading times on ambiguous sentences.

3. Voice Onset Time
   Compared to sham, excitatory tDCS over left LPFC induced no changes in naming times.

Production

1) tDCS-modulated comprehension effects appear to be more robust than production effects.

2) Are the individuals with larger comprehension effects those with production effects?

Compared to sham, excitatory tDCS over left LPFC led to slower rereading times on ambiguous sentences.
Relating Sentence Processing & Picture Naming

Low-Conflict

High-Conflict

$R^2 = 0.20$

$R^2 = 0.18$

$R^2 = 0.31$

$R^2 = 0.08$
To Conclude…

We observed selective effects of exciting left lateral PFC on conflict processing in comprehension:

1. Subjects receiving active stimulation were **more accurate** in their recovery from high-conflict ambiguous structures compared to their sham counterparts.

2. Subjects receiving active stimulation took **more time** to read high-conflict ambiguous items compared to their sham counterparts.

Although we did not observe effects of active stimulation on picture naming latencies, we did note that subjects with faster naming latencies to high-conflict pictures were also those with faster reading times on high-conflict sentences.

This profile of results suggests that targeting inhibitory control with brain stimulation may selectively improve performance **within the same individuals** across production and comprehension measures containing elevated conflict demands.
Thanks for your attention.

Special Thanks to:
Agilda Dema
Hyunsoo Jin
Sangyun Joung
Shaina Martis
Zoya Siddiqui

NIH T32 award HD055272 to UIUC

Educational Psychology Psycholinguistics Lab @ UIUC
Lifelong Brain and Cognition Lab @ UIUC
Questions?