

# Eye movements reveal the time-course of multiple context effects in assimilated speech.

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## Introduction

Recent research has demonstrated the sensitivity of on-line spoken word recognition processes to fine-grained phonetic detail. (Gow & Gordon, 1995; Salverda, Dahan & McQueen, submitted; McMurray, Tanenhaus & Aslin, 2002). Few studies, however, have examined the timecourse of its integration with other information during online word recognition.

Place assimilation phenomena provide an excellent avenue for examining this integration. Assimilation creates subphonemic regularities that could be used to progressively anticipate upcoming material. It can also create ambiguity which is regressively resolved by subsequent information.

These temporal properties required the use of a measure sensitivity to the detailed temporal dynamics of processing. Therefore, we assessed the time course of assimilation phenomena with an eye-tracking task (Tanenhaus, Spivey-Knowlton, Sedivy & Eberhart, 1995).

## Assimilation

Coronal consonants (/n/, /t/, and /d/) can **assimilate** the place of a following non-coronal consonant (e.g. /m/ or /g/).

Maroon <sup>n</sup>Goose => Maroon <sup>g</sup>Goose

This assimilation is typically not complete, with the coronal segment having acoustic (and articulatory) properties of both a coronal and non-coronal (Gow, 2001). This information could then be used to predict an upcoming non-coronal (experiment 1).

Occasionally assimilation creates *lexical* ambiguity.

Cat <sup>p</sup>Box => Cat <sup>p</sup>Box

This could be resolved in the process of integrating and segregating contextual information in the post-assimilated item (e.g. box) and subphonemic detail in the assimilated consonant (experiment 2).

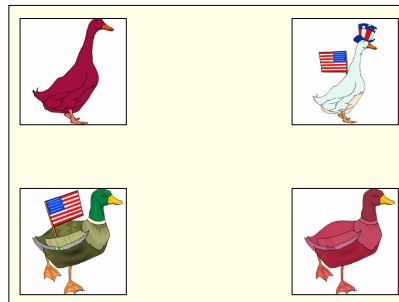
## Experiment 1: Progressive

**Hypothesis:** Subphonemic cues for assimilation can be used by listeners to anticipate an upcoming non-coronal.

We should see earlier eye-movements to non-coronal items (goose) after hearing an assimilated coronal (maroon<sup>n</sup>) than after an unassimilated one (maroon).

## Experiment 1: Progressive

Subject hears...	
Maroon <sup>n</sup>	Goose (felicitous assimilation)
Maroon	Goose (no assimilation)
Maroon <sup>n</sup>	Duck (infelicitous assimilation)
Maroon	Duck (no assimilation)
Patriotic	Goose (filler x2)
Patriotic	Duck (filler x2)



- "Select the maroon goose": Stimuli cross-spliced from natural running-speech—partial, natural assimilation.
- Eye-movements monitored at 250 hz.
- Eye-movements recorded relative to onset of second word ("goose")
- 200 ms delay added to accommodate known oculomotor delay.

### Results

Results suggest anticipation.

- More looks to the target ("goose") after an assimilated consonant (p=.046)

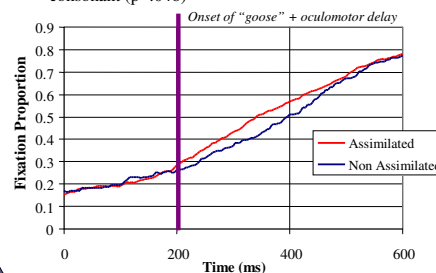


Figure 1: Looks to "Goose" as a function of time

## Experiment 1: Results

- Fewer looks to the competitor ("duck") after an assimilated consonant (p=.024)

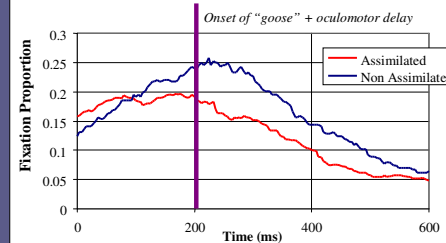


Figure 2: Looks to "Duck" as a function of time

- Caveat: *Perceptual learning*. Computer problem led to more non-coronals following coronals. Does not appear to interact with assimilation (see handout).

## Experiment 2: Regressive

**Hypothesis:** Lexical ambiguity is resolved in the process of integrating and segregating contextual information in the post-assimilated item and subphonemic detail in the assimilated consonant.

Given an initial ambiguous, assimilated coronal we should get more looks to initial-coronal items (cat) after hearing a non-coronal (box)? When does disambiguation occur?

### Subject hears...

Ca <sub>p</sub>	Box (felicitous assimilation, ambiguous)
Cat	Box (no assimilation)
Cap	Box (no assimilation)
Ca <sub>p</sub>	Drawing (infelicitous assimilation, ambiguous)
Cat	Drawing (no assimilation)
Cap	Drawing (no assimilation)

### Subject sees...



## Experiment 2: Results

### Results

- Early fixations equibaised: assimilation => ambiguity.
- Regressive disambiguation effect is late (~1000ms).
- More looks to initial coronal (cat) when second word was non-coronal (box).

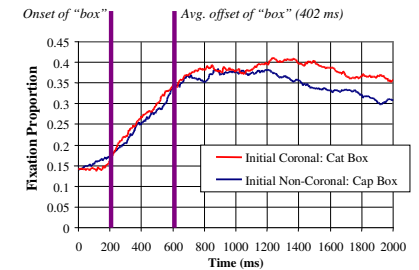


Figure 3: Looks to Cat Box vs. Cap Box after hearing "Ca<sub>p</sub> Box"

- More looks to initial non-coronal (cap) when second word was coronal (drawing).

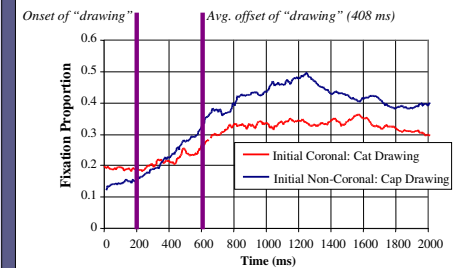


Figure 4: Looks to Cat Drawing vs. Cap Drawing after hearing "Ca<sub>p</sub> Drawing"

- Interaction supports late regressive effect (p=.003).
- Early progressive effect as well (Target: p=.081; Comp: p=.024)—both processes active for these stimuli.

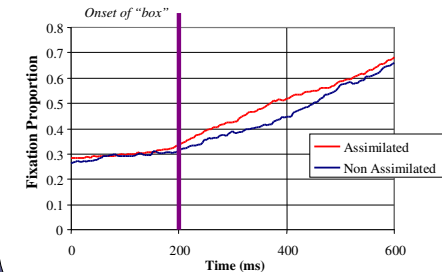


Figure 5: Looks to target ("box") after hearing Ca<sub>p</sub> Box (assimilated) or Cat Box (non assimilated)

## Conclusions

- Eye-tracking paradigm is sensitive to detailed temporal dynamics of information integration during lexical access.
- Subphonemic information is useful during word recognition: assimilated consonants anticipate upcoming materials
- Contextual information can be regressively integrated with subphonemic detail to resolve lexical ambiguity created by assimilation.

## Perceptual Learning

In **Experiment 1** a computer problem caused an imbalance in the number of repetitions for each condition.

Condition	# of Trials
Assim-Coronal	32
Assim-Non	64
Coronal-Coronal	56
Coronal-Non	32
Non-Coronal	48
Non-Non	56

That this imbalance makes it statistically more likely that a non-coronal follows an assimilated consonant than a coronal does. Thus, short-term perceptual learning may yield similar effects to our predicted progressive effect.

It is also more likely for a coronal to precede a coronal. Perceptual learning, then cannot account (and works against) findings in experiment 2.

## Testing Perceptual Learning 1

To test this account of our results, we looked at the anticipatory effect very early in the experiment: at the first 72 trials (1/4 of the 288 trials) and the first 18 (1/16). If short-term perceptual learning accounts for these effects, we expect to see reduced or non-existent anticipatory effects early in the experiment (before contingencies can be learned).

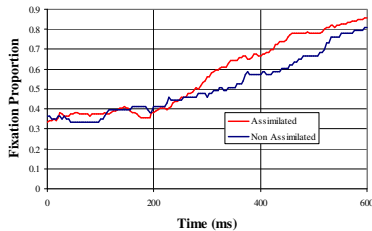


Figure 5: Looks to target goose over 1<sup>st</sup> 72 trials of experiment 1

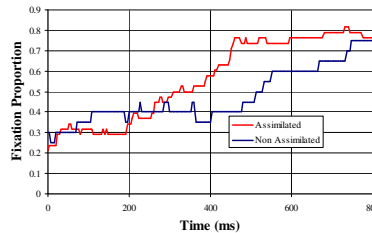


Figure 6: Looks to target goose over 1<sup>st</sup> 18 trials of experiment 1.

## Testing Perceptual Learning 1

- Reduction of dataset yielded more variability between subjects and reduced statistical significance.
- The first 72 trials**  
Target:  $p=.173$   
Competitor:  $p=.127$
- The first 18 trials**  
Target:  $p=.040^*$   
Competitor:  $p=.126$
- All effects were in the predicted direction.
- Data from experiment 1 are not consistent with perceptual learning (unless learning occurs VERY fast).

## Testing Perceptual Learning 2

Experiments in progress attempt to rule out perceptual learning more explicitly.

- 10 subjects run with identical materials and the correct number of replications in each condition.
- Results favor anticipation.

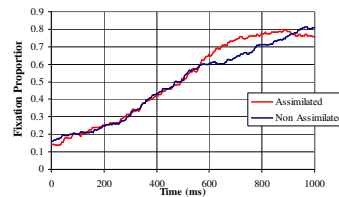


Figure 7: Looks to target, "goose" as a function of time

- Later anticipatory effect on fixations to target non-coronal (goose) than experiment 1.
- This may be because looks to "goose" are also looks to "maroon". If activation of initial word (maroon) is reduced by assimilation, this may mask anticipatory excitation of goose (since subject must look to the "maroon goose").

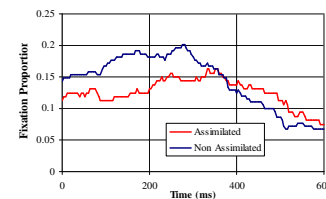


Figure 8: Looks to competitor, "duck" as a function of time

- Similar effect on competitor as experiment 1.
- Effect of perceptual learning in experiment 1 is minimal. May need to unpack relationship between lexical activation and fixations when targets measure activation of two items.

## Stimulus Materials

Stimuli were cross-spliced from recordings of naturally produced assimilated and non-assimilated items. The following is a list of the items used in each experiment. Splices were made before the second word (e.g. "goose") to insure that these were acoustically identical across conditions.

Experiment 1: Progressive				Experiment 2: Regressive			
Coronal-Non	Non-Non	Coronal-Coronal	Non-Coronal	Coronal-Non	Non-Non	Coronal-Coronal	Non-Coronal
Green Boat	Swamp Boat	Green Dog	Swamp Dog	Eight Babies	Ape Babies	Eight Dolls	Ape Dolls
Brown Pig	Slim Pig	Brown Tree	Slim Tree	Mat Book	Map Book	Mat Drawer	Map Drawer
Red Monkey	Plump Monkey	Red Notebook	Plump Notebook	Bud Case	Bug Case	Bud Tie	Bug Tie
Maroon Goose	Patriotic Goose	Maroon Duck	Patriotic Duck	Cat Box	Cap Box	Cat Drawing	Cap Drawing
Gold Medal	Platinum Medal	Gold Necktie	Platinum Necktie	Cone Bending	Comb Bending	Cone Dropping	Comb Dropping
Tan Pants	Denim Pants	Tan tie	Denim tie	Gun Popping	Gum Popping	Gun Twins	Gum Twins
Salmon Blouse	Plum Blouse	Salmon Dress	Plum Dress	Heart Breaker	Harp Breaker	Heart Doctor	Harp Doctor
Violet Bikini	Cream Bikini	Violet Door	Cream Door	Road Patch	Robe Patch	Road Twisting	Robe Twisting
Crimson Clock	Pink Clock	Crimson Tire	Pink Tire	Rat Gleaming	Rack Gleaming	Rat Dangling	Rack Dangling
Scarlet Curtain	Black Curtain	Scarlet Train	Black Train	Phone Box	Foam Box	Phone Donor	Foam Donor
Chocolate Pie	Grape Pie	Chocolate Tart	Grape Tart	Street Cleaner	Streak Cleaner	Street Train	Streak Train
One Ball	Aluminum Ball	One Daisy	Aluminum Daisy	Line Peeler	Lime Peeler	Line Tag	Lime Tag
Seven Band-aids	Drab Band-aids	Seven Darts	Drab Darts	Mast Creator	Mask Creator	Mast Trophy	Mask Trophy
Ten Bats	Damp Bats	Ten Dollars	Damp Dollars	Bite Guard	Bike Guard	Bite Damage	Bike Damage
Nine Bees	Dim Bees	Nine Dice	Dim Dice	Net Cushion	Neck Cushion	Net Trap	Neck Trap
Eleven Goldfish	Dark Goldfish	Eleven Dwarves	Dark Dwarves	Mud Gear	Mug Gear	Mud Drinker	Mug Drinker

## References & Acknowledgements

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### Acknowledgments

The authors would like to thank Joe Toscano, Dana Subik, Athul Acharya and John Costalis for assistance in compiling stimulus materials and running subjects. This work supported by NIH grants R29DC03108 to DG, F31DC006537-01 to BM and DC005071 to MKT.