Noise, Attention and Economics

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Research Questions

1. What are the **costs of noise**?
   - In terms of **attention** and **consumer welfare**

- **Noise:** unchosen sound
- Noise sources: transport, industrial, work, recreational activities, ...

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2. How well do individuals **understand** how noise affects them?
   - Do they hold **correct beliefs** about the impacts of noise?

3. Do individuals take **protective actions**?
   - **Willing to pay** for quiet when it increases their productivity?

- **Noise:** unchosen sound
- Noise sources: transport, industrial, work, recreational activities, ...

Importance and Context

Importance of noise pollution first explored by cognitive science research

- **Noise pollution** is ubiquitous and will continue to grow in extent, frequency and severity
  - EU: 100 mn exposed to road traffic noise $>$ EU's daily exposure threshold
  - US: 30 mn workers exposed to hazardous sound levels
  - US: $>$ 10 mn schoolchildren chronically exposed to noise levels sufficient to cause adverse psychological stress reactions

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  - Hearing loss, cardiovascular diseases, sleep disturbance, mental health, ...
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  - EU: well-being loss due to road traffic noise estimated at 0.4% GDP
- **Cognitive science** recognized importance of noise decades ago
  - Reading comprehension, math skills, psycho-motor skills, ...
- **Impaired cognitive function suggested as mechanism**
  - Ex. attention and working memory
- However, **exact mechanism** remains **uncertain** and **unquantified**

Importance and Context

New measurement tools to quantify costs of attention and noise exposure

- **Rational Inattention:**
  - Theoretical framework for mechanism
  - Recovery of costs of attention from choice data
    - Recent advances by ex. Caplin et al. (2018)
  - Incorporation of beliefs and direct utility effects possible
  - $\Rightarrow$ Allows to **quantify costs of attention**

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- **Audio and Cognitive Science Research:**
  - Precise noise measurement and manipulation
  - Design of noise features and noise levels
  - $\Rightarrow$ Enables **controlled noise exposure**

Importance and Context

Economists also started to examine impacts of noise

- Urban & transportation economists long interested in **effect of noise on land and property values**
  - Research dates back to 1970s (ex. Crowley 1973)
  - Negative association beyond air pollution and n'hood effects

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- Recent advances directly link noise to economic outcomes
- **Noise lowers worker productivity**
  - Dean (2017): $\uparrow$ noise (from dishwasher to vacuum cleaner) $\Rightarrow$ productivity $\downarrow$ by 5%
  - Comparable, or larger, effects than other environmental pollutants such as temperature, alcohol, air pollution, and hunger

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- **Noise has detrimental effects on future generations of workers**
  - Over 20 studies found noise to adversely affect children's learning and attainment (ex. Shield and Dockrell 2003)
  - Far-reaching consequences for human capital accumulation in presence of dynamic complementarities

My Contribution

Cognitive Science + Rational Inattention + Experimental Economics

Contributions:

- Quantify costs of attention of noise $\rightarrow$ economic valuation of noise
- Assess individuals' understanding of noise and their WTP for quiet

How? New measurement tools + Experimental economics lab

- Measurement tools:
  - Cognitive science: noise exposure
  - Rational inattention: costs of attention
- Experimental economics lab
  - Beliefs about productivity impact of noise
  - Incentive-compatible WTP elicitation

Research Design

1. **Theory: Rational Inattention**
   - Recovery of Costs of Attention
   - Introducing Noise

2. **Experimental Implementation**
   - Noise
   - Task
   - Elicitations

Theory

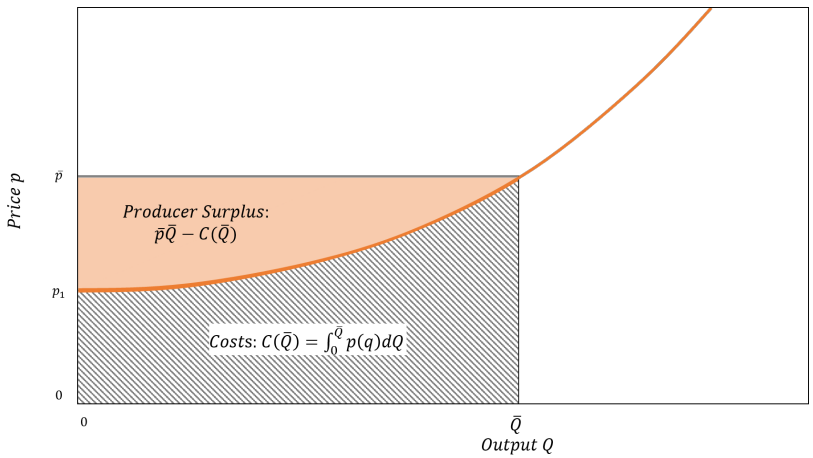
Recovery of Costs of Attention

- Recent work by Caplin et al. (2018) provides method to recover costs of attention from choice data
- Individuals assumed **rational** $\rightarrow$ optimally choose attention ($MC = MB$)
- Introduce **attentional incentives** π
- Appropriately **normalize** utility $\overline{U}(\pi) := \frac{U(\pi)}{\pi}$
- Utility cost curve $\overline{K}_A(u)$; free inattention
- DM chooses attention strategy by $\max_u \left\{\pi u - \overline{K}_A(u)\right\}$
- $\Rightarrow$ *Costs of attention recovered analogously to costs of production from competitive firm's marginal cost curve*

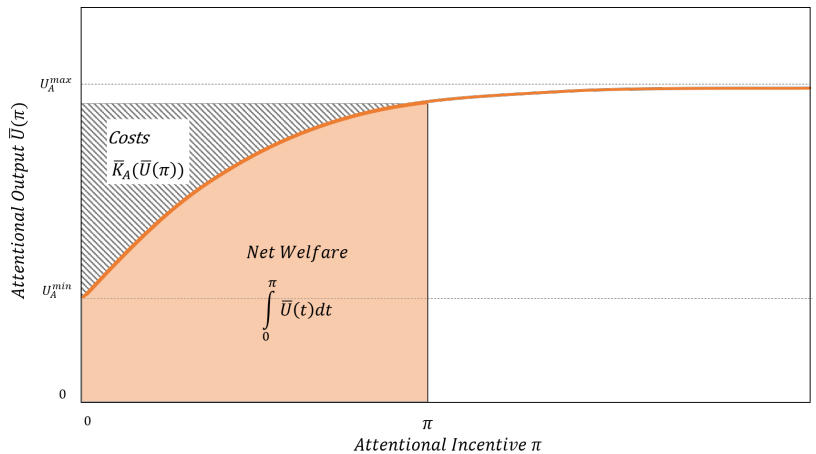
$$\underbrace{\overline{K}_A\left(\overline{U}(\pi)\right)}_{costs} = \underbrace{\pi\overline{U}(\pi)}_{\text{"revenue"}} - \underbrace{\int_0^{\pi} \overline{U}(t)dt}_{net\ \ welfare}$$

Theory

Recovery of Costs of Attention



(a) Competitive Supply Curve



(b) Incentive-based Psychometric Curve

Theory

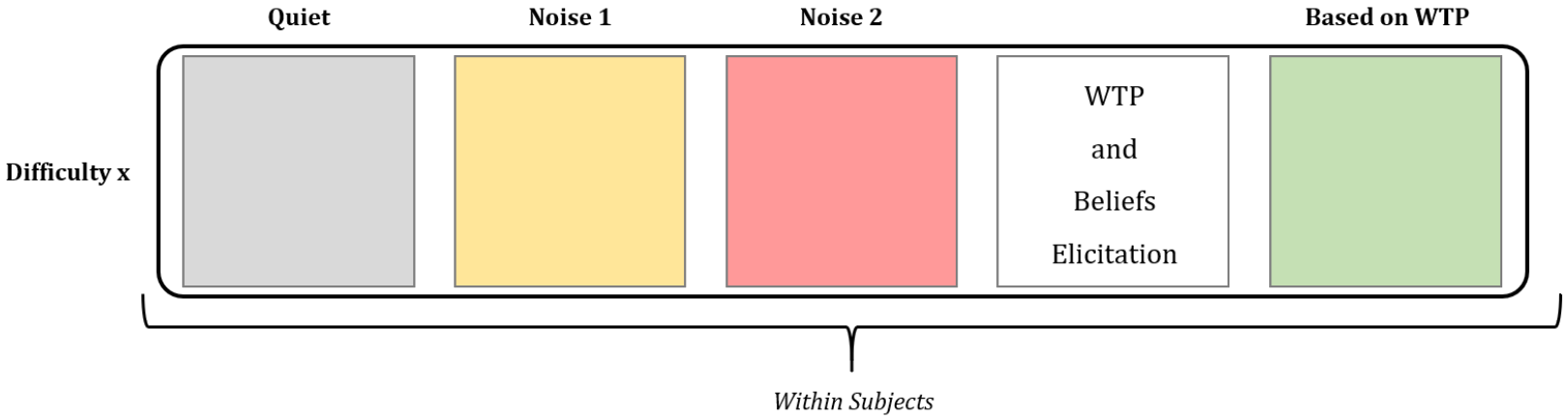
Introducing Noise

1. **Change in marginal costs of attention**
   - Change in slope, intercept, or both
2. Inducing a **direct disutility** ψ
   - Can be viewed as *fixed* cost of noise
3. Individuals hold **beliefs** about impacts of noise $\theta \in [0, 1]$
   - From complete ignorance ($\theta = 0$) to correct prediction ($\theta = 1$)

- Noise-specific and individual-specific: $\overline{U}_i^n$, ψ_i^n, θ_i^n ($n \in$ *noise types*)

Experimental Implementation

Experimental Design



- Order of within-subjects noise conditions will be randomized
- Order of WTP and beliefs elicitation also randomized
- Task difficulty can be incorporated as between-subjects component

Experimental Implementation

Noise - following decades of cognitive science research

- **3 noise conditions:**
  - (i) quiet
  - (ii) irrelevant speech *(office or classroom babble; internal)*
  - (iii) environmental noise *(cities, transportation, etc.; external)*

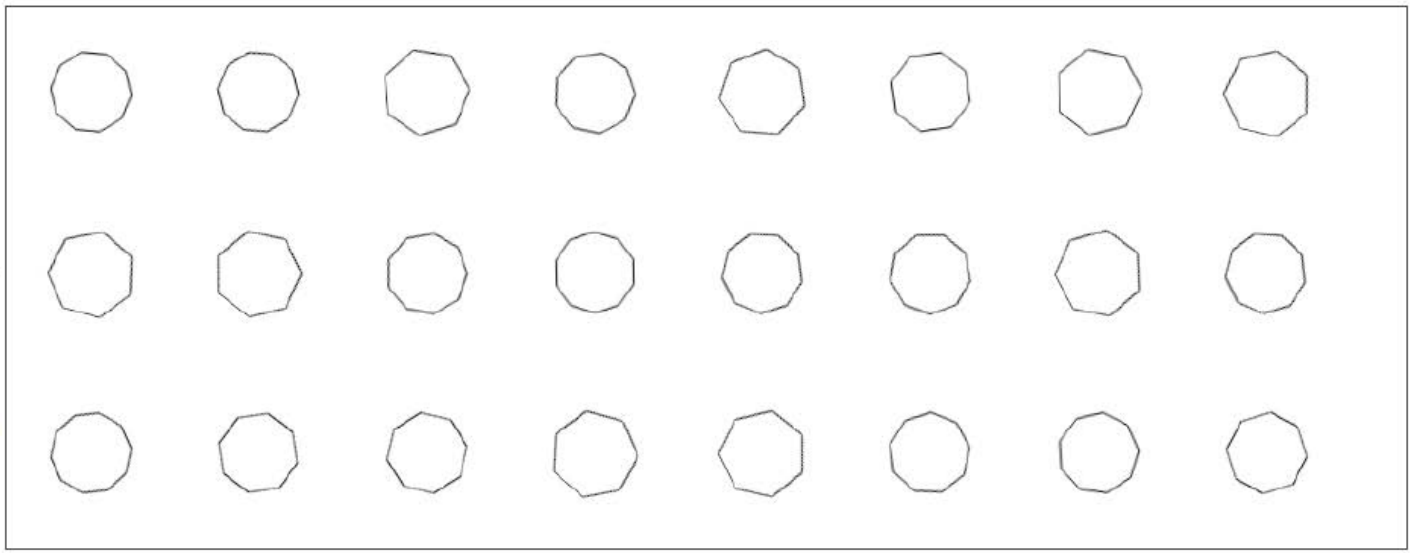
Experimental Implementation

Noise - following decades of cognitive science research

- **3 noise conditions:**
  - (i) quiet
  - (ii) irrelevant speech *(office or classroom babble; internal)*
  - (iii) environmental noise *(cities, transportation, etc.; external)*
- **Controlled noise levels:**
  - Quiet: 45 dB(A)
  - Noise: 65 dB(A) with superimposed pieces of up to 75 dB(A) in random intervals and of random duration
  - Sufficient to provoke reaction but not to cause hearing loss, etc.
- **Cognitive science research informs noise manipulation:**
  - Speech might have higher disruptive potential
  - Discrete tons or noise bursts more disruptive than sequence of repeated sounds
  - Noise particularly aversive when occurrence unpredictable and uncontrollable
- Played to participants via headphones
- Audiometric screening prior to experiment

Experimental Implementation

Example of cognitive task - Caplin et al. (2018)



- 24 geometric shapes on screen
- 4 distinct shapes: 7-, 8-, 9-, 10-sided polygons
- Determine whether more 7- or 9-sided polygons $(\omega_7 = \omega_9 = \frac{1}{2})$
- Location and rotation of shapes randomly determined
- No time limit and no feedback

Experimental Implementation

Elicitations

1. **WTP elicitation for quiet final session**
   - Incentive compatible implementation (BDM)
   - Elicited for all levels of attentional incentives
   - Elicited for both speech and environmental noise
   - Respondents asked to explain their WTP
   - Noise type and incentives level randomly determined, i.e. only 1 final session

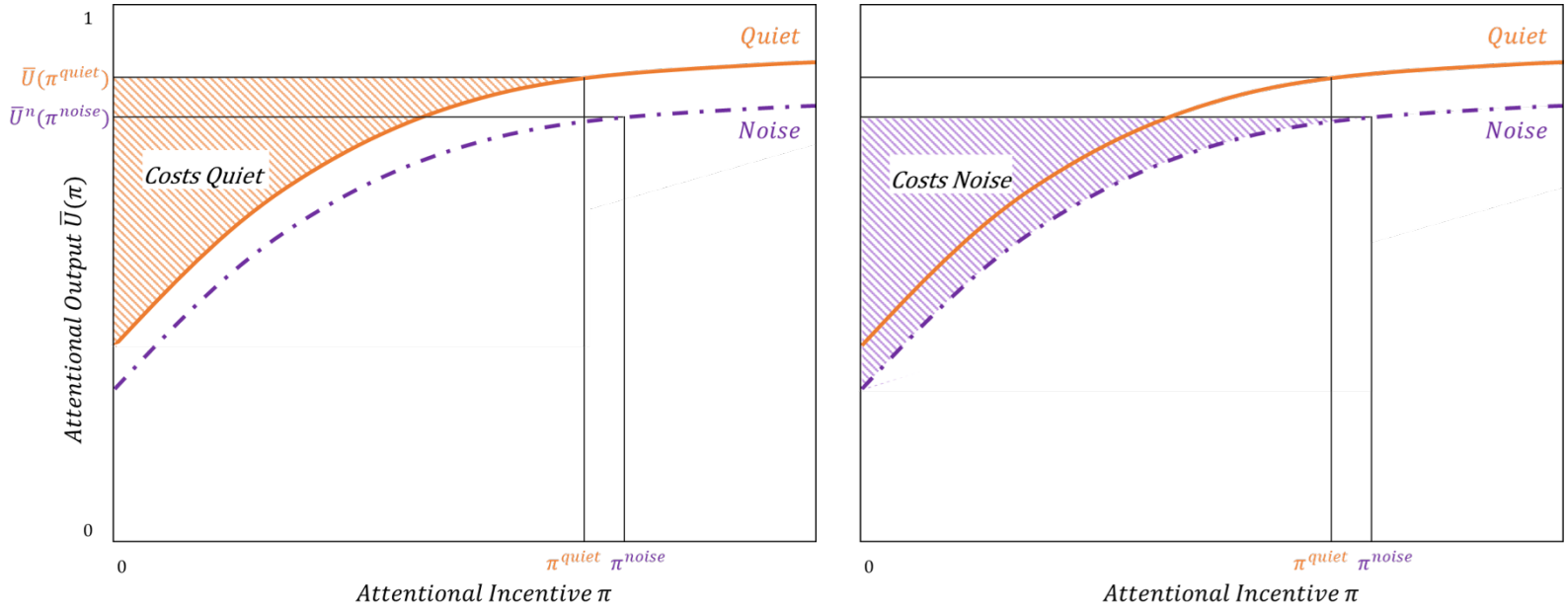
2. **Beliefs about performance across noise conditions**
   - Pairwise comparisons of performance
     - Pairs: quiet-speech, quiet-environment, speech-environment
     - Scale: *"much higher"*, *"higher"*, *"same"*, *"lower"*, *"much lower"*
   - Estimate total score in each noise condition

Order of elicitation will be randomized

Analysis Plan

1. What are the costs of noise?

- Estimate incentive-based psychometric curve for each noise condition
- Compute associated costs and consumer welfare
- Compare **quiet-speech**, **quiet-environmental**, **speech-environmental**



$$\bar{U}(\pi^{quiet}) \times \pi^{quiet} = \bar{U}^n(\pi^{noise}) \times \pi^{noise}$$

Analysis Plan

1. What are the costs of noise?

2. **How well do individuals understand how noise affects them?**
   - Estimate beliefs about impacts of noise ($\widehat{\theta}$)
   - Test for correct beliefs ($\widehat{\theta} = 1$)
   - Test for differences by noise type, i.e. whether $\widehat{\theta}^{speech} = \widehat{\theta}^{environment}$
   - Supplementary evidence: beliefs elicitation data

Analysis Plan

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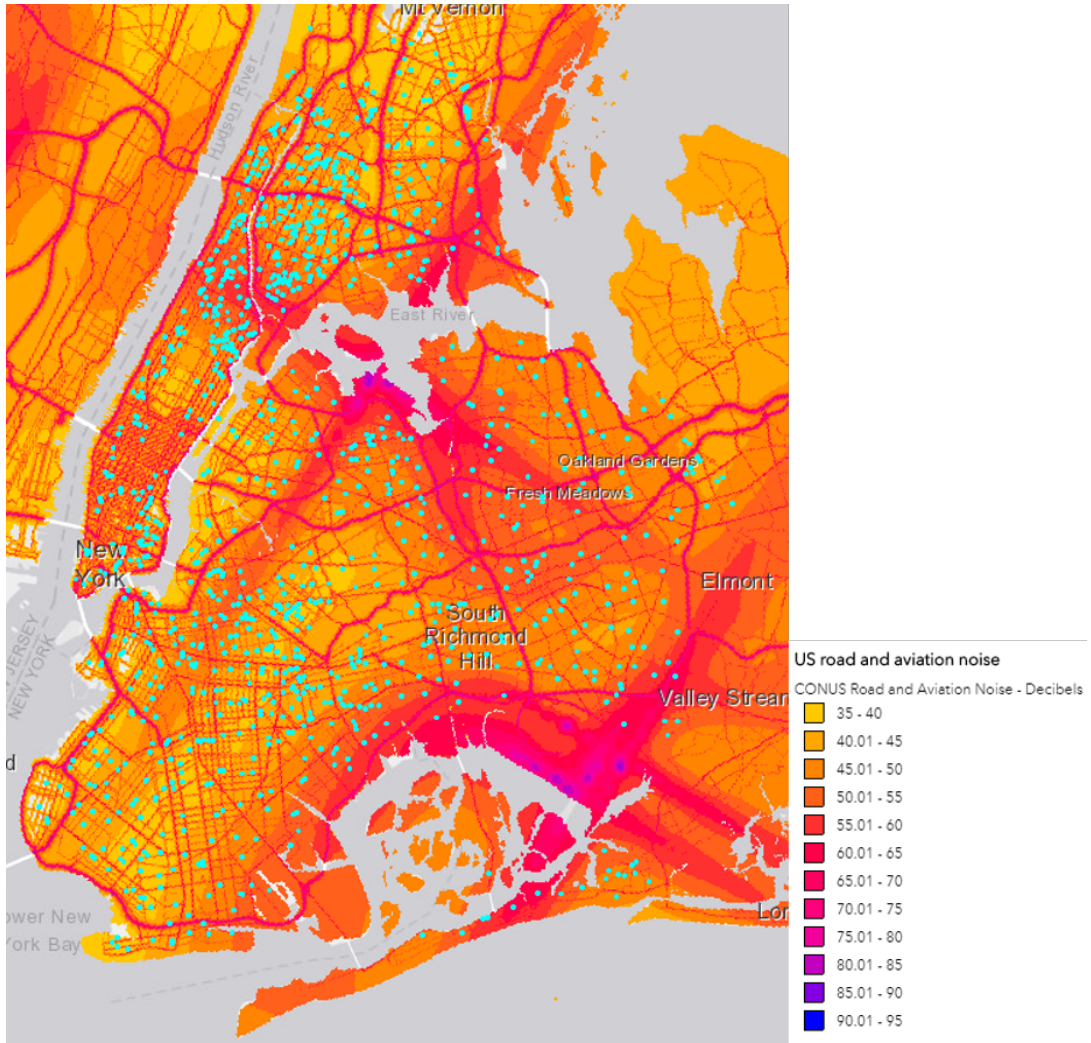
3. **Do individuals take protective actions?**
   - Test whether $WTP > 0$ when noise affects productivity
   - Test whether WTP varies with π and size of estimated welfare loss
   - Test for differences by noise type
   - Supplementary evidence: compare WTP to beliefs elicitation data

Policy Implications

How should policy maker evaluate school location and value noise abatement?



- Road and aviation noise, 24h equivalent sound level (source: US Department of Transportation)
- New York elementary schools (grades 1 to 6), all school types

Policy Implications

Providing:

1. Unconfounded cost estimates
2. Whether actual and perceived costs coincide
3. Whether protective measures are taken

has implications for:

- Awareness and educational campaigns
- Quantification of value of noise abatement
- Urban planning based on noise maps
- New legislative measures, ex. noise limits for schools
- Promotion of noise control programs
- Investigate and tackle noise injustice

Challenges and Open Questions

Challenges:

- Convince economists of importance of understanding and quantifying effects of noise exposure
- Design and piloting of noise conditions for lab experiment
- Identify field setting and relevant productivity measures

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Open Questions:

- Develop classification based on productivity impact and WTP?
- Variability based on task at hand?
- Stronger effects when noise more variable?
- What role plays noise volume?
- What predicts correct beliefs about noise impacts?
- Is there acclimatization and adaptation to some types of noise?
- Importance of short-run vs. long-run effects?
- How do effects and strategies vary by age?