Making Decisions by Seeing or Hearing? The Role of Basic Senses on Economic Rationality

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Abstract

Human choice behavior primarily depends on two basic senses: seeing and hearing. However, there is little research on whether decision-making through these two senses can have different economic consequences. This paper examines this question with respect to economic rationality. We design and implement a controlled laboratory experiment where subjects are randomly assigned to make decisions by hearing or by seeing the options. We find that making decisions by hearing, compared to by seeing, leads to severe impairment in economic rationality. We also find that subjects spend more time deciding when hearing the options than when seeing the options. Furthermore, subjects, especially females, reveal lower risk aversion when making decisions by hearing than by seeing. Our results highlight the importance of basic senses in economic decision-making.

JEL codes: C91, D81, D91, G11, I31.

Keywords: revealed preference, economic rationality, seeing and hearing, experiment.

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Introduction

The notion of economic rationality that people make choices consistent with maximizing a well-behaved utility function poses one of the main foundations of neoclassical economics and social sciences (Kahneman, 2003). A growing body of literature on examining economic rationality is established primarily based on a standard and intuitive choice paradigm in which options are presented visually to individuals (Choi et al., 2007, 2014; Kim et al., 2018). The literature also documents the relationship between cognitive ability and economic rationality (Burks et al., 2009; Cappelen et al., 2020), suggesting that one cause of economic "irrationality" may be cognitive limitations; this is aligned with Simon's seminal works (Simon, 1955, 1956). The limits on individual capacities may constrain individuals to maximize their preferences. Intuitively, these constraints might be distinct for decision-making by different senses, i.e., seeing or hearing. Yet, there is still little empirical evidence on the relationship between basic senses and economic rationality.

We present the first study on examining the effects of basic senses on economic rationality. The aforementioned standard choice paradigm represents the broad contexts where they make decisions based on the visual description of options. However, there are important contexts in which the auditory description of options plays a key role, such as business negotiations, job interviews, and telephone sales. Thus, a close examination of economic rationality in these two basic senses may enrich our understanding of individual choice behavior and generate important implications for welfare policies.

Indeed, the cognitive sciences have long acknowledged a crucial distinction in the individual processing mechanisms of visual and auditory information (Kahneman, 1973; Kubovy and Van Valkenburg, 2001; Shinn-Cunningham, 2008). Recent studies further suggest that auditory cognitive capacity may be inferior to visual cognitive capacity (Cohen, Horowitz and Wolfe, 2009; Kaiser, 2015; Plakke and Romanski, 2016). Given this evidence, we hypothesize that the economic rationality revealed in the two senses might be substantially different. For the same information content, individuals may be less efficient with processing information via the hearing sense than via the seeing sense, resulting in a lower level of economic rationality revealed in the former case.

This paper focuses on the impact of the hearing sense on economic decisions compared to the seeing sense. To this end, we introduce a novel experimental paradigm. Subjects are randomly assigned to make decisions under one of the two treatments: the Seeing Treatment, where they only see each option's information serially, and the Hearing Treatment, where they only hear each option's information serially. Both treatments comprise the identical incentivized twenty decision problems adapted from Kim et al. (Kim et al., 2018). Each decision problem represents eleven portfolio options from a two-dimensional budget line; each option rewards x or y amounts of experimental tokens with equal probability. An option's visual and auditory information is designed to convey the exact content of two numbers, i.e., "x or y". The speed rates of playing auditory information and displaying visual information of an option are fixed and designed to be comparable to control for the differences in exposure to information between treatments. Further details of the treatments are reported in the Methods section, and screenshots are in the Supplementary Materials section.

As established by the revealed preference theory, choices are consistent with utility maximization if and only if they satisfy Generalized Axiom of Revealed Preference (GARP) (Afriat, 1967; Varian, 1982, 1983). The experimental setup allows us to measure economic rationality by two conventional indexes. Firstly, we compute the number of GARP violations to indicate the frequency of individual choices that violate economic rationality. Secondly, to infer the severity of the deviations from economic rationality, we use Afriat's Critical Cost Efficiency Index (CCEI), which finds the minimal wealth change to rationalize the choice data (Afriat, 1972). The number of GARP violations is a nonnegative integer, and CCEI ranges continuously from 0 to 1. More GARP violations or a higher CCEI indicate a lower level of economic rationality. The computational rationales of the rationality measures are reported in the Methods section.

In the Supplementary Materials section, we also report additional measures of economic rationality, including the number of first-order stochastic dominance (FOSD) violations (Choi et al., 2014), the Houtman–Maks (HM) index (Houtman and Maks, 1985), and the Money Metric Index (Halevy, Persitz and Zrill, 2018; Kurtz-David et al., 2019). A violation of FOSD is defined as choosing an option over another that provides better outcomes without more risk. The HM index finds the minimum number of choices to be removed such that the remaining data is consistent (Houtman and Maks, 1985). MMI finds the minimal percentage of adjustments in expenditure required to reconcile an individual's choices with the best-fitting parametric utility function.

We compare the economic rationality measures revealed in the two treatments to test the hypothesis. To precisely investigate the extent of the economic rationality differences between the two basic senses, we account for demographics (including age, gender, education) and cognitive ability, which are suggested to influence economic rationality (Burks et al., 2009; Choi et al., 2014; Dean and Martin, 2016; Kim et al., 2018). To investigate the driving mechanism of the results, we analyze differences in response times and the number of options that subjects explore between the two treatments. Finally, we examine the treatment effects on risk preferences that revealed using the MMI method.

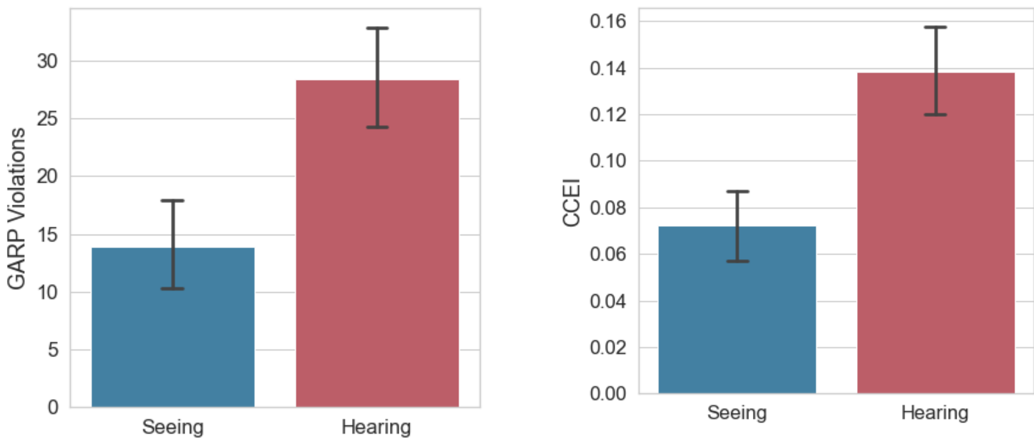
Results

Economic rationality. Fig. 1 and Fig. 2 present the key results of our study, including the mean GARP violations and CCEI, their standard errors, and empirical cumulative distributions. We find that subjects commit, on average, 13.91 GARP violations in the Seeing Treatment, and their mean CCEI is about 0.072, as shown in Fig. 1a and b. This level of economic rationality differs from that found in the related literature with the closest design. In particular, Kim et al. (Kim et al., 2018) conduct the experiment to a sample of Malawian secondary school female students in which they find a CCEI of 0.19 in their baseline control group. The difference in economic rationality may be attributed to the gaps in education (Choi et al., 2014) and economic development (Cappelen et al., 2020) between their study and ours.

Fig. 1a and b also show that the mean GARP violations and CCEI in the Hearing Treatment are 28.45 and 0.138, respectively. With the switch from the Seeing Treatment to the Hearing Treatment, subjects' GARP violations increase by about 104% and CCEI by almost 92%, on average. Furthermore, Fig. 2 displays that the cumulative distributions of GARP violations and CCEI in the Hearing Treatment (first-order) stochastically dominates that in the Seeing Treatments strongly (except on the extreme right tails of the distributions in Fig. 2a. This suggests that it is more likely to observe a lower level of economic rationality in the Hearing Treatment than in the Seeing Treatment.

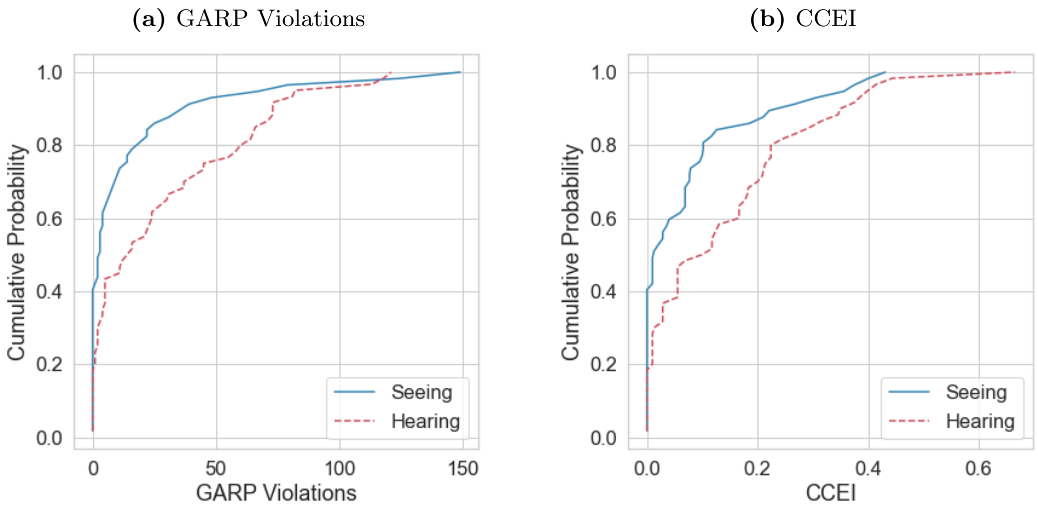
Figure 1: Th Average of Economic Rationality in The Experiment

(a) GARP Violations **(b)** CCEI



To identify the treatment differences precisely, we conduct a negative binomial regression analysis for GARP violations and a linear regression analysis for CCEI. Table 1 presents the results in the form of average marginal effects. All full tables and all regressions in the original form are reported in Supplementary Materials. In line with the descriptive evidence, the GARP violations and CCEI between the two treatments differ significantly ($P < 0.01$), robust across

Figure 2: Cumulative Distributions of Economic Rationality in The Experiment



all models. Specifically, the Hearing Treatment increases 22.522 GARP violations (almost 162%, Model 2) and 0.093 (about 129%, Model 4) CCEI compared with the Seeing Treatment taking into account all controls.

Apart from the treatment differences, only the effect of response time is significant on GARP violations ($P < 0.05$, Model 2) and CCEI ($P < 0.01$, Model 4). Longer response times may involve more (deliberate) processing of choice tasks, thus improving economic rationality, as implied by the speed-accuracy tradeoff hypothesis (Wickelgren, 1977). We do not find effects of demographics and cognitive ability in the experiment, although they have been suggested by the literature (Burks et al., 2009; Choi et al., 2014; Echenique, Imai and Saito, 2021). To some extent, our design of sequentially delivering option information may increase the difficulty of choice tasks compared to other studies. The results lead to the question of the robustness of relationships between economic rationality and demographics or cognitive ability, which desires further investigations.

In addition, Supplementary Table 6 shows that the main result is robust to other measures of rationality, including FOSD violations ($P < 0.01$, Model 2), HM index ($P < 0.01$, Model 4), and MMI ($P < 0.01$, Model 6) when all controls are included. Consistently, all the results indicate a substantial impairment of economic rationality caused by an auditory environment, in terms of frequency and severity.

Response Time and Search Behavior As discussed previously, one possible mechanism of lower economic rationality revealed in the Hearing Treatment is that subjects spend less time in it. It is also possible that subjects search for fewer options in the treatment. To verify these possibilities, we examine treatment effects on response time. We count the number of (unique) options that each subject has explored in total as an indicator of search behavior. We conduct

Table 1: Impacts of the Hearing Treatment on Economic Rationality

	GARP Violations		CCEI	
	(1)	(2)	(3)	(4)
Hearing Treatment	14.538**	22.522***	0.066***	0.093***
	(5.705)	(6.263)	(0.024)	(0.027)
Response Time (Minutes)		-1.185**		-0.006***
		(0.475)		(0.002)
Other Control variables	No	Yes	No	Yes
N	117	117	117	117

Robust Standard errors in parentheses. ** $p < 0.05$, *** $p < 0.01$.

Other control variables include Age, Female, Education, IQ, Selective Attention, and Working Memory.

a linear regression analysis for response time and a negative binomial regression analysis for the number of explored options.

Fig. 3a shows that subjects spend, on average, more time making decisions in the Hearing Treatment than in the Seeing Treatment. Meanwhile, the gap between the numbers of explored options in both treatments seems not large, as shown in Fig. 3b. Table 2 shows the results of the regression models in the form of average marginal effects. The Hearing Treatment is associated with over 3.1 minutes longer response time, compared to the Seeing Treatment ($P < 0.05$, Model 1); and this becomes longer when taking into account controls ($P < 0.05$, Model 2). As a baseline, subjects spend 16.37 minutes in the Seeing Treatment, on average. This indicates that subjects spend markedly more time in the Hearing Treatment, with the increment being almost 22% of the baseline group. Meanwhile, we do not find that the numbers of explored options differ significantly between the two treatments (Model 3 and 4). These findings together rule out the potential mechanism that the treatment effect operates through the response time channel. Also, they imply that subjects may spend more time processing each option in the Hearing Treatment than in the Seeing Treatment. The observation that the subjects make choices with lower economic rationality while they spend more time in the Hearing Treatment suggests plausibly low information processing efficiency caused by this choice environment.

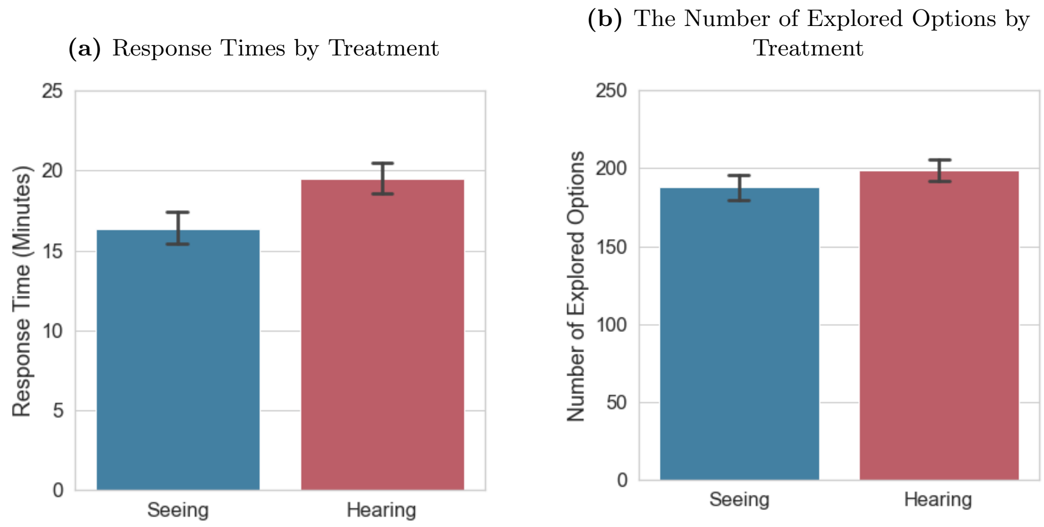
Table 2: Impacts of the Hearing Treatment on Response Time and Search Behavior

	Response Time (Minutes)		Number of Explored Options	
	(1)	(2)	(3)	(4)
Hearing Treatment	3.115**	3.555***	10.459	10.379
	(1.351)	(1.336)	(10.563)	(10.452)
Control variables	No	Yes	No	Yes
N	117	117	117	117

Robust Standard errors in parentheses. ** $p < 0.05$, *** $p < 0.01$

Control varibles include Age, Female, Education, IQ, Selective Attention, and Working Memory.

Figure 3: Search Behavior in The Experiment



Risk Preferences Would the different choice environments cause other behavioral consequences? A key variable of interest in the present context is risk aversion. To measure risk preferences, we consider the coefficient of relative risk aversion (CRRA) form expected utility model. The CRRA parameter is recovered using the MMI (Halevy, Persitz and Zrill, 2018), the detail of which is included in the Methods section.

Fig. 4a shows that subjects in the Hearing Treatment reveal a higher degree of CRRA than in the Seeing Treatment, on average. Specifically, women reveal a higher degree of CRRA than men in the Seeing Treatment, consistent with the literature on risk preferences (Eckel and Grossman, 2008; Croson and Gneezy, 2009), as shown in Fig. 4b. Interestingly, 4b also shows that women's revealed CRRA becomes lower in the Hearing Treatment compared to that in the Seeing Treatment, while men reveal similar degrees of CRRA in both treatments.

Table 3 presents the linear regression results of treatment effects on the CRRA. We find that the Hearing Treatment corresponds to a lower level of CRRA ($P < 0.01$, Model 1). The treatment effect on risk preferences remains significant in the presence of all controls ($P < 0.01$, Model 2), displaying a slightly smaller magnitude. Although the relationship between cognitive ability and risk aversion is suggested in the literature (Dohmen et al., 2010, 2018), it is not found in the present experiment. This is perhaps due to the complexity of the choice task. Indeed, Benjamin et al. (Benjamin, Brown and Shapiro, 2013) suggest choice mistakes may drive the revealed risk preferences to be different. We confirm that female is associated with a higher level of risk aversion ($P < 0.01$, Model 2). In Model 3 and 4, we additionally control for the potential interaction between the treatment and female dummies. Aligned with the descriptive evidence, while the Hearing Treatment does not seem to affect males' CRRA significantly, we find a significant negative impact on women's CRRA ($P < 0.10$, Model 3) in the absence of controls. The significance of this effect is approaching conventional levels ($p = 0.105$) in Model 4. The evidence suggests that women may drive the Auditory' treatment s overall impact on risk preferences.

Figure 4: Th Average of CRRA Revealed in the Experiment

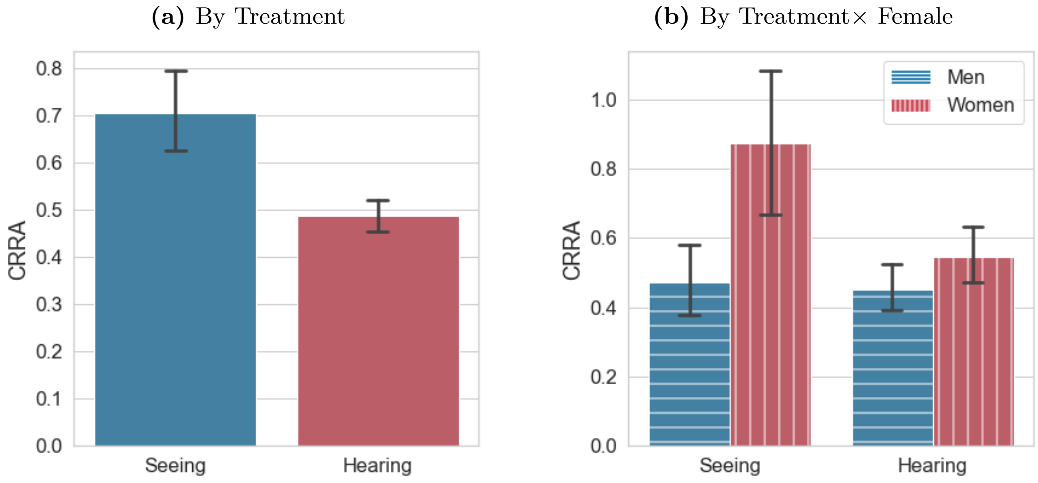


Table 3: Determinants of Risk Preferences

	CRRA			
	(1)	(2)	(3)	(4)
Hearing Treatment	-0.217**	-0.180**	-0.020	-0.053
	(0.091)	(0.090)	(0.076)	(0.082)
Female		0.218***	0.402***	0.355**
		(0.075)	(0.148)	(0.139)
Hearing Treatment×Female			-0.308*	-0.257
			(0.162)	(0.157)
Other Control Variables	No	Yes	No	Yes
N	117	117	117	117

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Other control variables include Age, Education, IQ, Selective Attention, and Working Memory.

Discussion

Our paper builds on the influential choice experiments to study the revealed economic rationality of individuals when they make decisions by hearing. In addition to providing visual information of the options, which is standard in the literature, we provide auditory information. This design allowed us to identify the effect of basic senses while preserving the information content, thus complementing the existing literature.

Using a randomized controlled experiment, we first discover that decision-making in an auditory environment rather than in a visual one may impair economic rationality substantially, both in terms of frequency and severity. While we find no treatment differences in searching behavior, subjects spend more time deciding by hearing than by seeing. To some degree, our results suggest people may be less efficient with processing options in the auditory environments than in the visual environments.

This paper could have important policy implications. Consider a policy in where identification of individual preferences is crucial. Our results would suggest that policymakers may need to tread cautiously with choices made in an auditory environment. Perhaps, policymakers may want to promote a visual environment to facilitate individual rationality. According to our results, females may become less risk-averse in the auditory environments; this could be relevant for a policy aiming to reduce risk-taking behavior. While we do not claim that the impairment in economic rationality is prevalent across all auditory environments, our experiment presents the first evidence showing this issue may deserve some concerns. Our study and, desirably, more research on richer variations of basic senses should be considered together to draw firm conclusions.

Methods

Experimental treatments. In both treatments, decision problems are described to reward experimental tokens. Subjects are informed that one of the decision problems will be randomly selected for their payment with the conversion rate of five tokens to one Chinese Yuan. In the Hearing Treatment, the voice data is generated by Python *pyttsx3* library, which synthesizes text into audio using native speech drivers from Windows. The auditory information is, literally, "x or y", in the subjects' native language (Mandarin Chinese) in a female voice. The evidence suggests that lower speech rates improve information processing (Picheny, Durlach and Braida, 1985, 1986). The playing speed of an option's auditory information is set to be 120 words per minute, which is slightly slower than the recommended conversational speech rate for Mandarin Chinese (Li, 2010). The duration of playing auditory information varies depending on the information content of each option, which ranges from 3 to 4 seconds. To control for the differences in exposure to information between treatments, we set the display of an option's visual information to be 4 seconds. In both treatments, subjects are informed that they can not reveal (visual or auditory) information of other options in the corresponding treatment until 4 seconds after clicking on an option. Subjects are allowed to reveal each option's information unlimited times.

Our main analysis is based on the examination of between-subjects treatment differences in choice behavior. For robustness analysis, the experiment also includes a within-subjects design. Specifically, after making decisions under their assigned treatments (e.g., the Seeing Treatment), subjects are asked to make decisions under the other treatments for the same decision problem (e.g., the Hearing Treatment). Supplementary Table 10 and 11 present the estimations of the within-subjects treatment effects, which finds results consistent with the between-subjects treatment analysis.

Participants. A total of 117 subjects (47.9% females, mean age 22.1 years, all at least in undergraduate) were recruited to participate in the experiment in 24 sessions of maximum 10 subjects from July 07 to July 16, 2021. 57 (57.9% female, mean age 22.2 years) were randomly allocated into the Seeing Treatment and 60 (38.3% female, mean age 22 years) into the Hearing Treatment. All subjects passed the pretests of correctly identifying visual and auditory information relevant to the experiment.

Experimental procedure. The experiment was conducted through Qualtrics at the Neuromanagement Lab of Zhejiang University. The experiment had received the approval of the Internal Review Board of the university. All subjects agreed with the information consent before starting the experiment and were free to leave the experiment at any moment without giving a reason. There was a physical distance of a minimum of 2 meters between each computer in the laboratory. There was no interaction between subjects by design during each experimental session, and subjects were also asked to keep quiet. Subjects received their earnings by cash after the experiment. On average, subjects spent 94 minutes in the experiment and earned 71.9 Chinese Yuan.

Measuring cognitive ability. Cognitive ability is mainly expressed as IQ scores using the matrix reasoning and three-dimensional rotation questions from the ICAR test. The two types of questions are independent of language skills. They are commonly used as the primary measure of fluid intelligence, which relates to problem-solving and reasoning abilities. We also measure selective attention by the Stroop test (Stroop, 1935) and working memory capacity by the Sternberg test (Sternberg, 1966), which involves twenty and ten trials, respectively.

Economic rationality measures. Each subject's choices in the experiment can be represented by a dataset $D = \{(p^i, x^i)\}_{i=1}^n$, where $x^i = (x_1^i, x_2^i)$ describes the subject's chosen option at prices $p^i = (p_1^i, p_2^i)$. For any two options x^i and x^j, we define the direct revealed preference relation R^D as $x^i R^D x^j$ if there exists some p_i such that $p^i \cdot x^i \geq p^i \cdot x^j$. We also define the revealed preference relation, or the transitive closure of R^D, R as $x^i R x$ if there exists some sequence $x^j, x^k, ..., x^n$ such that $x R^D x^j, x^j R^D x^k, ..., x^n R^D x$. D is said to satisfy General Axiom of Revealed Preference (GARP) if for any pair of x^i, x^j, $x^i R x^j$, implies that $x^j R^D x^i$ is not true. GARP is a necessary and sufficient condition for a choice dataset to be rationalized by a well-behaved (continuous, monotone, and concave) utility function (Afriat, 1967, 1972). Supplementary Fig. 7 presents an example of GARP violations. We count the number of GARP violations for each subject to measure level of economic rationality.

We also measure economic rationality by the Afriat's Critical Cost Efficiency index (CCEI) (Afriat, 1972). Following Choi et al. (Choi et al., 2014), for any two options x^i, x^j and any number $0 \leq e \leq 1$, we define the direct revealed preference relation $R^D(e)$ as $x^i R^D(e) x^j$ if $ep^i \cdot x^i \geq p^i \cdot x^j$, and define $R(e)$ be the transitive closure of $R^D(e)$. We compute CCEI by $1 - e^*$, where e^* is the maximum value of e such that the relation $R(e)$ satisifies GARP. CCEI indicates the minimum wealth that needs to be wasted in order to rationalize the dataset. Thus, CCEI provides an indication of the severity of the violations in the dataset.

For robustness analysis, we consider other measures of rationality, including first-order stochastic dominance violations, Houtman–Maks Index, and Money Metric Index, which are explained in detail in Supplementary Materials. All economic rationality measures in the paper are computed by (Halevy, Persitz and Zrill, 2018)'s code packages.

Estimating risk preferences. To estimate risk preferences, we use the CRRA functional form of the expected utility model. Formally,

$$U(x_1, x_2; p) = pu(x_1) + (1-p)u(x_2) \tag{1}$$

$$u(x_i) = \begin{cases} \frac{x_i^{1-\rho}}{1-\rho} & , \rho \geq 0 \\ ln(w_i) & , \rho = 1 \end{cases}, \text{ for } i = 1, 2. \tag{2}$$

where p (which is 0.5 in the experimental setup) is that probability of rewarding x_1 is and $1-p$ (0.5 as well) is that probability of rewarding x_2. ρ is the CRRA, and $\rho = 0$ implies that the subject is risk-neutral, a higher CRRA indicates a higher level of relative risk aversion. Each subject's ρ is recovered using the MMI by (Halevy, Persitz and Zrill, 2018)'s code packages.

Statistical analyses and regression models. In order to estimate the treatment effects, we use two regression models. For the dependent variables of count data, including GARP violations, FOSD violations, HM index, and the number of explored options, we conduct negative binomial regressions, as suggested by Cameron and Trivedi (Cameron and Trivedi, 2013). The negative binomial distribution probability mass function is given by:

$$Pr(Y = y; \alpha, \delta) = \frac{\Gamma(y + 1/\alpha))}{\Gamma(1/\alpha)\Gamma(y+1)} (\frac{1}{1+\delta\alpha})^{1/\alpha} (1 - \frac{1}{1+\delta\alpha})^y \tag{3}$$

The negative binomial regressions result from finding the finding the maximum likelihood estimators $\beta_0, \beta_1, \beta_2$ by introducing coefficients via $\alpha = \theta exp(\beta_0 + \beta_1 Auditory + \beta_2 Controls)$ and $\delta = exp(\beta_0 + \beta_1 Auditory + \beta_2 Controls)$. *Auditory* is a independent dummy variable that takes value 1 if the subject is assigned to the Hearing Treatment and 0 otherwise. β_0 is a constant term, β_1 is the coefficient associated with *Auditory*. β_2 is a vector of coefficient associated with a vector of the corresponding variable. To compute the treatment effects or the effects of controls, the coefficient estimates can be converted to the form of average marginal effects (AMEs), which is given by:

$$AME_j = \sum_i exp(\hat{\beta}_0 + \hat{\beta}_1 Auditory + \hat{\beta}_2 Controls) \times \hat{\beta}_j \tag{4}$$

where the estimated coefficients are expressed with hats, AME_j refers to the average marginal effect of variable j. For example, the AME of *Auditory* is 22.52 on GARP violations, which implies that being assigned to the Hearing Treatment increases the number of GARP violations by almost 23, *ceteris paribus*.

For the dependent variables of continuous data, including CCEI, MMI, response times, and CRRA, we conducted linear regressions of the following form:

$$Y = \beta_0 + \beta_1 Auditory + \beta_2 Controls + \epsilon \tag{5}$$

The coefficient estimates of linear regression can be used directly to interpret the effect of the variables. For example, the estimated coefficient of *Auditory* on CCEI is 0.093, which implies that being assigned to the Hearing Treatment increases CCEI by about 0.09, *ceteris paribus*.

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Supplementary Materials

Screenshots in the Experiment

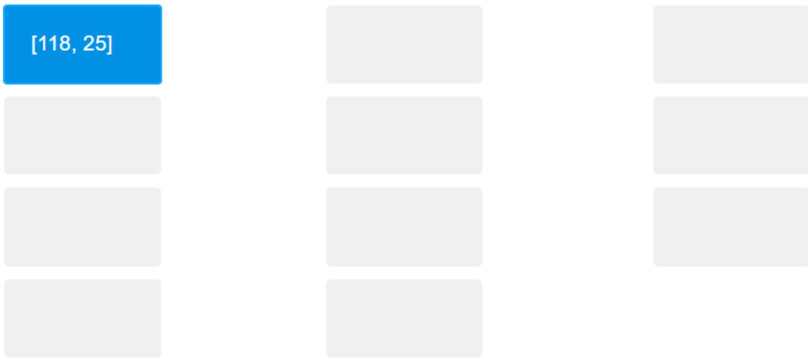

Figure 5: The Screenshot in Seeing Treatment

Figure 6: The Screenshot in the Hearing Treatment

Other Economic Rationality Measures

First-order stochastic dominance (FOSD). We compute FOSD violations by the following criterion: For each decision problem, a subject commits a FOSD violation if she or he choose an option (x, y) when there exists another option (z, w) in the same problem such that $w > x$ and $z > y$.

Houtman–Maks index. Houtman and Maks (HM) index is computed by finding the largest subset of the dataset D that satisfies GARPHoutman and Maks (1985).

Money Metric Index. As formulated by Halevy et al.Halevy, Persitz and Zrill (2018) and Kurtz-David et al.Kurtz-David et al. (2019), given the prices p^i and a utility function u, the

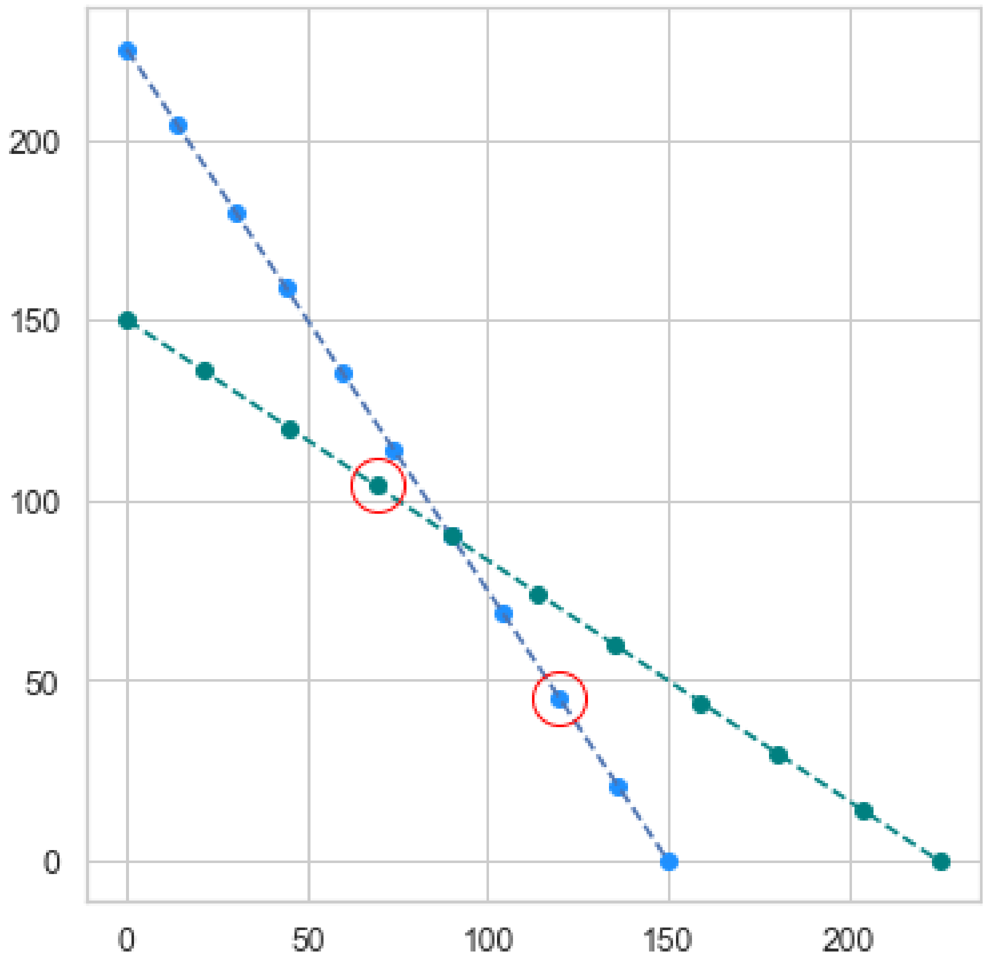

Figure 7: An Example of GARP Violation

money metric $m(x^i, p^i, u)$ for observation i is the minimal expenditure needed to include a bundle y in the dataset such that $u(y) \geq u(x^i)$:

$$m(x^i, p^i, u) = \min_{u(y \geq u(x^i))} p^i \cdot y \tag{6}$$

The money metric measure for observation i is then normalized by the original expenditure to compute the adjustment, $v_i(D, u) = 1 - \frac{m(x^i, p^i, u)}{x^i \cdot x^i}$. Halevy et al.Halevy, Persitz and Zrill (2018) propose to recover the utility function parameters by finding the parameter that minimizes the normalized average sum of squares aggregator of all v_i.

$$f(v) = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (1 - v_i)} \tag{7}$$

The MMI of the dataset D is then given by the $f(v)$ with the best fitting utility function u_i^*

Details of the Experimental Resultts

Table 4: Impacts of the Hearing Treatment on Economic Rationality (Average Marginal Effects)

	GARP Violations		CCEI	
	(1)	(2)	(3)	(4)
Hearing Treatment	14.538**	22.522***	0.066***	0.093***
	(5.705)	(6.263)	(0.024)	(0.027)
Age		-1.143		0.005
		(1.710)		(0.006)
Female		0.152		0.020
		(7.085)		(0.023)
Education		4.784		-0.007
		(4.638)		(0.014)
IQ		-0.968		-0.006
		(1.477)		(0.006)
Selective Attention		-0.133		0.001
		(1.128)		(0.003)
Working Memory		0.888		-0.005
		(1.962)		(0.006)
Response Time (Minutes)		-1.185**		-0.006***
		(0.475)		(0.002)
Constant			0.072***	0.107
			(0.015)	(0.134)
N	117	117	117	117

Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Impacts of the Hearing Treatment on GARP Violations (Original Form)

	GARP Violations	
	(1)	(2)
Hearing Treatment	0.715**	1.100***
	(0.311)	(0.276)
Age		-0.052
		(0.073)
Female		0.007
		(0.321)
Education		0.217
		(0.194)
IQ		-0.044
		(0.067)
Selective Attention		-0.006
		(0.051)
Working Memory		0.040
		(0.088)
Response Time (Minutes)		-0.054***
		(0.019)
Constant	2.633***	3.878**
	(0.273)	(1.531)
N	117	117

Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Impacts of the Hearing Treatment on Economic Rationality by Additional Measures (Average Marginal Effects)

	FOSD Violations		HM Index		MMI	
	(1)	(2)	(3)	(4)	(5)	(6)
Hearing Treatment	0.285	0.613***	0.031**	0.043***	0.161**	0.217***
	(0.272)	(0.228)	(0.014)	(0.014)	(0.062)	(0.062)
Age		-0.017		-0.003		-0.014
		(0.050)		(0.003)		(0.015)
Female		0.099		-0.001		0.053
		(0.225)		(0.014)		(0.061)
Education		0.039		0.008		0.045
		(0.144)		(0.008)		(0.035)
IQ		-0.002		-0.004		-0.005
		(0.056)		(0.003)		(0.014)
Selective Attention		-0.032		-0.002		-0.001
		(0.028)		(0.001)		(0.008)
Working Memory		-0.069		0.004		-0.011
		(0.064)		(0.004)		(0.016)
Response Time (Minutes)		-0.096***		-0.004***		-0.018***
		(0.020)		(0.001)		(0.004)
N	117	117	117	117	117	117

Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Impacts of the Hearing Treatment on Economic Rationality by Additional Measures (Original Form)

	FOSD Violations		HM Index	
	(1)	(2)	(3)	(4)
Hearing Treatment	0.259	0.551***	0.394**	0.539***
0.161**	0.217***			
	(0.256)	(0.213)	(0.191)	(0.181)
(0.062)	(0.062)			
Age		-0.015		-0.032
	-0.014			
		(0.045)		(0.036)
	(0.015)			
Female		0.090		-0.011
	0.053			
		(0.203)		(0.171)
	(0.061)			
Education		0.035		0.096
	0.045			
		(0.130)		(0.102)
	(0.035)			
IQ		-0.002		-0.044
	-0.005			
		(0.050)		(0.040)
	(0.014)			
Selective Attention		-0.029		-0.022
	-0.001			
		(0.025)		(0.019)
	(0.008)			
Working Memory		-0.062		0.056
	-0.011			
		(0.058)		(0.048)
	(0.016)			
Response Time (Minutes)		-0.086***		-0.045***
	-0.018***			
		(0.017)		(0.014)
	(0.004)			
Constant	-0.036	2.120**	-2.748***	-1.302
0.514***	1.046***			
	(0.213)	(1.039)	(0.158)	(0.870)
(0.047)	(0.336)			
N	117	117	117	117

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Impacts of the Auditory Treatment on Response Time and Search Behavior

	Response Time (Minutes)		Number of Explored Options	
	(1)	(2)	(3)	(4)
Auditory Treatment	3.115**	3.555***	10.459	10.379
	(1.351)	(1.336)	(10.563)	(10.452)
Age		-0.370		-7.016**
		(0.312)		(3.428)
Female		3.594**		17.788
		(1.420)		(11.350)
Education		-0.632		-0.311
		(0.724)		(6.258)
IQ		0.617**		6.496**
		(0.280)		(2.714)
Selective Attention		0.043		1.063
		(0.196)		(1.920)
Working Memory		-0.282		-0.291
		(0.338)		(2.725)
Constant	16.368***	21.322***		
	(0.978)	(7.742)		
N	117	117	117	117

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Control varibles include Age, Female, Education, IQ, Selective Attention, Working Memory, Response Times (Minutes).

Table 9: Impacts of the Auditory Treatment on Search Behavior (Original Form)

	Number of Explored Options	
	(1)	(2)
Auditory Treatment	0.054	0.061
	(0.055)	(0.059)
Age		-0.036**
		(0.018)
Female		0.092
		(0.059)
Education		-0.002
		(0.032)
IQ		0.034**
		(0.014)
Selective Attention		0.005
		(0.010)
Working Memory		-0.002
		(0.014)
Constant	5.237***	5.683***
	(0.042)	(0.359)
N	117.000	117.000

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Within-Subjects Treatment Differences in Economic Rationality (Average Marginal Effects)

	GARP Violations (1)	FOSD Violations (2)	HM Index (3)
Auditory Treatment	15.583**	0.323**	0.025***
	(6.104)	(0.159)	(0.009)
Age	-0.020	-0.030	-0.002
	(1.535)	(0.037)	(0.002)
Female	7.681	0.205	0.012
	(6.622)	(0.162)	(0.009)
Education	0.269	0.064	0.006
	(3.577)	(0.093)	(0.005)
IQ	0.213	-0.034	-0.001
	(1.149)	(0.038)	(0.002)
Selective Attention	0.305	-0.040*	-0.002**
	(0.932)	(0.021)	(0.001)
Working Memory	0.595	-0.026	-0.001
	(1.521)	(0.051)	(0.003)
Response Time (Minutes)	-1.290***	-0.073***	-0.003***
	(0.443)	(0.013)	(0.001)
N	234	234	234

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Within-Subjects Treatment Differences in Economic Rationality (Original Form)

	GARP (1)	FOSD (2)	HM (3)	CCEI (4)	MMI (5)
Auditory Treatment	0.762***	0.275**	0.342***	0.056***	0.145***
	(0.206)	(0.138)	(0.120)	(0.018)	(0.045)
Age	-0.001	-0.025	-0.025	0.005	-0.007
	(0.059)	(0.031)	(0.029)	(0.005)	(0.010)
Female	0.360	0.174	0.162	0.019	0.082*
	(0.246)	(0.138)	(0.120)	(0.017)	(0.044)
Education	0.013	0.054	0.083	-0.009	0.027
	(0.147)	(0.079)	(0.072)	(0.010)	(0.027)
IQ	0.010	-0.029	-0.012	-0.002	0.003
	(0.051)	(0.032)	(0.029)	(0.004)	(0.011)
Selective Attention	0.014	-0.034*	-0.030**	-0.002	-0.004
	(0.034)	(0.018)	(0.014)	(0.003)	(0.006)
Working Memory	0.028	-0.022	-0.010	0.001	-0.011
	(0.058)	(0.043)	(0.037)	(0.005)	(0.013)
Response Time (Minutes)	-0.061***	-0.062***	-0.045***	-0.006***	-0.015***
	(0.017)	(0.010)	(0.010)	(0.002)	(0.003)
Constant	2.918**	2.112***	-1.275*	0.132	0.873***
	(1.201)	(0.741)	(0.691)	(0.109)	(0.240)
N	234	234	234	234	234

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$