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# Pitch Right: The Effect of Vocal Pitch on Risk Aversion

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## Abstract

During interpersonal interactions, individual perceptions and judgment are unavoidably influenced by speech cues, such as vocal pitch. This paper experimentally examines the effect of vocal pitch on risk attitudes. In a lottery-choice task, subjects made a series of binary choices between a 50–50 lottery and a sure outcome option and were asked to listen to a voice recording verbalizing the payoff information of these options. We manipulated the vocal pitch of the voice recordings and administered three treatment conditions: control, low-pitch, and high-pitch. We found that a higher-pitched voice increased risk aversion, while a lower-pitched voice raised risk tolerance. As a relatively small sample size was employed, the results should be considered preliminary; future replications are indeed necessary to confirm the robustness and generalizability of the findings.

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## 1. Introduction

In 2018, Elizabeth Holmes, founder and CEO of the currently defunct healthcare unicorn Theranos, was charged with fraud for exaggerating and lying about her low-cost illness detection device while raising $700 million from investors (Thomas and Abelson, 2018). The trick to her fraud partly lies in her effective communication skills, a carefully crafted and maintained persona, and an artificially deepened voice (Leskin, 2019). That voice was her trademark to gain trust from investors and employees in Silicon Valley, convincing them to work on and invest in her ideas. Through her lower pitch, for instance, she gained the trust of and convinced experienced venture capitalist Tim Draper and former Secretary of State Henry Kissinger to invest in her product, enabling her to become the world's youngest billionaire before the scandal exposing her fraud came to light (McKenna, 2018). This case provides anecdotal evidence on how vocal pitch can influence people's financial risk-taking.

Face-to-face and other verbal modes of communication contribute largely to people's daily interactions with others. In fact, advice from professionals and other individuals—such as financial consultants, doctors, lawyers, trustable friends, and family members—regarding risk decisions is often given verbally. Such interactions bring forth the importance and significance of voice because individual perceptions, and judgment are unavoidably influenced by speech cues, such as vocal pitch.

Prior studies in related fields, especially psychology, have shown that vocal pitch affects listeners' perception of speaker's personal traits and qualities. Lower-pitch voices are frequently associated with qualities such as credibility, tranquility, persuasion, attractiveness, trustworthiness, and maturity. In contrast, higher-pitch voices are often associated with immaturity, nervousness, and informality, and are perceived as less credible and less persuasive (Martín-Santana, Muela-Molina, Reinares-Lara, and Rodríguez-Guerra, 2015; Klofstad, Anderson, and Peters, 2012; Feinberg, Jones, Little, Burt, and Perrett, 2005; Chattopadhyay, Dahl, Ritchie, and Shahin, 2003). This pitch effect can be extended to influence learning effectiveness (Helfrich and Weidenbecher, 2011), career success (Mayew, Parsons, and Venkatachalam, 2013), the effectiveness of crisis and post-crisis management (Claeys and Cauberghe, 2014), court outcomes (Chen, Halberstam, and Yu, 2016), political behaviors (Klofstad, Anderson, and Peters, 2012; Tigue, Borak, O'Connor, Schandl and Feinberg, 2012), and even mating choices (O'Connor, Re, and Feinberg, 2011; Apicella and Feinberg, 2009; Puts, 2005). Hence, professionals tend to lower their voice pitch when giving expert advice, regardless of gender, as it is perceived as more authoritative and competent (Sorokowski et al., 2019).

Despite the varied studies on the influence of vocal pitch in related fields, very few studies have been devoted to exploring how pitch affects economic decision-making. Given that most economic transactions are facilitated through certain forms of verbal communication, it is thus important to understand how people's economic decisions and outcomes are affected by this seemingly neglectable environmental cue.

## 2. The Experiment

We measure risk attitudes using a lottery-choice task, consisting of 20 rounds. In each round, subjects make a binary choice between a safe (sure outcome) option and a 50–50 lottery option. Table 1 lists the payoffs of all 20 decision items that are presented to the subjects in a random order throughout the entire task. The payoffs of all lottery options are non-negative and up to S$15. The expected value of the lottery option is slightly lower or higher than that of the corresponding safe option.

A unique feature of our experiment is that the payoff information is conveyed to the subjects through audio clips in which a local male voice recorder verbalizes the two options.[1] In each audio clip, a one-second pause is used between each option so that the subjects can process the information. Within each round, subjects are asked to listen to the respective audio clip before making a decision. To prevent subjects from skipping the audio clips, payoff information is presented via the audio clip with no visual aid. Subjects are allowed to repeat the audio for full understanding.

The only manipulated variable in our experiment is the vocal pitch of the audio clips. In the Control condition, we play unedited audio clips with voice frequency of around 130–140 Hz. We use Audacity, a sound-editing software program, to adjust the vocal pitch of the voice recordings. This procedure ensures nearly ideal control of any other vocal characteristics that may help explain the observed treatment effect. In the low-pitch (hereafter, Low) and high-pitch (hereafter, High) treatments, we lower/raise the voice frequency by 10%, leading the voice frequency of the voice recording to range from 117 Hz to 126 Hz in the Low condition and 143 Hz to 154Hz in the High condition. A between-subject design is adopted to avoid the potential carryover and demand effects.[2]

Each session proceeds in the following manner. After arriving and signing the consent form, each participant is given a set of computerized instructions. The actual experiment starts once the participant completes a trial round with comprehension questions. After 20 rounds of the lottery-choice task, a post-experiment questionnaire is administered to collect information on (a) demographic characteristics; (b) the participants' emotions during the experiment, including if they felt engaged, bored irritated, anxious, and stressed; (c) their subjective evaluation of the voice recording, including maturity, trustworthiness, and naturalness; and (d) the rationale behind their decisions and their guesses about the objective of this experiment. Experimental materials are relegated in Online Appendix A. At the end of the sessions, one round in the lottery-choice task is randomly selected to implement the payment. Participants receive their payments before leaving the lab. The experiment is programmed and administered using Qualtrics.

## 3. Results

We conducted the experiment with a total of 92 undergraduate students at Nanyang Technological University with 30 or 31 subjects randomly allocated into one of the three conditions. All sessions were private. Each session lasted for approximately 15 minutes. Roughly half of the subjects were female, and nearly a quarter were economics or business majors.

We first compared the number of safe options chosen in the 20 rounds of the lottery-choice task: 10.33 (SD=3.50) in the Low condition, 12.03 (SD=2.80) in the Control condition, and 13.65 (SD=3.46) in the High condition. The effect size in terms of Cohen's d was 0.54 for the Low condition and 0.51 for the High condition, suggesting a medium-sized effect. Additionally, we performed the two-sided Mann–

[1] All decision items are read to subjects using a standard script: "Option A: 100% chance of receiving X dollars. Option B: 50% chance of receiving Y dollars and 50% chance of receiving Z dollars."

[2] Sample voice recordings for each of the three conditions can be found using the following link: https://drive.google.com/drive/folders/19xI6saLbbH734w9608VWJnj8cOG0TrLa

Whitney test; the p-value was 0.03 for Low vs. Control, 0.08 for High vs. Control, and less than 0.01 for Low vs. High. This result provides preliminary support for the treatment effect of vocal pitch on risk aversion; yet this aggregate measure still presented at least two complications: a) choosing a safe option in a decision item did not necessarily indicate risk-aversion if the safe option had an equal or higher expected value than that of the lottery option (i.e., $EV(A) \geq EV(B)$), and b) subjects could make inconsistent choices across decision items. For example, a subject could exhibit risk-loving by choosing the lottery option in item 1 but reversely exhibit risk-aversion by choosing the safe option in item 8. Similarly, choosing the lottery option in item 3 and the safe option in item 17 also produced inconsistency because the item 17 lottery option dominated that of item 3, even though both items share an identical safe option. Including observations from the subjects who either exhibited preference reversal or violated the non-satiation property in the analysis could lead to mistakenly rejecting the null hypothesis. Thus, we have illustrated the treatment effect by decision item and excluded such observations in the regression analysis to more cleanly identify the treatment effect.

Table 1 presents the treatment effect of vocal pitch by decision item. The decision items are categorized by the range of the risk-aversion parameter, assuming the CRRA (constant relative risk aversion) utility function, required to choose the safe option in the corresponding decision item. We compared the proportion of safe choices among the three treatment conditions for each decision item. A general pattern emerged: those in the High condition were more likely to choose safe options, followed by those in the Control condition; those in the Low condition were the least likely to choose safe options. Notably, the treatment effects were more pronounced among the decision items for which choosing a safe option required a higher level of risk-aversion (i.e., items 14–20). Overall, these results suggest that a higher-pitched voice increases people's risk-aversion, whereas a lower-pitched voice has the opposite effect.

We further performed OLS regressions to estimate the treatment effect of vocal pitch on risk aversion, as shown in Table 2. Column (1) depicts the results from regressing the total number of safe options chosen on the two treatment dummies only. If the subject was in the High (Low) condition, *High* (*Low*) takes the value of 1. Otherwise, it takes the value of 0. In Column (2), we further included *Female* (which equals 1 if the subject was female and 0 otherwise) and *EconMajor* (which equals 1 if the subject was an economics or business major and 0 otherwise) into the regression. Clearly, the regression results corroborate what we observed in Table 1. The coefficients of *Low* were significantly negative, and those of *High* were significantly positive, indicating that people are less risk-averse when the vocal pitch is lower and more risk-averse when the vocal pitch is higher. Consistent with the literature on the gender gap in risk preference (Eckel and Grossman, 2008), the coefficients of *Female* were positive and statistically significant.[3] To check whether the observed treatment effect was robust to the aforementioned issues regarding choice inconsistency, in Column (3), we modified the dependent variable into the number of safe options chosen among the 13 decision items, with $EV(A) < EV(B)$ (i.e., items 8–20), In Columns (4)–(6), we stepwise excluded the observations that involved choice inconsistency (see

[3] The existence of a riskless alternative in our design may help explain the gender difference in risk-aversion (Crosetto and Filippin, 2017; Filippin and Crosetto, 2016). Another side note worth mentioning is that we also examined the interaction effect between gender and treatment dummies, and none of the coefficients of the interaction terms were statistically significant. Given the small sample size in this study, the results provide some suggestive evidence that the treatment effect is similar for both genders.

Online Appendix B for the list of exclusion conditions employed). The coefficients of *Low* and *High* are qualitatively similar and statistically significant across all six specifications, providing further (and more robust) support for our main findings that people are less risk-averse when the vocal pitch is lower and more risk-averse when the vocal pitch is higher.

Some may argue that the modification of pitch might affect the naturalness of the voice in the treatment groups, influencing risk-taking. Indeed, Tamura, Kuriki, and Nakano (2015) investigated the effects of real and artificial voices on the human brain and showed that it can process the sense of humanness and generate more positive feelings toward the human voice. For this reason, we adjusted the voice frequency by 10% in the treated conditions to ensure the voice recordings still sound natural to subjects. We also asked subjects to rate for the naturalness of the voice in the post-experiment questionnaire, on a scale between 1 (*natural*) and 7 (*artificial*). The results from the pairwise Mann–Whitney test comparing the mean score suggest that no significant difference exists among the three conditions (p=0.48 for Low vs. Control; p=0.15 for High vs. Control; and p=0.47 for Low vs. High).[4] Hence, we can plausibly refute the possibility that the observed treatment effect was driven by the artificiality of the voices.[5]

Given that, we also elicited the emotions participants experienced in the experiment and their perceptions about the voice recordings. The data collected allowed us to perform mediation analysis–testing if any of these emotion/perception variables functioned as a channel through which vocal pitch influenced subjects' risk aversion. In particular, we have several ex ante conjectures: a) a higher-pitched voice may cause people to feel more anxious and stressed, leading to a higher level of risk-aversion (Cohn, Engelmann, Fehr, and Maréchal, 2015); b) a lowered-pitched voice sounds more mature and trustworthy, as evident in Tigue et al.'s (2012) study, which may increase people's risk tolerance; and c) research on paralinguistic cues has suggested that low pitch serves as a signal for boredom. The vocal range for low pitch is often associated with being monotonous (Carlson, Elenius, and Swerts, 2004) and tends to enhance situational boredom, resulting in riskier behaviors (Dahlen, Martin, Rayon, and Kuhlman, 2005). This psychological–emotional state would encourage participants to choose more lottery options.

We followed Baron and Kenny's (1986) approach by first regressing a potential mediating variable on treatment variables. If the coefficients of the treatment variables were significant, then we regressed the dependent variable on both the mediating variable candidate and the treatment variables. Finally, we observed whether the coefficients of the treatment variables obtained in the last step were smaller in absolute value than those in the regression, without including the mediating variable candidate. If so, the candidate was regarded as a mediating variable. We tested all of the emotion/perception variables collected, and only the trustworthiness and mature variables were significantly predicted by vocal pitch. Neither of these two candidates

[4] Cohen's d=0.24 for Low vs. Control, 0.43 for High vs. Control, and 0.18 for High vs. Low.

[5] We also checked whether the number of clicks per round differed among the three conditions and found, interestingly, that subjects on average had more clicks per round in the manipulated voice conditions than they did in the Control condition: the average number of clicks per round was 1.60 in the Control condition, 1.92 in the High condition, and 2.09 in the Low condition (using the two-sided Mann–Whitney test, the p-value was 0.02 for Low vs. Control, 0.16 for High vs. Control, and 0.49 for High vs. Low). One possible explanation is that the manipulation of vocal pitch reduces the clarity of the voice recordings, and subjects were thus more likely to replay the recordings.

passed the test in the final step. Overall, then, we did not find a mediating variable that could explain the observed treatment effect.[6]

## 4. Conclusion

In sum, we conducted an experimental investigation to test the effect of vocal pitch on risk aversion. We found that a higher-pitched voice increased risk aversion, while a lower-pitched voice raised risk tolerance. Before extrapolating policy implications from our results, we acknowledge a major limitation of the present study. Given the sample size of 30–31 per condition, we computed the power of our statistical tests based on two-sided t-test of the means for different effect sizes. At the 5% significance level, the power of finding a medium effect size (Cohen's $d \approx 0.5$) is approximately 0.5. As a power of 0.8 is typically considered acceptable, the present study is somewhat underpowered. This low statistical power issue can also lead to an increased risk of a false positive result (Gelman and Carlin, 2014). For this reason, the results reported in this study should be considered preliminary; future replications are indeed necessary to confirm the findings.

This limitation aside, our results suggest an alternative platform for policymakers or practitioners seeking to influence people's risk behaviors through a subtle change in vocal pitch in oral communication. For example, when a financial company plans to make hiring decisions related to selling risky financial products, agents with a lower vocal pitch should be tasked with helping convince clients to purchase risky assets. Additionally, vocal training may be effective for individuals to change the perception and impact of their voices, depending on each risk situation involved.

Besides risk preferences, future research can look into the relationship of pitch on other aspects of economic decision-making. For example, studies can research the effect of pitch on pro-social behavior of individuals with activity requiring social interactions or verbal communication, such as when volunteering or donating. Apart from research on the vocal pitch, it may be interesting to explore the effects of other characteristics, such as how tone affects economic decision-making and the interaction effects upon combining different vocal characteristics. Such research would allow for exploring the power of voice in a plethora of decision-making opportunities from an economics perspective, which is a less examined topic in economics literature to date.

[6] A related question correctly pointed out by one reviewer is whether the observed effect of vocal pitch is driven by changes in people's risk perception or risk preference per se. Although our current design does not allow for further analysis to tease out the underlying mechanism, future research can explore these issues to gain a fuller understanding of the processes that underlie the pitch effect.

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**Table 1 The Treatment Effect of Vocal Pitch on Risk Aversion by Decision Item**

| Item | Option A | Option B | EV(B)-EV(A) | CRRA Parameter | % of Safe Option | | | P-value, proportion test | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Low | Control | High | L vs. C | H vs. C | L vs. H |
| 1 | $6 | ($1, $9) | -$1.0 | <0.1 | 96.67% | 93.55% | 96.77% | 57.34% | 55.40% | 98.12% |
| 2 | $7 | ($0, $12) | -$1.0 | <0.1 | 90.00% | 96.77% | 100.00% | 28.53% | 31.34% | 7.10%* |
| 3 | $4 | ($1, $6) | -$0.5 | <0.1 | 93.33% | 96.77% | 96.77% | 53.44% | 100.00% | 53.44% |
| 4 | $5 | ($2, $7) | -$0.5 | <0.1 | 86.67% | 96.77% | 100.00% | 15.02% | 31.34% | 3.54%** |
| 5 | $7 | ($4, $9) | -$0.5 | <0.1 | 83.33% | 100.00% | 77.42% | 1.77%** | 0.50%*** | 56.13% |
| 6 | $4 | ($1, $7) | $0.0 | <0.1 | 90.00% | 87.10% | 90.32% | 72.21% | 68.82% | 96.63% |
| 7 | $7 | ($4, $10) | $0.0 | <0.1 | 76.67% | 80.65% | 80.65% | 70.44% | 100.00% | 70.44% |
| 8 | $7 | ($2, $13) | $0.5 | <0.1 | 56.67% | 80.65% | 83.87% | 4.32%** | 73.96% | 1.99%** |
| 9 | $6 | ($5, $8) | $0.5 | <0.1 | 6.67% | 9.68% | 16.13% | 66.83% | 44.86% | 24.64% |
| 10 | $5 | ($4, $7) | $0.5 | <0.1 | 13.33% | 9.68% | 25.81% | 65.42% | 9.65%* | 22.05% |
| 11 | $3 | ($2, $5) | $0.5 | <0.1 | 13.33% | 16.13% | 22.58% | 75.82% | 52.03% | 34.76% |
| 12 | $5 | ($3, $9) | $1.0 | <0.1 | 13.33% | 29.03% | 22.58% | 13.44% | 56.16% | 34.76% |
| 13 | $4 | ($2. $8) | $1.0 | 0.1~0.3 | 23.33% | 32.26% | 35.48% | 43.70% | 78.84% | 29.82% |
| 14 | $5 | ($1, $10) | $0.5 | 0.1~0.3 | 60.00% | 77.42% | 90.32% | 14.19% | 16.72% | 0.60%*** |
| 15 | $3 | ($0, $7) | $0.5 | 0.1~0.3 | 66.67% | 64.52% | 90.32% | 85.97% | 1.51%** | 2.41%** |
| 16 | $7 | ($1, $15) | $1.0 | 0.1~0.3 | 53.33% | 64.52% | 83.87% | 37.46% | 8.16%* | 1.00%** |
| 17 | $4 | ($1, 8) | $0.5 | >0.3 | 46.67% | 74.19% | 70.97% | 2.78%** | 77.59% | 5.37%* |
| 18 | $5 | ($1, $12) | $1.5 | >0.3 | 36.67% | 45.16% | 70.97% | 50.00% | 3.95%** | 0.72%*** |
| 19 | $3 | ($1, $7) | $1.0 | >0.3 | 13.33% | 22.58% | 48.39% | 34.76% | 3.37%** | 0.31%*** |
| 20 | $4 | ($1, $10) | $1.5 | >0.3 | 13.33% | 25.81% | 61.29% | 22.05% | 0.48%*** | 0.01%*** |

*Notes:* The table presents the proportion of safe option chosen among treatment conditions for each decision item. Option A represents the safe option while Option B represents the 50-50 lottery option. All amounts are in Singapore dollars. EV(B)-EV(A) indicates the difference in expected value between the two options. CRRA category indicates the range of the risk-aversion parameter, assuming the CRRA utility function, required to choose the safe option in the corresponding decision item. We report the p-values from the two-sided proportion tests pairwise comparing the proportion of safe option among the three conditions. *** p<0.01, ** p<0.05, * p<0.1.

## Table 2 Regression Results

| Dependent variable | (1)<br>*No. of Safe_20* | (2)<br>*No. of Safe_20* | (3)<br>*No. of Safe_13* | (4)<br>*No. of Safe_13* | (5)<br>*No. of Safe_13* | (6)<br>*No. of Safe_13* |
|---|---|---|---|---|---|---|
| *Low* | -1.6989** | -1.7206** | -1.3730** | -1.5219** | -1.8656** | -2.1411** |
| | (0.8362) | (0.8225) | (0.6780) | (0.7485) | (0.8739) | (0.9177) |
| *High* | 1.6129* | 1.6673** | 1.7907** | 2.0530*** | 1.7994* | 1.6440* |
| | (0.8292) | (0.8197) | (0.6757) | (0.7655) | (0.9008) | (0.9269) |
| *Female* | | 1.5692** | 1.7916*** | 2.1966*** | 2.1966*** | 2.1777*** |
| | | (0.7020) | (0.5786) | (0.6575) | (0.7600) | (0.7858) |
| *EconMajor* | | -0.5622 | -0.8372 | -1.0631 | -1.3741 | -1.2934 |
| | | (0.8407) | (0.6929) | (0.7601) | (0.8597) | (0.9105) |
| Constant | 12.0323*** | 11.3818*** | 4.8113*** | 4.6722*** | 5.0431*** | 5.1787*** |
| | (0.5864) | (0.6644) | (0.5476) | (0.5918) | (0.7201) | (0.7372) |
| Exclusion condition | No | No | No | E1 | E2 | E2–E12 |
| No. of observations | 92 | 92 | 92 | 77 | 63 | 60 |
| Adjusted $R^2$ | 0.1307 | 0.1591 | 0.2233 | 0.2470 | 0.2489 | 0.2597 |

*Notes:* OLS estimates. Standard errors are reported in parentheses. The dependent variable is the number of safe options chosen across all 20 items in Columns (1)–(2) and across items 8–20 in Columns (3)–(6). *High*/*Low* refers to the treatment dummy that equals 1 if the participant was in the High/Low condition and 0 otherwise. *Female* is a gender dummy that equals 1 if the subject was female and 0 otherwise. *EconMajor* is a dummy that equals 1 if the subject was an economics or business major and 0 otherwise. In Column (4), we exclude those who chose at least one lottery option among items 1–5 (indicating risk-loving) but then chose at least one safe option among items 6–20 (indicating either risk-neutrality or risk-aversion). In Column (5), we exclude those who chose at least one lottery option among items 1–7 (indicating either risk-loving or risk-neutrality) but then chose at least one safe option among items 8–20 (indicating risk-aversion). In Column (6), in addition to the exclusion condition employed in Column (5), we further exclude those who violated the non-satiation property. Please refer to Online Appendix B for the list of exclusion conditions (i.e., E1–E12) employed in the regression analysis. *** p<0.01, ** p<0.05, * p<0.1.