Effects of noise on risky decision making and decision confidence

Marc Syndicus[1] & Bettina S. Wiese[1]

[1] RWTH Aachen University, Personnel and Organizational Psychology, Aachen, Germany

Corresponding author's e-mail address: marc.syndicus@psych.rwth-aachen.de

ABSTRACT

Nearly half of the European workforce is working in an office or office-like environment. While the detrimental influence of some workplace stressors (e.g., time pressure) on our decision making behavior has repeatedly been shown, it remains unclear whether noise impairs decision making, too.

Study 1 (N = 97) employed a lottery task, the Balloon Analogue Risk Task and two risk scenario questionnaires (Choice Dilemma Questionnaire and Risk Scenario Questionnaire). The tasks were performed while being exposed to one of three noise stressors presented at 60dB(A) or in a quiet condition. Compared to the other conditions, a radio podcast sound-file caused a significant increase in risk aversion in the CDQ task.

Study 2 (N = 48) involved three decision tasks. In the first two tasks, participants answered trivia questions and were required to state the confidence they place in their decisions. The third task surveyed the probabilities participants assign to various negative events like accidents or risk of illnesses, incorporating a confidence judgment after each question. Participants completed these tasks either in an office noise condition or a quiet control condition.

INTRODUCTION

Since the beginning of the 20th century, a shift from blue collar work towards white collar work took place. Today, nearly half of the employees fulfill their tasks in offices or office-like environments. Regarding the German labor force, this corresponds to about 17 million people. Especially if work is performed in multi-person and open-plan offices, a variety of workplace stressors related to the indoor environment occur. Among these stressors, noise has been one of the most often complained about disruptive factor [1, 2].

Besides being considered as annoying, noise seems to be able to impair performance as well. Meta-analytic results confirm that this holds true for basic cognitive abilities like mental arithmetic, rote learning or vigilance tasks [3]. The magnitude of impairment nevertheless depends on factors like noise type, intensity, duration as well as the task at hand and the performance measure applied. What remains mostly unclear is whether decision making involving risk or uncertainty is impaired by noise as well.

Risky decision making describes the propensity of individuals to take or avoid risks. Risk taking behavior seems to be highly domain-specific, which means that intra-individual variation can be noticed. It is therefore common to observe that some people reveal risk propensity in the health domain (e.g., driving recklessly), while showing a strong risk aversion in other fields (e.g., regarding investment and gambling decisions in the financial domain).

In order to account for this variety in risk taking, we employed three different tasks in study one. The tasks utilize different risk elicitation methods and had different emphasizes regarding the aforementioned risk domains. The Holt & Laury Lottery requires decisions under risk, probabilities of the outcomes are depicted. Decision making under uncertainty was measured with two scenario tasks (Choice Dilemma Questionnaire, Risk Scenario Questionnaire) and the Balloon Analogue Risk Task (BART).

Stress and Decision Making

Morgado, Sousa and Cerqueira (2015) [4] reviewed the effects of stress and showed that it increases risk prone behaviors. Starcke and Brand [5] also describe detrimental effects of stress on decision making, leading to more risk taking in specific and disadvantageous decisions in general. The concept of ego depletion can serve as an explanation for this reaction to stressors. When the limited resource of self-control is depleted before a risk taking task, subjects reveal higher risk taking behavior [6]. This may be due to a reduced willingness to evaluate the consequences of risky decisions, therefore underestimating their possible threats. This effect is also known as premature closure or satisficing [7], which describe taking a decision after considering only a few decision alternatives, often observed in situation of stress (e.g., time pressure). Another possible mechanism is the somatic marker hypothesis, formulated by Damasio (1994) [8]. It describes the negative “gut feeling” we experience when we face decisions with potentially negative outcomes. It does not prevent the decision maker from overriding or ignoring this feeling, but it initially creates a cautious state of risk aversion. When being exposed to a stressor like noise, we may confuse the arousal with these somatic signals. This, in turn, could lead to an attenuation of this “warning mechanism”.

STUDY ONE: DECISIONS UNDER RISK AND UNCERTAINTY

Study one was conducted to test whether noise impairs decisions under risk and uncertainty. Based on the abovementioned findings, the main hypothesis is that noise causes an increase in risk proclivity. A more detailed description of the experiment can be found in Syndicus, Wiese and van Treeck [9].

Method

Noise Conditions

A total of 88 participants (65 female) with a mean age of M = 22.3 (SD = 3.3) completed three different risk tasks in one of three noise conditions or in a quiet control condition. For the noise conditions, three different sound files were presented via headphone: (1) An office noise including sounds emitted by air conditioning, office machines and occasional telephone rings, (2) a podcast featuring a discussion about a five year jubilee of museums in the Rhine-Ruhr metropolitan region, and (3) a similar discussion podcast about the outbreak of the Ebola virus (All soundfiles are available upon request from the first author). The sound files (2) and (3) were employed to vary the semantic relevance for risky decisions. It was assumed that the “Museum” sound file has no association with risky decision making in this regard, while the “Ebola” file might reveal such associations due to the dangerous, threatening topic. All sound

files were present with a sound pressure level of 60 dB[A], measured at the ear-pad outlet of Sennheiser HD 25-1 headphones. The average exposure time was about 45 - 50 min, depending on how much time subjects needed to complete the tasks.

Risk Tasks

The Holt & Laury lottery task [10] can be used to examine decision making under risk, i.e. with known probabilities. Participants are required to make ten paired lottery decisions with varying payoffs, depicted in Table 1. The payoff differences are positive for Option A from row one to four, the risk neutral subject is expected to switch to Option B in the fifth row. Risk seeking subjects switch to the B options earlier, while risk averse subjects choose the A options on the left side more often. Risk taking is therefore operationalized as the average switching point.

Table 1: Chances, payoffs and systematic variation of the Holt & Laury lottery.

Row	Option A	Option B
1	0.1 of 2.00 €; 0.9 of 1.60 €	0.1 of 3.85 €, 0.9 of 0.10 €
2	0.2 of 2.00 €; 0.8 of 1.60 €	0.2 of 3.85 €, 0.8 of 0.10 €
3	0.3 of 2.00 €; 0.7 of 1.60 €	0.3 of 3.85 €, 0.7 of 0.10 €
[…]	[…]	
10	1.0 of 2.00 €; 0.0 of 1.60 €	1.0 of 3.85 €, 0.0 of 0.10 €

In the Balloon Analogue Risk Task (BART) [11], subjects can collect small amounts of money by inflating a balloon on the computer screen. Each mouse click corresponds to one pump stroke, and is rewarded with 0.10 €. The actual lifetime of the balloon is randomly drawn from a normal distribution and remains unknown to the subject. Three balloon types are presented, with average lifetimes of 4, 16, and 64 clicks and a corresponding color. The money can be transferred to a safe account as long as the balloon is intact; if it bursts, the money of the trial is lost. Subjects face the conflict of collecting money by applying many clicks, while at the same time increasing the risk of destroying the balloon (and therefore losing the money collected so far).

The third task involved two risk scenarios. In the Risk Scenario Questionnaire [12], 20 risky behaviors are described (e.g., sunbathing without sun cream or stating publicly that one's own taste in music differs from that of a peer group). Subjects rated their propensity for engaging in the described behaviors on a ten-level scale, with 0 = *"total avoidance"* and 9 = *"nearly certain engagement"*.

Comprising twelve scenarios, the Choice Dilemma Questionnaire [13] involves situations in which a protagonist is facing various two-alternative decisions (e.g., whether to undergo surgery or not, make a job change from a mediocre but safe position to an attractive but unsafe occupation in a start-up company). Subjects were invited to state minimum probabilities of success that should be met in order to recommend the protagonist to choose the risky alternative. Answers could be given on a scale ranging from 10% to 90% in steps of ten, while a certainty option (100%) was excluded. A higher percentage represents greater risk aversion.

All tasks were presented on a PC using the Psychological Experiment Building Language (PEBL) [14].

Results

There were only minor differences regarding the switching point in the lottery task. The overall ANOVA was not significant, $F(3,84) = 0.44$, $p = .73$. Subjects in the Ebola condition showed a decreased risk proclivity with an average switching point of $M = 5.8$ (choosing the safe options more often), while subjects in the office noise condition revealed a small increase in risk proclivity, $M = 5.1$.

Regarding the BART task, there were no significant differences between the four conditions. A comparison of the combined speech noise conditions with the control and office noise condition revealed that speech noise caused a slight risk aversion. The amounts of money collected were $M_{Control} = 54.8$ €, $M_{Office} = 56.5$ €, $M_{Speech} = 47.5$ €, $F(2,85) = 1.78$, $p = .17$.

An overall comparison (ANOVA) of the CDQ results showed no significant difference, $F(3, 84) = 1.33$, $p = .11$. A gender specific comparison revealed a significant difference for the female participants, $F(3, 61) = 3.39$, $p = .02$, $\eta_p^2 = .14$. Post hoc tests indicated that this result is presumably caused by the difference of the control condition ($M = 5.6$) and the Museum noise ($M = 6.5$), $t(30) = 2.8$, $p = .01$, $d = .56$.

Brief Discussion

The three noise conditions revealed only marginal effects on subjects' decision making behavior. Against our hypothesis, participants showed a tendency towards risk aversion instead of risk proclivity. This shift in decision making was significant for female participants when comparing the CDQ results of the control condition and the Museum noise condition. The required probability of success before recommending the risky alternative were $M = 5.6$ and $M = 6.5$, respectively, which corresponds to percentages of 56% and 65%. While the risky decisions involving oneself were mainly unaffected, a higher risk aversion could be observed when the participants faced decisions affecting another person.

STUDY TWO: DECISION CONFIDENCE AND SATISFACTION

Decision confidence can be described as the strength of belief about the correctness of a prediction or judgment. Confidence and satisfaction focus the post-decision evaluation by the decision maker, while the quality of the decision (how good or bad; if applicable: how close to the true answer an estimation is) is of lesser interest. Although the quality of the decision is relevant in terms of performance evaluation, it seems worthwhile to scrutinize this post-decision evaluation to gain further understanding of this process and how it affects the decision maker's feelings. It is conceivable that wellbeing, satisfaction and confidence are influenced by an averse environment in which the decision is reached, while leaving the decision quality mostly unimpaired.

Previous research shows that occasionally a higher decision confidence can be observed if decision are taken under stress [15, 16]. As explanatory mechanisms, the premature closure and satisficing concepts can be applied. Being exposed to noise, resources are needed in order to cope with this stressor. The remaining attentional and motivational resources to conduct a comprehensive evaluation of decision alternatives are reduced [17].

We hypothesized that participants in the noise condition show higher levels of decision confidence. Furthermore, noise is expected to increases subjects' feelings of psychological strain. Lastly, we expect that noise impairs the satisfaction with and evaluation of the decisions.

Method

Noise condition

We employed the same office noise that has been described in the method section of study one. Exposition duration was about 40 min. Subjects completed the tasks in the quiet (*N* = 22) or office noise condition (*N* = 26). The mean age of the participants was *M* = 23.4 (*SD* = 5.2).

Decision Confidence Tasks

We employed three different types of tasks to probe the decision confidence. In the Calibration Task [18], subjects answered 60 trivia questions with two answer options, for example: "*Which river is longer? A: Mississippi or B: Ganges?*". After each question, the degree of certainty has to be stated. One of five categories could be selected: 50%-59%, indicating uncertainty or guessing, 60%-69%, 70%-79%, 80%-89% or 90-100%, the last category indicating certainty or near certainty about the correctness of the answer. The overall confidence can be obtained by averaging the certainty statements of all 60 tasks or analyzing how often each of the five percentage categories were chosen. The number of correct answers in this task is not of primary interest. It nevertheless serves as a control variable to exclude general knowledge as a confounding variable.

Another approach to obtain confidence judgments is the Interval Production Task [19]. Subjects are required to estimate various numbers, for example the travel distance between two cities or how much water is needed to grow a kilogram of tomatoes. A total of 45 questions were presented. In order to answer these questions, an interval can be stated in which the correct answer is expected to be located. Subjects entered these lower and higher boundaries in two corresponding boxes depicted on the computer screen. A higher decision confidence is represented by choosing a narrow interval.

It is not feasible to directly compare the differences between the upper and lower boundary. An example might clarify this: If subject A estimates the distance between two cities ranging between 100 and 110 km, while subject B states 300 and 310 km, the absolute difference of higher and lower boundary is 10 km in both situations. Nevertheless, Subject B seems to be more confident, since his/her interval estimate is smaller compared to the lower boundary (10/300 for B, 10/100 for A). We calculated an index in order to take these range differences into account. The formula is depicted in Equation 1 (with x_1 denoting the lower, x_2 denoting the upper interval boundary).

$$Index_{Range} = \frac{x_2 - \left(\frac{x_1 + x_2}{2}\right)}{\left(\frac{x_1 + x_2}{2}\right)} \quad (1)$$

The third task involved the estimation of subjective probabilities [20], for example the probability of being involved in a car crash or the risk of dying while skydiving. This task was employed to elicit absolute probability estimates regarding averse events. After each question, the confidence placed in the answers could be rated on a scale ranging from 1 = *"very uncertain"* to 6 = *"very certain"*.

Measures of Psychological Strain and Post Decision Satisfaction

In order to measure the psychological strain, we employed the "Scales of Psychological Strain" (German: "BMS Beanspruchungsmessskalen" [21]). It comprises the four subscales

positive mood, fatigue, monotony and psychic satiation. Subjects rated how well twelve adjectives (e.g., tired, bored, angry) represent their current feelings/mood on a scale ranging from 1 = *"not at all"* to 6 = *"very well"*, and answered these questions before and after completing the three tasks.

At the end of the testing session, an overall judgment regarding post decision satisfaction was obtained. Six items from the Decision Attitude Scale by Sainfort and Booske [22] were used, and participants were instructed to base their judgment on all three decision tasks. Subjects rated their satisfaction with their decisions, how difficult it was to make the decisions or if they wished somebody else would have taken the decisions for them. The scales ranged from 1 = *"completely disagree"* to 6 = *"totally agree"*. A brief description of the items can be seen in Table 2.

Results

Based upon power analysis (assuming a medium effect size of d = .50), the required sample size was estimated to be N = 80. The following results must therefore be considered as preliminary.

Calibration Task: Participants in both conditions revealed overconfidence, which means that they overestimated the probability that their answers were correct. The lower two confidence categories were chosen more often by subjects in the control condition, while the other three categories have been selected more often by subjects in the noise condition. Differences in category selection frequency were significant for the 50%-59% category, $t(46) = 1.90$, p = .03, and the 80%-89% category, $t(46) = 1.74$, p = .05.

Figure 1 depicts how often the five confidence categories were chosen. The mean confidence rating stated in all 60 questions was $M_{Control}$ = 64.2% and $M_{Office\ noise}$ = 67.1%. Participants in the office noise condition were significantly more confident, $t(46) = 1.84$, p = .04, d = .53.

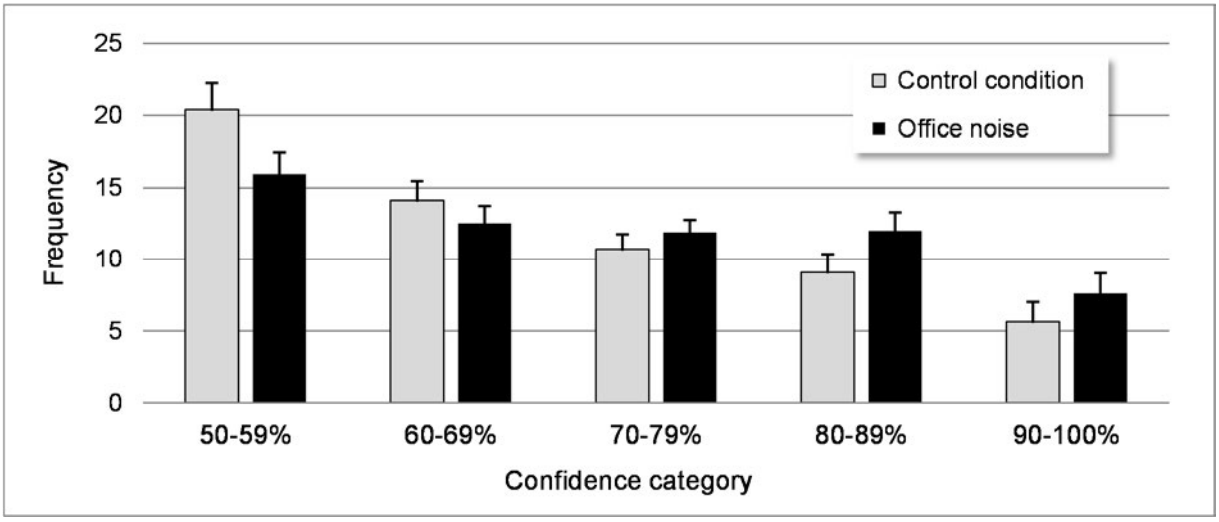

Figure 1: Confidence category selection. Error bars represent the standard error of the mean.

Interval Production: The comparison of the range index values (cf. Equation 1) revealed a significant difference, $t(46) = 1.89$, p = .03, d = .55. Participants gave larger interval estimates in the quiet control condition ($M_{Range\ index}$ = 27.5), which represents a lower level of confidence compared to the interval estimates of the noise condition ($M_{Range\ index}$ = 22.1).

Subjective probabilities: While there were no significant differences in terms of the decision quality (i.e., how close participants' estimations of the various probabilities have been relative to the true value), we observed a significant difference with regard to the confidence ratings. Averaged across the 20 questions, the mean ratings were $M_{\text{Control}} = 2.77$ and $M_{\text{Office noise}} = 3.10$, $t(46) = 1.66$, $p = .05$, $d = .48$.

Regarding the psychological strain, participants in both conditions revealed a decrease in positive mood, $F(1,46) = 5.86$, $p = .02$. A marginally significant interaction revealed that the decrease was stronger in the noise condition, $F(1,46) = 3.23$, $p = .07$. Fatigue increased in the noise condition and decreased in the quiet condition, but the overall effect was not significant. The same pattern could be observed for the subscale monotony (increase in the noise condition, decrease in quiet condition), but with nonsignificant differences as well. The analysis of psychic satiation revealed a significant effect, $F(1,46) = 6.69$, $p = .01$. Although the increase of feeling satiated was stronger for the noise condition, this interaction was not significant, $F(1,46) = 2.04$, $p = .15$.

Table 2 summarizes the differences for the six items from the Decision Attitude Scale. There was only a significant tendency regarding the item about subjects' consideration of how good their decisions were (item 3). The participants in the noise condition seemed to be less satisfied with their decisions (item 1), had more difficulties in taking the decisions (item 2), reported lower needs of consultation with others (item 5) and revealed a higher urge that someone else should have taken the decisions for them (item 6).

Table 2: Mean values, standard deviations (in brackets) and significance values of the mean differences for the six items of the Decision Attitude Scale.

Item description	M_{Control}	$M_{\text{Office noise}}$	*p*-value
1. Satisfaction with decisions	3.50 (0.96)	3.27 (0.87)	.39
2. Difficult to take the decisions	4.27 (1.20)	4.42 (1.06)	.65
3. Considering the decisions as good	3.14 (0.94)	2.69 (0.88)	.09
4. More Information would have helped	5.04 (1.04)	4.96 (1.07)	.79
5. Consultation with others would have helped	4.91 (0.87)	4.42 (1.44)	.17
6. Somebody else should have taken the decisions	2.18 (0.85)	2.50 (1.17)	.29

Brief Discussion

In general, there were no significant differences regarding the decision quality (i.e. correct answers or how good the probability estimates have been). Subjects in both conditions revealed overconfidence, a common finding in confidence tasks [23], but they did not differ significantly in this regard.

At first glance, this could lead to the assumption that decision making rests unaffected when a noise stressor is present. On closer inspection, changes in decision confidence and psychological strain could be observed. Participants in the noise condition reported higher levels of decision confidence in all three tasks, while at the same time decreases of positive mood and increases in psychic satiation were reported in the noise condition.

GENERAL DISCUSSION & CONCLUSION

It could be shown that decision making and confidence can be affected when noise is present. The impact seems to be depending on the semantic content of the unwanted sound, and whether decision are made for ourselves or on behalf of others. In study one, female participants revealed a significant increase in risk aversion when taking decisions for other people. We observed an increased decision confidence in the noise condition for all three tasks employed in study two. This finding is in line with prior research about decision making in stressful situations [15, 16]. It appears that these findings, mostly reported with time pressure as the main stressor, can also be applied to an office noise stressor.

The Process of Decision Making

Problems may arise due to the complexity of decision making. Process models by Weber and Johnson [24] and Schiebener and Brand [25] show that various sub-processes are involved before a decision is reached. This involves the stage of information encoding (perception), the influence of memory effects as well as emotion and affect. Decision making can also be systematically influenced by characteristics of the decision maker, for example gender, age, personality or specific decision making styles (e.g., rational, intuitive or dependent). Furthermore, decision making behavior can be expected to change over time. Experience and learning effects may alter preferences or decision making styles.

Potential Limitations

Regarding ecological validity, we identify two major drawbacks. First, the samples comprised rather young student participants, which limits the generalization of the results to workforce members. Second, the exposition to noise lasted only 40 – 45 min. It remains to be tested whether noise exposition for longer periods would intensify the observed effects. Alternatively, habituation to the sound stressor could occur and mitigate the effects. Lastly, the results have to be considered preliminary until the predicted number of participants has been tested.

Conclusion

In sum, it could be shown that office noise has the potential to influence our decision making behavior, especially when risk and uncertainty are involved. Even if the quality of the decision may remain unimpaired at first glance, effects on psychological strain and post decision evaluation can occur. Especially elevated decision confidence can be a result of premature closure and satisficing. It can be argued whether noise effects should be of concern if they do not impair the objective decision quality, as shown in study two. But taking this perspective would lead to a neglect of impaired wellbeing or the increase in psychological strain, which are not easy to detect at first glance. Over the last years, there has been considerable effort to incorporate findings from behavioral decision making into policy making, investment and health decisions [26]. Fostering research in the field of workplace stressors and decision making might therefore provide helpful knowledge and advice not only to office workers harassed by noise, but also the general public.

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