The Effect of Audience Response on Heart Rate Variability in Public Speaking

Emma Vooijs

S3662705

Department of Psychology, University of Groningen

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Supervisor: Dr. Mark M. Span

Second evaluator: Dr. Pieter de Vries

In collaboration with: Aili Claus, Ryan Kooi, Ilse Rodermond, Mandy Verhoef, Irene Versteegh

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Abstract

Public speaking is a well-established stressor, and this study aims to establish if how an audience responds to a presentation may influence a person's stress physically, psychologically, or both. A between-subjects design was used with participants (N = 27) being assigned to either an unsupportive or supportive audience while simultaneously measuring the participants heart rate and giving stress questionnaires at set intervals. The results show a non-significant effect between conditions. However, deeper analysis reveals a trend of increased stress in the unsupportive condition and calls the reliability of the stress questionnaire into question. Future research would benefit from a larger sample group and an alternative measure of psychological stress.

Keywords: Public speaking, stress, heart rate variability , audience response

The Effect of Audience Response on Heart Rate Variability in Public Speaking

As we currently know it, public speaking anxiety is believed to clinically affect anywhere from 15% to 30% of the general population (Pull, 2012) and yet it is something a majority of us have had to do as part of our work or education. We are well acquainted with the fear and everything it brings with it; a raised heart rate, sweaty palms, and a tight chest etc.. As this study aims to look at stress, it is important to note here the differentiation between stress and anxiety; stress tends to be specific, acute, and related to an external trigger while anxiety tends to be non-specific, chronic, and related to an internal trigger (APA, 2019). Public speaking in many forms is practically unavoidable, and so this study allows us to ask ourselves if the way an audience responds to a speaker can affect the speaker's level of stress.

Stress response

The autonomic nervous system, more specifically the sympathetic nervous system, is involved in possibly the best known stress response; *fight or flight* (Cannon, 1915). Fight or flight is a response to a threat in which the body tells us to either attack the threat or flee it. This response is triggered alongside the sympathetic nervous system, leading to various physiological responses including an increase in respiration, an increase in heart rate, and a rush of adrenaline. All of these responses prepare the body to react quickly regardless of which response is chosen, i.e., to either attack quickly or run quickly. The model tells us that this activation of the sympathetic nervous system would lead to a reduction in heart rate variability as the body prepares itself to respond to the threat before it. Additionally, Britton, Kavanagh, and Polman (2019) reported that you do not need a physical threat to have a stress response. Rather, perceived stress is also linked to the physiological stress response. Both physiological (e.g., pain) and psychosocial (e.g., exclusion) stressors present with similar

physiological stress responses (Kogler et al., 2015). As such we expect to see this reflected in this study.

Heart rate variability

McCraty and Shaffer (2015) define heart rate variability as the fluctuation in the time intervals between adjacent heartbeats. Normal heart rate variability (HRV) is modulated by the sympathetic and parasympathetic nervous system, parts of the autonomic nervous system (Berntson et al., 1997), along with heart rate, blood pressure, digestion, and breathing (WebMD, 2021). In other words, HRV is an involuntary and autonomous response to the demands of the multiple internal systems a person has. A healthy heart rate should show a certain amount of variation; a healthy heart is not a metronome (Shaffer et al., 2014, title). HRV indicates that your heart has the ability to adapt to an ever changing environment (Beckers, 2005) and by its very nature, HRV can be affected by factors ranging from simply breathing to age or disease (WebMD, 2021). A consistently low HRV implies current or future issues with health as it shows the body is less resilient and handles change poorly (Cleveland Clinic, 2021) due to the dominance of one system, for example, the sympathetic nervous system during fight or flight (Cannon, 1915).

Due to its high test-retest reliability (Bertsch et al., 2012), HRV is a frequently used measure of stress. It is a commonly held view that high stress leads to a high heart rate, but less discussed is the concept of HRV. Simply put, the more stress a person is under, the less variation seen in the time between each heartbeat (Perira et al., 2017; Appelhans & Leucken, 2006).

Public speaking as a stressor

Oldehinkel et al. (2011) used a public speaking task to measure the association between psychological stress measures and physiological stress measures. Included in the physiological measure were heart rate and cortisol levels, which was compared to

measurements taken by the Self-Assessment Manikin (SAM) as the psychological measure of stress. Heart rate and cortisol levels were found to be significantly correlated with perceived arousal, suggesting perceived stress can indicate physiological stress responses. Overall it was found that the speaking task was associated with greater levels of perceived stress, a higher heart rate, and high cortisol levels establishing public speaking as a stressor. Further studies have also found that audience response can influence the speaker's HRV (Lepore et al, 1993), specifically that there is indeed a difference in stress levels when presented with a positive or negative audience (Hilmert et al., 2002). This experiment aims to add to this existing literature.

The experiment

The goal of this study is to investigate if heart rate variability and perceived stress levels are influenced by audience response in a public speaking setting. As such, there are three main hypotheses:

1. Heart rate variability will decrease when self-perceived stress increases.
2. Heart rate variability correlates with self-perceived stress.
3. A negative audience response correlates with higher stress levels than a positive audience response.

Method

Participants

This study had a total of 27 participants with 7 males and 20 females, with a mean age of 19 years and 6 months. Majority of students were recruited via SONA, a research participant pool from University of Groningen used by first year students. Secondary were participants recruited by the researchers, such as family and friends. All participants gave

informed consent, with students recruited by SONA still obtaining credits regardless of participation to avoid influencing consent.

Instruments and materials

The instrument used to measure heart rate (HR) was the Polar H10 Band. Buist (2022) found the Polar band to be highly accurate regardless of movement. Participants were given an A4 notebook to use for drafting their speeches. The lab streaming layer protocol (Kothe & Makeig, 2013) was used to match the ECG reading to timestamps of the experimental phases.

Experimental procedure

The experiment took place in the in the Faculty of Behavioral and Social Sciences of the University of Groningen with all participants being tested in the same room. For each session there was one participant with at least 4 researchers as audience members. All participants were led through the same procedure (see Appendix B) and each session took approximately the same amount of time (1 hour). Researchers alternated between conditions, giving one participant a supportive response and the following participant an unsupportive response. Following this alternating pattern was to ensure as equal distribution of audience responses as possible.

Experimental manipulation

The experimental design was between-subject testing two conditions; a positive audience response (supportive) or a negative audience response (unsupportive). The supportive audience appeared interested, smiled, and clapped for the participants during their speech. Conversely, the unsupportive audience appeared bored, focused on other things such as phones or out a window, and did not clap. In case participants stopped talking before the 5 minutes were complete, the researchers encouraged them to finish in accordance with the assigned audience response. In the supportive response group, they were asked to elaborate on certain points. In the unsupportive response group, the researchers bluntly stated the

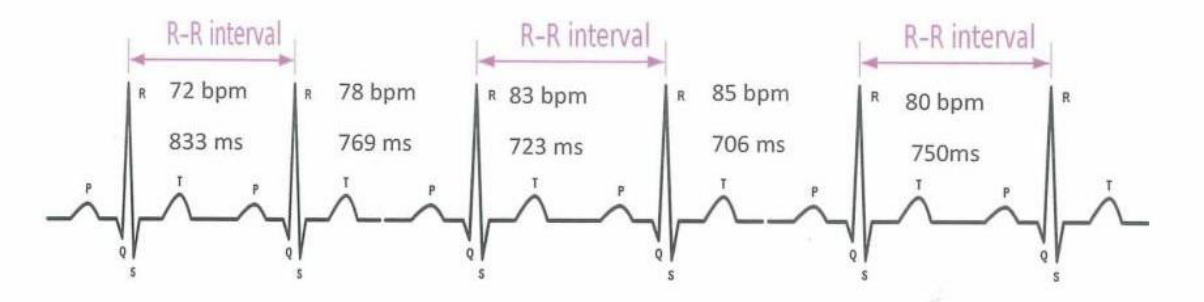
amount of time the participant still had to fill. Additionally, participants were led to believe that they were being recorded by way of having a camera (JVC model GZ-MG335HE) with a red light pointed at them and their image projected onto a large screen within their view. Participants were asked during the debrief if they believed they were being recorded and if they felt the audience response affected their self-perceived stress levels.

Measures

The two measures used in this experiment were heart rate variability (HRV) and a self-perceived stress questionnaire. The parameters used to describe HRV were the cRMSSD and the SDNN. The root mean squared of the successive differences (cRMSSD) describes the variation in heart rate within a certain time frame. The SDNN, the standard deviation of the inter-beat intervals (IBI), describes the standard deviation of the inter-beat intervals of a normal sinus rhythm. Below (Fig 1.) is a visual representation of an IBI showing HRV. In summary, IBI was the measurement taken in this experiment which was used to calculate HRV using the cRMSSD. IBI was measured across the entire experiment, with baseline measurements being taken at the beginning and multiple measurements taken at various points (see Appendix B). Perceived stress was measured using SAM, a Self-Assessment Manikin used to measure valence, arousal, and dominance (Fig. 2).

Figure 1

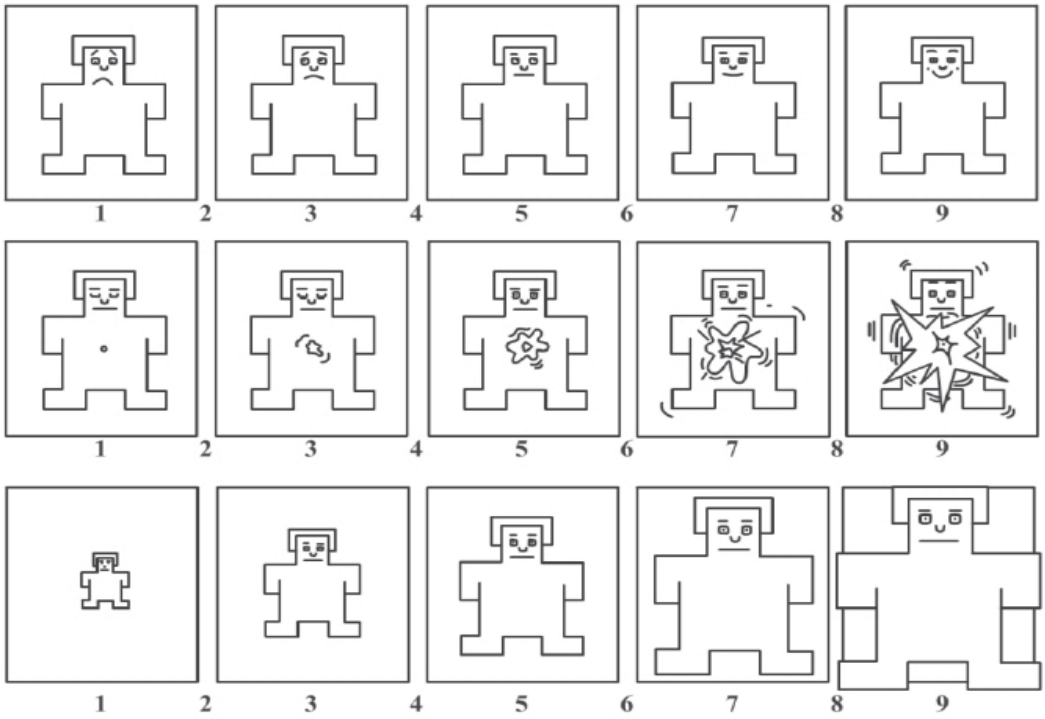
A visual representation of heart rate variability



Note. Retrieved from "Genetic and Environmental Determinants of Blood Pressure: the role of Obesity and the Autonomic Nervous System," by T. Man, (2022), *University of Groningen,* p. 61 (https://doi.org/10.33612/diss.255261014)

Figure 2

The SAM questionnaire with levels Valence, Arousal, and Dominance



Note: From the top down: Valence, Arousal, and Dominance. Retrieved from "Affective auditory stimuli: Adaptation of the International Affective Digitized Sounds (IADS-2) for European Portuguese." by A.P. Soares, A.P. Pinherio, A. Costa, C.S. Frade, M. Comesana, & R. Pureza, 2013, *Behaviour Research Methods, 45*(4), p. 1170 (https://doi.org/10.3758/s13428-012-0310-1)

Statistical analysis

Using the programs R and RStudio (R Core Team, 2013), we performed an analysis on the cRMSSD and the stages of the experiment comparing the two conditions as well as

correlational analyses between the levels of the SAM and the cRMSSD. We obtained the cRMSSD by dividing the RMSSD by the mean of the IBI values.

Results

Descriptive statistics

There was initially a sample of 32 participants, however 5 were removed due to technical difficulties affecting the heart rate readings leaving a sample of 27. There was both an unequal distribution of males vs. females and the number of participants assigned to each condition, with the latter being due to the aforementioned removal of participants. There were no reported cardiac or neurological conditions.

Table 1

Descriptive statistics of sample

Characteristic	N=27
Age	19.50 (19.00, 20.38)
Gender	
Male	7 (26%)
Female	20 (74%)
Condition	
Unsupportive	15 (56%)
Supportive	12 (44%)
ConditionAware	
Unaware	3 (12%)

Aware	23 (88%)
Unknown	1
Neurological	0

Manipulation checks

88% of the participants reported that they experienced their assigned condition as intended during the presentation period, i.e., those in the supportive condition believed they were in the supportive condition and those in the unsupportive condition believed they were in the unsupportive condition.

Table 2

Main Contrast Effects of Condition and Period on cRMSSD

Characteristic	B	p	%CI
Period			
Baseline standing	-	-	
Baseline sitting	.09	>0.9	[-1.7, 1.9]
Preparation	-.14	0.9	[-1.9, 1.6]
Wait for audience	-.96	0.3	[-2.7, 0.81]
Presentation	-1.8	0.047*	[-3.6, -0.03]
Rest	.52	0.6	[-1.3, 0.37]
Post standing	-1.4	0.12	[-3.2, 0.37]
Post sitting	.28	0.8	[-1.5, 2.1]
Condition			
Unsupportive	-	-	

Supportive	-2.4	0.092	[-5.2, 0.40]
Period*Condition			
Baseline sitting*Supportive	2.9	0.032*	[0.25, 5.6]
Preparation*Supportive	1.4	0.3	[-1.3, 4.0]
Wait for audience*Supportive	1.7	0.2	[-0.92, 4.4]
Presentation*Supportive	2.7	>0.05*	[-0.01, 5.3]
Rest*Supportive	1.4	0.3	[-1.3, 4.0]
Post standing*Supportive	2.0	0.15	[-0.7, 4.6]
Post sitting*Supportive	2.2	0.1	[-0.41, 4.9]

Note. * indicates a significant result.

Heart rate variability and the experiment conditions

As seen in Table 2, the presentation period has a significant effect on the cRMSSD with the cRMSSD 1.8 lower in comparison to the baseline standing measurement ($p = 0.047$). The unsupportive condition can not technically be considered as more stressful than the supportive condition during the presentation as the $p = >0.05$, but as it is on the border it could be considered that there is a trend of lower stress during the supportive condition which dually implies more stress during the unsupportive condition. Ultimately the unsupportive condition did not cause significantly more stress overall ($p = 0.092$), however the interaction between supportive condition did add 2.7 onto the cRMSSD when contrasting the presentation period so it could be argued that the conditions were successful in manipulating stress (albeit a trend).

Table 3

Correlation Table of SAM, meanRR, and cRMSSD in Supportive Condition

	meanRR	cRMSSD	Valence	Arousal
meanRR				
cRMSSD	.35*(<.014)			
Valence	.34*(<.019)	.20		
Arousal	-.07	-.13	-.38*(<.008)	
Dominance	.17	.19	.29*(<.042)	-.54*(<0)

Note. * indicates a significant result.

Table 4

Correlation table of SAM, meanRR, and cRMSSD in Unsupportive Condition

	meanRR	cRMSSD	Valence	Arousal
meanRR				
cRMSSD	.36*(<.005)			
Valence	.12	-.36*(<.005)		
Arousal	-.25	.16	-.39*(<.002)	
Dominance	.23	-.04	.28*(<.03)	-.45*(<0)

Note. * indicates a significant result.

Heart rate variability and the SAM

Correlations between the cRMSSD and the levels of the SAM were calculated to test if they correspond (Table 3 and 4). No significant correlation was found for any of the levels

of the SAM with the cRMSSD in either of the conditions. A trend for valence could be argued but overall, this measurement of psychological stress barely correlates with the measure of physiological stress.

Discussion

For the first hypothesis, the results support that heart rate variability will significantly decrease when perceived stress increases when talking about the presentation period and not accounting for the experimental conditions, adding support to Cannon's fight or flight model. However, the second hypothesis has no support as there is a poor correlation between the HRV and the levels of the SAM. The SAM appears to be insensitive to stress levels, as seen in tables three and four. This could be due to the SAM measuring either different elements of the same stress or measuring a completely different underlying concept than the HRV. Finally, the third hypothesis and overall research question is arguably both supported and not supported. While the unsupportive condition was not significantly more stressful (in terms of physiological stress), the p-value is exactly on the border of significance. It is likely that the small sample size in this experiment limits how accurate this p-value is. The SAM scores were unable to show a significant difference between the conditions for psychological stress, however it seems the SAM was a poor measure for this experiment. Alternatively, the participants may not have recorded how they truly felt; perhaps to appear less stressed out of social desirability, or giving us the results they think the research "wants" and ultimately warping the results. If focusing on technicalities, the third hypothesis of a negative audience leading to higher stress levels is not supported by this study's results, but given a better suited measure for self-perceived stress and a larger sample size this may not hold.

Strengths and limitations

This study showed a desirable outcome in terms of how clear the feedback conditions were for participants. Irregardless of the significance of results between conditions, 88% of participants assumed correctly which condition they were assigned to when asked during the debrief. Furthermore, the design of the study is deemed effective as reflected by the fact that the HRV significantly decreased during every participant's presentation period. The study was also relatively standardized for each participant, with every participant going through the same periods in the same order as well receiving the same script for the instructions and debrief decreasing the possibility that instruction has influenced the participants behavior. This also enables any future researchers to easily replicate our study should they choose to. Finally, using HRV as a measure of physiological stress is very robust and well recorded as an accurate and effective measure of stress and the results reflect previous studies in terms of establishing public speaking as a stressor.

Conversely, there are many limitations, in particular the sample. The size was cut down 16% from 32 participants to 27 due to technical issues with the recording of the heart rate as well as the timing of the phases. This is in addition to already being a significantly smaller sample size than other studies in this area, for example Oldehinkel et al. (2011) had a much larger sample at N = 715. Furthermore, the majority of participants were women with a mean age of 19 years and 6 months and all but two were first year psychology students. This leads to poor generalizability to the wider population as well as a low effect size. Outside of the sample composition, language was also a factor that should be considered in the future. The participants had the option of receiving instructions and performing their presentation in either English or Dutch. Only those whose native language is English or Dutch had the option to speak in their native language. With Groningen being a popular University for internationals, several people speak English as a second language which can be considered an additional, unaccounted stressor that could influence the results regardless of

the assigned condition. Naturally, the very fact that participants were aware they were in a study may have influenced results due to them attempting to guess the experimental condition, giving alternative responses for the SAM in an attempt to be socially desirable, or feeling no real world consequences like one normally would during a presentation as they were receiving SONA credits regardless.

The insensitivity of the SAM as a measure for psychological stress in this experiment means the research question could not be effectively or completely answered. The SAM showed rather unusual results as there were differences in perceived stress levels between the two conditions before the conditions were even applied to the experiment, i.e., before the presentation phase. As previously mentioned, it may be that the SAM and HRV simply measure different underlying concepts, meaning the SAM has low content validity for this experiment. While the results of the study do suggest audience response may influence stress, they only effectively address the physiological stress response with the psychological aspect still left unaddressed. Finally, the statistical analysis involved comparing HRV to baseline standing measures when a comparison to post-test rest periods may be better suited due to the lack of anticipation effects (Hansen et al., 2003).

Future directions and implications

While the design of the study appears effective, the sample and selected measurement tools for psychological/self-perceived stress leave something to be desired. Future studies may want to include a larger, more generalizable sample, specifically with a more equal distribution across sex and age as well as more representation outside of higher education. A further consideration may be social media; the majority of this sample fit into the category of Gen Z (those born in 1997 or after). An argument could be made that with the increase in the presence of social media, response to social pressure such as public speaking may be

influenced. Another point of consideration would be to replace the SAM with a better suited measure of self-perceived stress within this context to be able to effectively address the research question.

Despite the aforementioned limitations and future alterations this study does contribute to the existing literature in a unique way, namely that it shows that HRV is an effective measurement of physiological stress even in such a small sample. Unlike previous studies, the sample was also non-clinical so may add to the understanding of how public speaking affects a wider population.

Conclusion

Public speaking is a well-known stressor, with this study aiming to add to the existing literature by establishing a link between the physiological and psychological stress caused by public speaking and how an audience's response may influence that. The results show that there is no significant effect of audience response on either physiological or psychological stress. If the conclusion is based only on the numbers, only the first hypothesis is accepted and the others are rejected. However, once these numbers are placed into context and trends are taken into consideration, the second hypothesis is unanswered. The insensitivity of the SAM means there is no accurate data on the psychological stress of the participants so establishing the presence or lack of a link is not possible. With regards to the third hypothesis, the results are on the border of significance with a trend that suggests audience response may in fact have an influence on at least physiological stress. To address the research question more effectively, future studies should include a larger, more representative sample with a more reliable measure of psychological stress.

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Appendix A

Script for Instructions

We will ask you to prepare a 5 minute speech in the next 15 minutes that you will present to a small group. You will be able to draft your speech on paper that you can bring while presenting. When you are done, we will give you a short questionnaire to fill in. You will then go into the next room where there will be a small group of people and a camera. The camera will record your presentation and the researchers will evaluate it later. The group will be evaluating your performance and the overall content of your speech as well as timing it for you. We will tell you when the 5 minutes are complete. You must fill the whole 5 minutes. For the topic, you can talk about a personal topic, such as your experience as a student.

Script for Debrief

What did you think about the experiment? (Response.) We manipulated a few different things in this experiment. There were two different conditions for the audience, a supportive audience and non-supportive audience. Which condition do you think you were in? (Response). You were assigned to the supportive/non-supportive condition. Another manipulation was that you were told you were recorded but this was not the case. We only told this to induce stress. Therefore it is necessary to fill in the informed consent again, with now all the information. We would like to thank you very much for participating in this research! If you want to take a look at your own data, that is possible. Please remove the band and we ask that you do not tell anyone else about the experimental conditions.

Appendix B

Experiment timeline

Welcome participant	Participants are welcomed by one researcher and ask which language they prefer the experiment be conducted in, English or Dutch.	2 min
Informed consent	Participant reads and fills in an informed consent form, and a researcher signs it. Researchers make it clear the participant may leave at any time with no explanation necessary.	2 min
Place Polar band	Researcher places the polar band on the torso of the participant and checks the signal.	5 min
Stress questionnaire and bio information	Participants fill in a stress questionnaire for the first time alongside health information.	5 min
Baseline measurements	The participant is asked to stand in place for 2 minutes in silence while researchers record their heart rate.. They are then asked to do the same again while seated.	4 min
Instructions	A researcher will explain the experiment procedure to the participant using the script (see Appendix A).	5 min
Prepare presentation	Participants are left alone for 15 minutes to prepare a short presentation to present to the	15 min

	researchers.	
Stress questionnaire	Participants fill in a stress questionnaire for the second time.	3-5 min
Audience enters	Audience enters the room and the participant is asked to wait outside for a moment. After 1-2 minutes the participant re-enters the room and is set up for their speech. The camera is turned on, pointed at the participant, and the participant can see themselves on a screen near them.	3 min
Presentation	Participants will present their speech to one of two conditions; a positive audience or a negative audience. They will be encouraged to fill the full 5 minutes regardless of the audience response assigned to them. When finished, the audience leaves the room.	5 min
Stress questionnaire	Participants will then fill out the questionnaire for the third time.	3-5 min
Rest period	Participants will be asked to wait for 5 minutes. Researchers leave until the rest period is over.	5 min
Stress questionnaire	Participants will fill in the questionnaire for the fourth and final time.	3-5 min
Heart rate measurement	Participants will stand for 2 minutes while researchers record their heart rate. They are	4 min

	then asked to do the same again while seated.	
Debrief	Experimental conditions will be explained to the participant and researchers will ask for consent a second time now the participant is aware of the manipulations.	5 min