Heart Rate Variability and Perceived Stress in Public Speaking with regard to Supportive and Non-supportive Feedback

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Abstract

The aim of this paper is to find out if heart rate variability (HRV) and perceived stress correlate in public speaking and if type of feedback given during public speaking influences HRV and perceived stress. We measured heart rate and perceived stress during a public speaking task and differed between a supportive and non-supportive feedback condition. Perceived stress was measured using the Self-Assessment Manikin (SAM), which consists of three sub-values: valence, arousal and dominance. The results indicate that there is no association between HRV and perceived stress as measured with the SAM. Feedback type does influence HRV and perceived stress: there is a strong trend of less HRV during the presentation in the non-supportive condition as compared to the supportive condition; there is lower valence in the rest period in the non-supportive condition as compared to the supportive condition. Sub-scales arousal and dominance show no significant differences across the feedback conditions. Limitations of the study and health implications are discussed.

Keywords: feedback, heart rate, heart rate variability, perceived stress, public speaking

Heart rate variability and perceived stress in public speaking with regard to supportive and non-supportive feedback

Just about everybody has experienced the task of public speaking. In school everyone has had to give a presentation at some point. For job application and career advancement almost always a presentation or elevator pitch is needed. Therefore, everyone is probably familiar with the tension and stress that comes with public speaking. Sweating, freezing, accelerated heart rate and nervous thoughts are common in such situations. The aim of this paper is to find out if type of feedback given during public speaking influences perceived stress and heart rate variability. In addition we are interested in the correlation between heart rate variability and a subjective measure of perceived stress (SAM).

It is important to investigate whether feedback type influences heart rate and stress, as they are important health indicators. Feedback itself also has differing consequences for well-being. Expectancies play an important role in processing feedback (Hilmert et al., 2002; Pulopulos et al., 2020). Negative expectations are often followed by negative affect and positive expectations by positive affect. Siu et al. (2007) found that general self-efficacy moderated the relationship between mental well-being and stressors. Jovanović et al. (2021) found that self-efficacy only related to the positive affect aspect of subjective well-being (SWB), but not to SWB in general. Self-efficacy seemed to indirectly influence SWB as positive affect was associated with future positive expectations, which in turn related to SWB. Optimism was positively associated with SBW in general.

Expectancies, especially when they are negative or differ from reality, can cause stress. Russell's et al. (2022) study showed a positive relationship between perceived stress and less emotion regulation. Furthermore, perceived stress was associated with lower mental well-being and less use of active coping strategies. Besides mental well-being physical health is of great importance to humans. It is known that heart rate variability (HRV) is a marker for several diseases and a predictor of cardiovascular morbidity and mortality (Kristal-boneh et al., 1995). Decreased HRV is associated with cardiovascular disease, diabetes and psychiatric disorders. Generally higher HRV is associated with more psychological flexibility and resilience (Young & Benton, 2018). Since there are many health implications related to perceived stress and heart rate, it is important to find out if the manner in which feedback is given forms a risk factor. It would also be nice to see an association between perceived stress and HRV, as it could indicate HRV as an objective measure of perceived stress.

Heart rate (HR) is often measured in heartbeats per minute (bpm). Heart rate variability (HRV) is defined by Schaffer and Ginsberg (2017) as ‘’the fluctuation in the time intervals between adjacent heartbeats’’. The time intervals are called interbeat intervals (IBIs) or RR-intervals. Figure 1 demonstrates variability in IBIs of a heart measurement, which can be caused by the autonomic nervous system (ANS). The ANS consists of two main systems: the parasympathetic nervous system (PSNS) and sympathetic nervous system (SNS). The PSNS is active when the body is in rest and the SNS prepares the body for action.

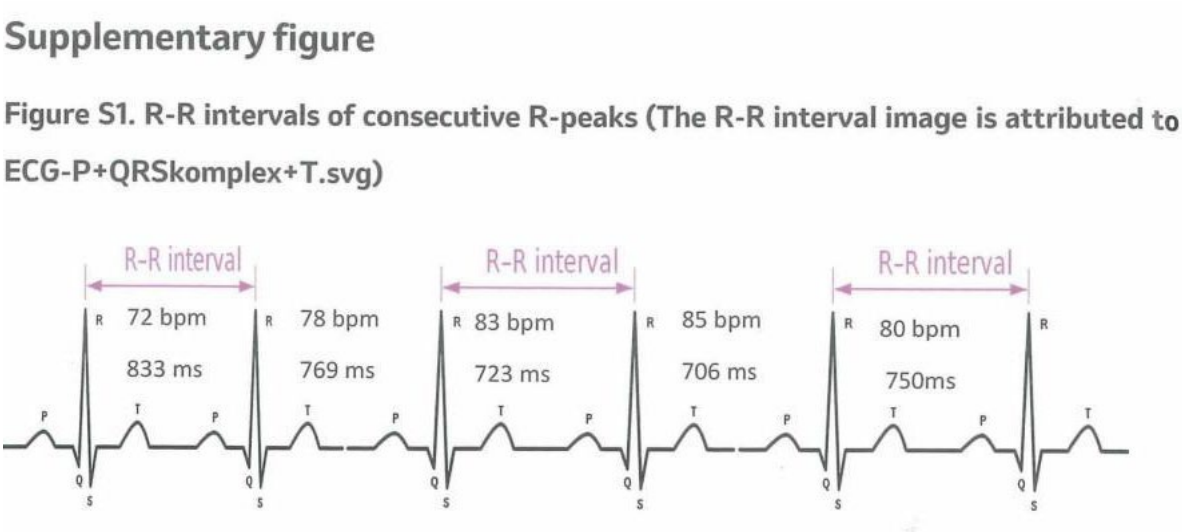
High frequency heart rate variability (HRV) is associated with activation of the parasympathetic nervous system, corresponding High HRV has been associated with better stress and emotion regulation (Thayer et al., 2012). Low frequency (LF) HRV often reflects sympathetic nervous system activation (a characteristic of being stressed). When the heart beats at its fastest there is little to no room for fluctuations in HRV, reflecting a LF HRV.

Lazarus and Folkman (1994, as cited in Whitney et al., 2022) explained that people experience psychological stress when demands of a situation, which is perceived as demanding or threatening, are not met due to lack of resources or the inability to cope. Heart rate variability is often used as a marker of the capacity to regulate internal and external demands.

Heart rate (variability) and stress

Figure 1

Heart rate variability reflected by differing IBIs



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)

People often assume that heart rate (HR) is linked to stress, namely that stress increases HR and thus decreases heart rate variability (HRV) frequency. Dishman et al. (2000) found in their study that physically fit participants, from around Dallas-fort Worth, who reported higher perceived stress also showed lower high frequency (HF) HRV. Increased fluctuations in HF HRV imply a less stable balance between the parasympathetic and sympathetic nervous system. This effect seemed to be independent of the participants' fitness and age. It is, however, questionable if this effect can be generalized to other ethnicities and less physically fit people. Others have shown that age and physical activity do influence HRV: physically active people show higher HRV and HRV declines with age (Estévez-Báez, 2018; McCraty & Schaffer, 2015; WebMD, 2021).

Sadeghi et al. (2022) looked at heart rates of participants, recruited from American recovery events for veterans, during posttraumatic stress disorder (PTSD) hyperarousal events. Their study showed that HR increased during and immediately after PTSD hyperarousal events, and more fluctuations in time periods between heart beats were noticed compared to healthy counterparts. Gender effects were not clear as there was an overrepresentation of males. According to WebMD (2021) gender influences heart rate variability (HRV), with men having a higher overall HRV. The study took place in group events with physical activity, so whether its results can be applied to other settings is yet to be seen. At least it can be assumed that there is an association between psychological stress and heart rate (variability).

Fight-or-flight

Cannon was the first person to publish the idea of a fight-or-flight response to feared threats in 1915, animals either confront (fight) the threat or try to escape (flight) it. This reaction as associated with physiological changes, often involves an adrenaline rush and activation of the sympathetic nervous system (Cannon, 1994). When the amygdala send a distress signal, the hypothalamus activates the sympathetic nervous system. Physiological changes happen automatically making it possible for the body to react quickly and to increase chance of survival. Physiological changes include changes in heart rate (HR) and respiration, which affect blood flow, blood pressure, heart rate variability and oxygen availability.

A secondary reaction is activation of the HPA-axis, which regulates stress response over extended periods. It activates cortisol release when a person is stressed, increasing heart rate. Besides fight and flight, Bracha et al. (2004) found other fear responses and a specific natural order of reacting to threats in nonhuman primates. Freezing, a state of hypervigilance, seemed to be a primary response when encountering a threat. Subsequent were flight, fight and fright, fright reflecting tonic immobility.

Many people find public speaking stressful and fear it as people are socially evaluated, according to the fight-or-flight model the expected response would be a decrease in heart rate variability (HRV) if public speaking is seen as a threat. Sympathetic nervous system activity reflects lower HRV. Lower high frequency HRV is also associated with stress, panic, anxiety and worry (McCraty & Schaffer, 2015). Furthermore, prefrontal cortex activity is associated with HRV: when someone is stressed the prefrontal cortex shows less control of top-down regulation of actions, emotions and thoughts, which can lead to a state of hypervigilance and decreased HRV.

Heart rate and stress in public speaking

Oldehinkel et al. (2011) were interested in the association between physiological and psychological stress measures among Dutch adolescents. They held an experimental session consisting of four challenges among which a social stress test consisting of holding a recorded speech. Before and after the experimental sessions were 40 minute rest periods. Physiological measures included among other things heart rate (HR) and cortisol. The psychological variable was perceived stress, measured through the Self-Assessment Manikin (SAM). The SAM reflects three components of perceived stress: arousal, unpleasantness (valence) and dominance. Variables were measured pre-, during and post-test. Significant associations were found of perceived arousal and unpleasantness with HR and cortisol, implying that perceived stress partly reflects HPA-axis and autonomic nervous system activity (Oldehinkel et al., 2011). Furthermore, higher HR predicted less post-test unpleasantness and more post-test dominance, suggesting physiological variables to partly have an effect on perceived stress. Contrary, pre-test perceived stress did not predict following physiological responses. It should be noted that effect sizes were small and that pre-test levels were not measured immediately before the social stress task. In addition generalization to real life and other ethnicities is questionable.

A study going deeper into public speaking effects was carried out by Jezova et al. (2016). Participants consisted of student actors (from the Academy of Performing Arts

Bratislava) and non-actors; actors had experience in public speaking and non-actors did not. Participants had to hold a speech while being recorded. Salivary cortisol and HR were measured at baseline, at the end of preparation and speech, 15 minutes after the speech or 30 minutes after the speech. Salivary cortisol increased significantly after the speech compared to before and at the end of the speech, suggesting stress was highest at the end of preparation and speech taking into account a 20 to 25 minute delay in peak cortisol responses to experimental stressors (Kirschbaum et al., 1992). Similarly, HR increased significantly for non-actors just after the speech (at the end), although this was not the case at the end of preparation. HR did not significantly increase at any point for actors, suggesting that public speaking experience played a role. Note that the study contained only male participants and had a small sample size (N=22), making it susceptible to type II errors. In agreement with Jezova's et al. findings, Pulopulos' et al. (2020) study showed least HRV immediately after a public speaking task. It can be said that public speaking induces stress and relates to accelerated HR.

Feedback effects

Presentations are given for others to view and feedback is an essential part of it. Pulopulos et al. (2020) investigated the accuracy of the Neurocognitive framework for Regulation Expectation (NFRE), which proposes that ''higher positive expectancy will be associated with a proactive anticipation of stress, which will be reflected in an improved anticipatory stress regulation, resulting in a dampened response to stress''. Proactive coping aims to prevent a stressor from happening. Pulopulos found that females with low expectancies due to negative feedback reported less self-efficacy and that they rated stressors as more threatening or challenging. Furthermore, negative anticipatory cognitive stress appraisal was associated with a larger decrease in heart rate variability, indicating worse stress regulation, compared to participants with positive expectancies of stressors. It should be noted that participants had been using contraceptives. Corresponding, Hilmert et al. (2002) had found that women with high self-efficacy showed smaller cardiovascular responses compared to women with low self-efficacy. Their study also suggested that expectancies influence stress appraisal; cardiovascular response to a public speaking task did not differ among participants with varying confidence levels when the public was perceived as inexperienced in evaluating presentations.

Experimental study

The goal of this study is to investigate the association between heart rate variability (HRV) and perceived stress with regard to public speaking, and whether supportive and non-supportive feedback influences perceived stress and HRV with regard to public speaking. In our study participants have to give a presentation about a personal topic while being fake recorded. Participants will be divided between two conditions, one with supportive feedback and one with non-supportive feedback from the audience. HRV will be recorded during the experiment. Perceived stress will be measured at baseline, after preparation, immediately after the presentation and after a short rest period. We will compare data over and of corresponding time points. Previously appointed information suggests elevated stress in anticipation of a stressor and while being confronted by a stressor which is perceived as challenging or threatening. To add, expectancies play a role in stress appraisal, thus between conditions a difference in HRV and perceived stress is expected. Hypotheses are as followed:

1. Heart rate variability correlates with perceived stress in public speaking
2. Non-supportive feedback is associated with less heart rate variability compared to supportive feedback with regard to public speaking
3. Non-supportive feedback is associated with higher perceived stress compared to supportive feedback with regard to public speaking

Methods

Participants

A total of 32 participants took part in this study. We used data of 27 participants (20 females, 7 males, $M_{age} = 21.19$, $SD = 7.03$) and left out data of the remaining five participants as their data was deemed invalid. Participants were either recruited through family and friends or through the SONA research pool of the University of Groningen, consisting of first year Psychology students who needed study points (SONA credits) to complete the propaedeutic year. Students were able to choose in which studies to participate and all students had to give informed consent to participate. In this study SONA credits were the only incentives used for recruitment.

Procedure

The experiment took place in the psychological laboratories of the University of Groningen. There was one participant per session and a minimum of three researchers were present each session. Two researchers, the ‘’key presser’’ and the host, were present the whole session except for during preparation and rest time, while the researchers that were only part of the audience only showed up at the presentation. The host guided the participant through the experiment, while the key presser pressed the keys on the computer to distinguish between periods in the experiment. All participants went through the same procedure, for illustration see Appendix A. We alternated participants between conditions. Heart rate (HR) was measured in standing and sitting position as HR is significantly higher in standing position. SONA credits would be admitted if participants were present regardless of whether they finished the experiment.

Experimental manipulations

We used a between-subject design and tested two conditions: supportive feedback and non-supportive feedback. Stress was measured with heart rate variability (HRV) and perceived stress among these conditions. In the supportive feedback condition the audience was showing interest, smiling, clapping etcetera. In the non-supportive feedback condition the audience was looking away, looking bored, looking at their phones etcetera. We purposedly induced stress in the participants through the public speaking task, fake recording and fake informed evaluation. During the instruction (see Appendix B) participants were told they were being recorded and that their performance would be evaluated.

This study made use of one categorical independent variable and two continuous dependent variables. The independent variable was feedback type, either the supportive or non-supportive feedback condition. The first dependent variable was heart rate variability (HRV), measured from when the Polar H10 band was put on. The second dependent variable was perceived stress, measured at four corresponding time periods. HR and perceived stress were measured within the same person, reflecting a within subject factor, and making it possible to compare HR to perceived stress.

Material and apparatus

During preparation a blank A4 paper was used as draft paper. A silver colored hard disk camcorder (JVC GZ-MG335HE) was used for fake recording the presentation. The recording was visible on a beamer screen. A digital desktop clock was present in the room for indicating time. For measuring heart rate (HR) the Polar H10 band was used. Accuracy of the Polar H10 in HR measurement is high, almost equal to the standardly used ECG amplifiers, and the Polar H10 band is resistant to movement artifacts (Buist, 2022). Data was acquired using lab streaming layer (LSL) (Kothe & Makeig, 2013). The LSL LabRecorder was used to save the data.

Measures

Heart rate variability (HRV) was calculated using interbeat intervals (IBIs). HRV can be calculated from HR by taking the root mean square of successive differences (RMSSD) of IBIs. HR was recorded from SAM1 to Post Sitting.

Perceived stress was assessed through the Self-Assessment Manikin (SAM) invented by Bradley and Lang in 1994, for illustration see figure 2. The SAM is a ‘’non-verbal pictorial assessment technique that directly measures the pleasure, arousal, and dominance associated with a person's affective reaction to a wide variety of stimuli’’ (Bradley & Lang, 1994). Valence (pleasure), arousal and dominance (control) were each reflected by nine pictures, representing a nine-point scale with high scores reflecting more intense feelings of valence, arousal and dominance. Perceived stress was measured after informed consent was given (SAM1), after preparation (SAM2), directly after the presentation (SAM3) and post-test immediately after the 5 minute rest period (SAM4).

Statistical analysis

We used a correlation test for heart rate variability (HRV) and perceived stress. To see if there were differences in HRV and perceived stress among the feedback conditions we used a linear mixed effects (LME) model twice, one for HRV and one for perceived stress. A LME model accounts for variance caused by individual differences by using participant as random effect and copes better with missing data than repeated measures ANOVA. Analyses were carried out in R. HRV was measured time-dependently in the corrected root mean square of successive differences (cRMSSD), calculated by dividing the RMSSD by the average IBI, which reflects HRV in milliseconds.

Results

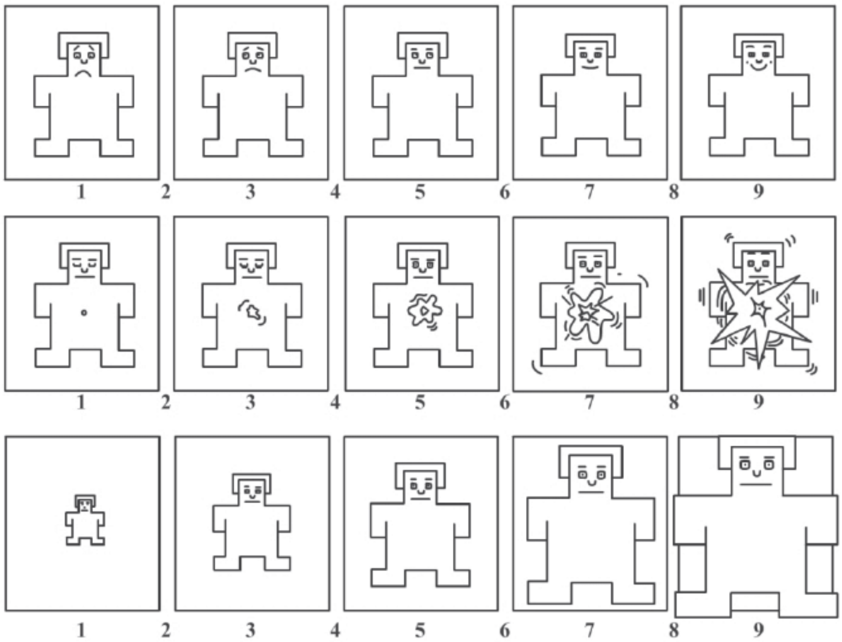
Valid data of 27 participants was used to calculate the statistics. Table 1 shows descriptive statistics regarding said participants’ age, gender, condition (awareness) and possible neurological conditions. Due to omitting invalid data group sizes differed between conditions ($N_{Sup} = 12$, $N_{Non} = 15$).

Heart rate variability and perceived stress

Following hypothesis 1 an association between heart rate variability (HRV) and

Figure 2

The Self-Assessment Manikin (SAM) Measure scales (valence, arousal, and dominance)



Note. From the top down: Valence, Arousal and Dominance. Retrieved from *Behavior Research Methods* by Soares, A. P., Pinheiro, A. P., Costa, A., Frade, S., Comesaña, M., & Pureza, R., 2013, Research Gate (https://www.researchgate.net/).

Table 1

Participants' descriptive statistics

Sample	Age	Gender		Condition		Condition aware			Neuro[7]
		Male	Female	Sup[2]	Non[3]	Un[4]	Aw[5]	Unk[6]	
N = 27[1]	19.50	7	20	12	15	3	23	1	0

Note. [1]Median (IQR). [2]Sup = Supportive and [3]Non = Non-supportive. [4]Un = Unaware, [5]Aw = Aware and [6]Unk = Unknown. [7]Neuro = Neurological condition.

perceived stress was expected. A correlation test was carried out and the corrected root mean square of successive differences (cRMSSD) was used as measure for HRV and valence, arousal and dominance were used as measures for perceived stress. We calculated the overall correlation between HRV and perceived stress in the supportive and in the non-supportive condition. No significant correlations between HRV and perceived stress measures were found (Table 2).

Table 2

Heart rate variability and stress correlations

Variable	cRMSSD	
	Supportive	Non-supportive
Valence	-.15	.11
Arousal	.09	-.03
Dominance	-.15	-.04

Note. α = .05.

Feedback and heart rate variability

Hypothesis 2 stated that non-supportive feedback is associated with less heart rate variability (HRV) compared to supportive feedback with regard to public speaking. We used a linear mixed effects (LME) model to trace the trajectory of cRMSSD over time and across the two conditions, with time representing the periods at which HRV was measured (Appendix C). Time and condition served as fixed effects and cRMSSD as dependent variable. We were only interested in possible differences from time Presentation onwards, as condition only played a role from that point. A main effect of Posture on cRMSSD was found, with cRMSSD significantly higher while sitting compared to standing ($\beta = 2.5$, $p = .013$). No other main effects were found (Appendix C). A trend of time * condition was found, during Presentation cRMSSD was lower in the non-supportive condition as compared to the supportive condition ($\beta = -2.7$, $p = .050$).

Feedback and perceived stress

We also used a linear mixed effects (LME) models with time and condition as fixed effects and valence, arousal or dominance as dependent variable (Tables 3, 4 and 5). Time represented the 4 periods to which the perceived stress measures corresponded. During the experiment SAM1 corresponded to Baseline Standing, SAM2 to Wait for audience, SAM3 to Rest and SAM4 to Post Standing. Baseline Standing and the supportive condition were used as reference group. A main effect of time on valence was found, valence was higher at Wait for audience and Rest (for both: $\beta = 0.83$, $p = .016$) (Table 3). Condition seemed to form a trend, the non-supportive condition increasing valence ($\beta = 0.88$, $p = .056$). An interaction effect of time * condition showed that during Rest valence was significantly lower in the non-supportive condition compared to the supportive condition ($\beta = -1.1$, $p = .017$). There were no main effects of either time or condition on arousal and no interaction effects of time * condition (Table 4). The p-value of Post Standing however suggested a trend was going on, with decreasing arousal during that period ($\beta = 1.0$, $p = .060$). Similarly no main and interaction effects were found regarding dominance (Table 5). Post Standing did indicate a trend, increasing dominance ($\beta = 0.75$, $p = .055$).

Table 3

Linear mixed effects model using condition and time to predict valence

Characteristic	Beta	95% CI[1] [LL, UL]	p-value
Condition			
Supportive	-	-	
Non-supportive	0.88	[-0.02, 1.8]	0.056
Time			
Baseline Standing	-	-	
Wait[2]	0.08	[-0.59, 0.75]	0.8

Rest	0.83	[0.16, 1.5]	0.016*
Post Standing	0.83	[0.16, 1.5]	0.016*
Time * Condition			
Wait[2] * Non[3]	-0.42	[-1.3, 0.48]	0.4
Rest * Non[3]	-1.1	[-2.0, -0.20]	0.017*
Post Standing * Non[3]	-0.77	[-1.7, 0.13]	0.094
Subject intercept	0.83		
Residual observation	0.82		

Note. [1]CI = Confidence Interval. LL and UL indicate the lower and upper limits of the confidence interval, respectively. [2]Wait = Wait for audience. [3]Non = Non-supportive. Supportive condition and time Baseline Standing were used as reference groups.

* indicates $p \leq .05$.

Table 4

Linear mixed effects model using condition and time to predict arousal

Characteristic	Beta	95% CI[1] [LL, UL]	p-value
Condition			
Supportive	-	-	
Non-supportive	-0.53	[-2.0, 0.95]	0.5
Time			
Baseline Standing	-	-	
Wait[2]	0.33	[-0.71, 1.4]	0.5
Rest	0.33	[-0.71, 1.4]	0.5
Post Standing	-1.0	[-2.0, 0.04]	0.060
Time * Condition			

Wait[2] * Non[3]	0.93	[-0.47, 2.3]	0.2
Rest * Non[3]	-0.07	[-1.5, 1.3]	> 0.9
Post Standing * Non[3]	-0.13	[-1.5, 1.3]	0.8
Subject intercept	1.4		
Residual observation	1.3		

Note. [1]CI = Confidence Interval. LL and UL indicate the lower and upper limits of the confidence interval, respectively. [2]Wait = Wait for audience. [3]Non = Non-supportive. Supportive condition and time Baseline Standing were used as reference groups.

Table 5

Linear mixed effects model using condition and time to predict dominance

Characteristic	Beta	95% CI[1] [LL, UL]	p-value
Condition			
Supportive	-	-	
Non-supportive	-0.73	[-1.9, 0.39]	0.2
Time			
Baseline Standing	-	-	
Wait[2]	-0.25	[-1.0, 0.52]	0.5
Rest	0.17	[-0.60, 0.93]	0.7
Post Standing	0.75	[-0.02, 1.5]	0.055
Time * Condition			
Wait[2] * Non[3]	0.38	[-0.65, 1.4]	0.5
Rest * Non[3]	-0.17	[-1.2, 0.86]	0.7
Post Standing * Non[3]	-0.62	[-1.6, 0.41]	0.2

Subject intercept	1.1
Residual observation	0.94

Note. [1]CI = Confidence Interval. LL and UL indicate the lower and upper limits of the confidence interval, respectively. [2]Wait = Wait for audience. [3]Non = Non-supportive. Supportive condition and time Baseline Standing were used as reference groups.

Discussion

Hypothesis 1

We hypothesized that heart rate variability correlates with perceived stress in public speaking. Our research findings were inconsistent with this hypothesis. There was no correlation between heart rate variability (HRV) and valence, arousal or dominance, suggesting that HRV is not a good reflection of the Self-Assessment Manikin (SAM) or vice versa. This contrasts with Oldehinkel's et al. (2011) findings, which showed associations of valence and arousal with heart rate.

Hypothesis 2

Hypothesis 2 stated that non-supportive feedback is associated with less heart rate variability (HRV) compared to supportive feedback in public speaking. Our findings show limited support for this hypothesis, a strong trend of less HRV was observed during the presentation in the non-supportive condition compared to the supportive condition. There were no significant differences in HRV during the other periods and there was no main effect of condition. The trend makes one question if the non-supportive feedback has an influence only at the moment of receiving feedback. A factor possibly contributing to the short influence of non-supportive feedback in our study could be that part of the audience was only present during the presentation, and the host and key presser did not act non-supportive during the rest of the experiment. It has also been suggested that talking aloud is associated with activation of the sympathetic nervous system, lowering HRV, which can make our effects seem larger (Bernardi et al., 2000). Regarding our findings, HRV results seem in favor of the Neurocognitive framework for Regulation Expectation (NFRE) mentioned by Pulopulos et al. (2020), as non-supportive feedback could cause negative anticipation and impair effective coping. The results partly support Cannon's fight-or-flight theory as there was a trend of less HRV in the non-supportive condition during the presentation. We would, however, also expect a decrease in HRV during the presentation in general if presenting was seen as a threat.

Hypothesis 3

Hypothesis 3 stated that there would be higher perceived stress in the non-supportive condition compared to the supportive condition. Higher perceived stress as measured by the Self-Assessment Manikin (SAM) is reflected by lower valence, more arousal and less dominance. Our findings partly support this hypothesis. In the non-supportive condition valence was lower during the rest period as compared to the supportive condition. Lower valence during Rest in the non-supportive condition as compared to the supportive condition was expected, as non-supportive feedback might lessen self-efficacy and in turn affect mood (Pulopulos et al., 2020). Other results showed no significance, but a trend of more valence in the non-supportive condition as compared to the supportive condition was found. This contradicts previous literature, suggesting non-supportive feedback may increase stress. These (lack of) results beg to question if the SAM is actually a good measure scale for perceived stress in the used setting or if some third variable played a role. It should be noticed that participants willingly participated. Regarding the nature of our study we expected participants with higher confidence or more experience in public speaking to take part, which could explain the relatively high scores on the SAM sub-scales.

Other results

Posture seemed to influence heart rate variability (HRV). HRV was higher in sitting position, which aligns with earlier findings indicating less HRV in standing position. Overall valence was higher in the rest period and during Post Standing. Furthermore, there was a trend of less arousal during Post Standing and a trend of higher dominance during Post Standing. This was expected as previous literature suggests people experience less stress and more pleasantness after a presentation (Kirschbaum et al., 1992; Oldehinkel et al., 2011). People tend to feel relieved after a public speaking task.

Strengths and limitations

This study contained a clear structure, a step by step plan was followed and a script was used as to minimize variation caused by external factors. Completely blocking noise however is impossible. Different hosts and key pressers could influence the experience of the participants and there were no rules set regarding clothes. Language fluidity or language used by the researcher could also play a factor in causing stress. Besides, the participants could choose to present in either Dutch or English, which made it possible for some to talk in their native language while others could not. Execution of the feedback conditions was done well, as 88% of the participants was aware of which condition they were in when asked during the debrief. It should be marked that most participants seemed to know some form of deception was going on, mostly that audience feedback seemed manipulated. This could lessen stress and influence the results. Furthermore, we compared stress in all periods to baseline standing, however Hansen et al. (2003) suggest that post-test rest measures are more suitable as baseline due to less anticipation effects. Our sample consisted of mostly young female students recruited through the SONA research pool of the University of Groningen, so generalizability to other age groups, males and ethnicities is yet to be seen. It is also questionable if results would differ in a real life situation.

Implications for future research

Feedback type does seem to influence heart rate variability (HRV) and perceived stress in public. This is important as presentations are an integral part of school and work life. If supportive feedback were to cause less stress, it would be nice to implement supportive or more positive feedback as many health concerns are related to stress, both mentally and physically. Manner of feedback could also play a role when treating specific disorders. The SAM showed low content validity in our study, so whether HRV could be a quantitative measure of perceived stress is unclear. For future research we commend using an alternative perceived stress measure to the SAM. Furthermore, in our research we did not include self-efficacy, which seems to have a substantial influence on stress (Hilmert et al., 2002; Pulopulos et al., 2020). For future research we commend to include self-efficacy. We also recommend using a larger sample with more variability regarding age, gender and ethnicity.

Conclusion

The current study suggests that heart rate variability (HRV) and perceived stress are not correlated. Besides, feedback type seems to have an influence on HRV and perceived stress. Participants showed less HRV during the presentation in the non-supportive condition as compared to the supportive condition. Besides, participants showed lower valence in the rest period in the non-supportive condition as compared to the supportive condition. No significant results were found between conditions regarding arousal and dominance. The Self-Assessment Manikin (SAM) did seem to have low content validity, possibly warping the results. It is thus unclear whether HRV can be used as an objective measure of perceived stress and in what manner feedback type exactly influences perceived stress.

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Appendix A

Table A

Procedure

Period	Function	Time (min)
Welcome	Host welcomes participant and lets participant fill in informed consent form. Voluntary participation and the right to stop at any time were emphasized. Participants were also informed of confidentiality of personal data.	4
Put on heart rate band	The Polar H10 band was put on the participant.	3
SAM1 + bio-information	The participant had to fill in a perceived stress questionnaire, the Self-Assessment Manikin (SAM), and a questionnaire about gender, age and any neurological conditions.	1
Walkthrough	Host explains all steps of the experiment.	1
Baseline Standing	Baseline heart rate in standing position was measured.	2
Baseline Sitting	Baseline heart rate in sitting position was measured.	2
Instructions	Host gave instructions about the presentation based on a script (see Appendix B).	5

Preparation	The participant had 15 minutes to prepare a presentation. Participants had access to a draft paper (A4) during preparation that could be used during the presentation. Heart rate during preparation was measured in absence of the researchers.	15
SAM2	Participant filled in a SAM.	1
Wait for audience	Audience entered and participant had to wait a little while outside.	1
Presentation	After returning to the room the participant held his/her presentation. A clock was present in the room to keep track of time and the camcorder was turned on.	5
SAM3	The participant filled in a SAM.	1
Rest	The participant got a 5 minute rest, Heart rate during the rest period was measured in absence of researchers.	5
SAM4	The participant filled in a SAM.	1
Post Standing	Post-test heart rate in standing position was measured.	2
Post Sitting	Post-test heart rate in sitting position was measured.	2
Debriefing	The participant was debriefed about the experiment and an assumption check was done to see if the participant was aware of the experimental manipulations. A second informed	4

	consent was needed as the participant became aware of the fake recording. At the end the participant was allowed to see her/his own live ECG.	
End recording	Recording of the heart rate was stopped	1

Appendix B

Script instructions

English:

Je krijgt zo meteen **15 minuten** om een presentatie van **5 minuten** voor te bereiden. Deze presentatie zal je aan een klein publiek presenteren. Je mag aantekeningen maken op een **kladblaadje**, en deze mag je tijdens de presentatie ook bij je hebben. Er zal een **camera** aanwezig zijn die jouw presentatie opneemt wat later door onderzoekers beoordeelt zal worden. Het publiek zal jouw presentatie op verschillende vlakken beoordelen en de tijd behouden. Je moet de **volledige 5 minuten** vol maken. Als onderwerp kan je een **persoonlijk** onderwerp kiezen bijvoorbeeld jouw ervaring als student.

Dutch/Nederlands:

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. During the presentation a **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.

Appendix C

Table C

Linear mixed effects model using posture, condition and time to predict cRMSSD

Characteristic	Beta	95% CI[1] [LL, UL]	p-value
Posture			
Standing	-	-	
Sitting	2.5	[0.54, 4.5]	0.013*
Condition			
Supportive	-	-	
Non-supportive	0.00	[-3.3, 3.3]	> 0.9
Time			
Baseline Standing	-	-	
Presentation	0.86	[-1.1, 2.8]	0.4
Rest	-0.64	[-2.6, 1.3]	0.5
Post Standing	0.55	[-1.4, 2.5]	0.6
Time * Condition			
Presentation * Non[2]	-2.7	[-5.3, 0.01]	0.050
Rest * Non[2]	-1.4	[-4.0, 1.3]	0.3
Post Standing * Non[2]	-2.0	[-4.6, 0.70]	0.15
Post Sitting * Non[2]	-2.2	[-4.9, 0.41]	0.10
Subject intercept	3.4		
Residual observation	2.5		

Note. [1]CI = Confidence Interval. LL and UL indicate the lower and upper limits of the confidence interval, respectively. [2]Non = Non-supportive. Standing posture, Supportive condition and time Baseline Standing were used as reference groups.

* indicates $p \leq .05$.