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PASCAL and DPA: A pilot study on using prosodic competence scores to predict communicative skills for team working and public speaking

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Abstract

Strong communication skills in public-speaking and team-working exercises are associated with specific acoustic-prosodic profiles and strategies. We hypothesize that analyzing and assessing these profiles and strategies allows us to predict communicative skills. To that end, we used two analysis methods, one for charismatic and persuasive public speaking (PASCAL), and one for cooperative communication (DPA). PASCAL and DPA competency scores are determined on an acoustic basis for speech recordings of 21 students whose task was to co-create, in 7 teams of 3 students, a fully functioning weather station over 14 weeks in an Electrical Engineering project course - and to jointly write a development report about it afterwards. Results show that the students' PASCAL scores are significantly correlated with both the grade in their final oral project presentation and the grade of their written report as assessed by an independent lecturer group. The DPA scores correlate with better time-management and team working as well as with the quality and functionality of the designed product. Explanations for the links between student performance and acoustic competence scores are discussed.
Index Terms: speech recognition, human-computer interaction, computational paralinguistics, voice profiling

1. Introduction

Proficiency in communication skills manifests itself in acoustic properties. Charismatic speakers who are ascribed extraordinary competences in self-presentation and persuasive public speaking by listeners are characterized by a strong "delivery", i.e. by a strong tone-of-voice performance, which proved to be valued higher by listeners than the choice of words [1-4]. For example, charismatic speech has frequently and consistently been associated with specific acoustic cues such as a higher f0 register, larger f0 excursions, a higher speaking rate, and a more energetic, louder voice quality [5-9]. Cooperative communication as found in collaborative team work situations, on the other hand, has been associated with the phenomenon of prosodic entrainment. Prosodic entrainment means that speakers adjust their acoustic features relative to those of their interlocutor [10,11]. A stronger degree of entrainment often co-occurs with a higher degrees of cooperation and rapport as well as with a closer collaboration [12]. Moreover, the higher the degree of entrainment the greater is the success in, e.g., learning tasks [12-14]. In general, prosodic entrainment has been linked to facilitating social bonds by signaling and shaping social closeness [10,11].

If proficiency in self-presentation and public speaking is linked with specific acoustic parameters that, together, form a charismatic tone of voice, then it should be possible to predict the general competence in self-presentation as well as the competence of structuring one's line of argument from the ability to use these acoustic features. Furthermore, if successful team working and cooperation in dialogues is linked with high degrees of prosodic entrainment, then the ability to perceive and employ prosodic entrainment should predict a speaker's cooperative communication and team working skills.

We want to note, however, that the link between prosodic competence scores and communicative skills does not need to be immediate to be assessable. A charismatic tone of voice may be linked to a strong self-presentation through tertiary feats such as confidence and expressiveness. Greater degrees of prosodic entrainment may be linked to a speaker's team working skills through empathy, general sociability or extraversion. This issues will be addressed with respect to the results in the discussion.

To assess both persuasive self-presentation and public speaking as well as the capability of prosodic entrainment we used two acoustically based assessment methods. Both are currently employed in business consulting and coaching. The PASCAL procedure ("Prosodic Analysis of Speaker Charisma: Assessment and Leaning", patent pending, [16]) calculates a charismatic persuasion score based on samples of audience-directed speech. The DPA score ("Dynamic Prosodic Adaptation") underlies the acoustic assessment of prosodic entrainment. Specifically, DPA calculates a speaker's ability to perceive and adapt to changes in prosody from short stretches of speech in communication-like situations. We assume that the PASCAL score can predict a speaker's ability to present him/herself as well as a given topic in a convincing, structured, and clear manner. Furthermore, we expect the DPA score to predict a speaker's ability to communicate in a team environment, with higher DPA scores resulting in better team work and, thus, a better output and internal organization of the team.

In this pilot study we test these assumptions by measuring, for 22 first-semester students of Electrical Engineering (BSc), the individual PASCAL and DPA scores and correlating them with the students' course grades and project work. In this setting we expect the PASCAL score to predict the students' behavior in terms of their final project presentation performances, both in oral and in written form. The DPA score is expected to predict how well the students performed within their project teams with respect to time management, distribution of workload, internal communication, and the overall outcome of team-related assignments.

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2. Method

1.1. Participants

The study was conducted with 22 first-semester Electrical Engineering students (BSc) at the University of Southern Denmark (SDU), 18 males and 4 females. The students were between 19 and 23 years old and proficient speakers of L2 English from a variety of different native languages (level B2 or higher according to SDU-internal entry tests). All students participated in a 14-week Electrical Engineering hands-on project whose goal was to design and create (from scratch) a weather station based on electrical sensors with at least three different functionalities (e.g., temperature, rain detection, wind speed, air pressure, humidity, night/day detection).

1.2. Procedure and acoustic analysis

In the first lecture of the 14-week Electrical Engineering hands-on project, the charismatic self-presentation score PASCAL and the dynamic prosodic adaptation score DPA were determined for all 22 participants as described below. The weather station project was conducted in 7 separate teams of 3-4 students. In order to assess the influence of the DPA score on team work, the students were assigned to their teams such that each team included members with very different (higher and lower) DPA scores. One of the participants dropped out during the course and did not take part in the final exams. Accordingly, we omitted this student from the analysis. Thus, the finally analyzed student sample is N=21.

1.2.1. PASCAL – Self-presentation performance

To assess the PASCAL score [16], students were asked at the beginning of the project course to give a short speech in the form of an engineering-product sales pitch directed at a larger audience (their course mates). The 21 speeches were recorded using a Zoom H5n digital speech recorder (48 kHz, 24 bit). Praat [17] was used for the acoustic analysis of the recordings. We automatically labeled phrase boundaries and syllable nuclei for the calculation of speech rate and articulation rate based on the Syllable Nuclei script [18,19]. Features of f0 and voice quality (BID) were extracted using the ProsodyPro script [20]. We calculated a basic PASCAL score from a sub-set of six features of the maximally 16 features that are included in the most comprehensive PASCAL score (typically, the Pascal score is based on 7-9 features). The basic PASCAL score used here relied on the six most important prosodic features.

In a nutshell, PASCAL is based on the idea that, firstly, all acoustic features have individual feature weights and that, secondly, feature values are not linearly correlated with perceived speaker charisma but show a sweet spot (see also [5]). The value of the sweet spot varies as a function of gender, age, culture/language, and speaking task. The charisma levels to both sides of the sweet spot decrease again with feature-specific slopes and to feature-specific degrees.

1.2.2. DPA – Team-working performance

For the DPA score, students took part individually in a 20-minute task designed to assess their ability to perceive and adapt to prosodic changes. The task was developed as an imitation experiment (cf. [21-23]) in order to link perception to production. Like for PASCAL, we also used only a basic version of the DPA score that focused on the f0 mean. Participants listened to a series of randomized speech stimuli (short sentences such as *I like to work in a team* or *Are you traveling a lot by train?*) from a speaker of the opposite sex whose f0 register varied in equidistant semitone intervals, and responded naturally and spontaneously but paying special attention to adapting to the speaker's register. Recordings were made using the same Zoom H5n digital speech recorder again (48 kHz, 24 bit). F0 features of the participants' responses were extracted using Praat [17] and a script written by the second author. From the participant's responses we calculated the DPA score as a weighted correlation between stimulus and response pattern based on previous research.

1.2.3. Assessment of performance

The assessment of the students' performance in the Electrical Engineering project consisted of three parts, all of them took place in the final (14th) week of the course: (1) an evaluation of the quality and functionality of the constructed weather station, (2) a written report about the entire design and construction process, and (3) an oral exam in which the students showcased and explained their finished weather station project.

Regarding (1), the quality and functionality of the weather station was assessed by the principal course lecturer who was neither a phonetician nor informed of the purpose of this study. We use the evaluation as a measure (dependent variable) to investigate whether a higher DPA score correlates with a better team performance connected to more effective team work.

From part (2), i.e. the written reports, we drew two dependent variables for this study. Firstly, the reports of all teams included a section in which the students graded their own team's performance and time management. That is, they rated how well they perceived the team members to work together, for example, in terms of remarks on internal communication, and effective distribution of workload and milestone responsibilities. This first variable served to assess how well the team members organized themselves, and how well this correlates with the DPA score. Secondly, the report was graded by an independent expert jury of engineers (lecturing at SDU) in terms scientific paper standards like clarity of presentation and illustration, choice of references, quality of arguments and critical reflection, etc. We used this report grade as a dependent variable to investigate whether the students' ability to express themselves persuasively in written language is correlated with the team's mean PASCAL score.

Figure 1: *Example of oral exam concerning the student's contribution to creating the weather-station (top right).*

Part (3), i.e. the oral exam, was subdivided into a team exam and individual exams. In the team exam, each project team as a whole presented their weather station to an expert jury of engineers (lecturing at SDU), mostly supported by a

PowerPoint presentation. In the separately graded individual oral exams, each student presented his/her individual contribution to the team's weather station project and motivated and justified the engineering decisions that s/he had made in front of the same an expert jury of engineers (without PowerPoint support). We used the latter individual presentation grades to correlate them with the PASCAL score. In this way, we test whether persuasive speaking correlates with giving good oral presentations (the teams' oral exam grades were also correlated with the team members' individual PASCAL scores, but these results are presented in a follow-up paper).

Figure 1 shows an example of an individual oral presentation in combination with the final weather station built within 14 weeks by one of the 7 student teams.

1.3. Statistical analysis

For the statistical analysis we calculated linear regression models using R's lm-function [24]. As fixed factors, we used the PASCAL score and the DPA score as well as their interaction. As dependent variables, we used the grades given in % of the best conceivable performance for the oral presentation (*oral grade*), the written report (*written grade*), the self-assessed time management and team working competence (*time management*), as well the quality and functionality of the finished product (*product quality*). These percentages were translated into the 7-point Danish academic grade scale at a later stage [25].

3. Results

Table 1 reports the statistical results for the PASCAL score. We find a significant effect with a strong positive correlation between the individual oral-exam grades and PASCAL scores, and another significant, but weaker positive correlation between the team grades of the written report and their PASCAL scores. There are no correlations between PASCAL scores and time management or product quality. For the DPA score, we find significant correlations with time management as well as with product quality. Like for PASCAL, both DPA score correlations are positive, see Table 2. That is, the higher the students scored along the PASCAL and DPA scores the better they performed in the weather-station project. Figure 2 illustrates the strongest correlation found in our data, i.e. that between the individual students' PASCAL scores and their performance in the graded oral exam.

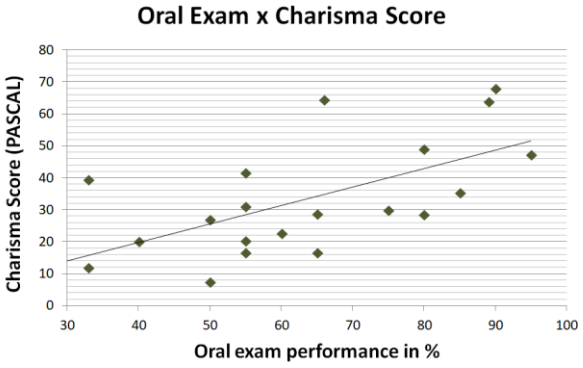

Figure 2: *Correlation (based on individual students) between PASCAL score and oral exam performance. N=21.*

Table 1: *Statistical results for effects of a speaker's PASCAL score on communicative performance.*

Dependent	*b*	*SE*	*t*	*p*	R^2
oral grade	0.84	0.17	4.95	<.001	0.56
written grade	0.08	0.03	2.44	<.05	0.24

Table 2: *Statistical results for the effects of a speaker's DPA score on communicative performance.*

Dependent	*b*	*SE*	*t*	*p*	R^2
time management	0.23	0.10	2.21	<.05	0.20
product quality	0.14	0.07	2.19	<.05	0.20

4. Discussion

The results show that both the charisma score PASCAL as well as the cooperative communication score DPA correlate with general communication competences. In fact, the two scores not only correlate directly with communication skills used in oral presentations and team work [5-15], but also indirectly with the measureable (here: graded and self-graded) outcomes of these skills. In short, what we show here is that we can predict students' exam grades on the basis of prosodic measurements in speech acoustics.

We find a strong correlation of the PASCAL score and the grade given for the final oral presentation. Accordingly, speakers who performed better in terms of a clear, fluent, and competent presentation of the weather station and its creation process also showed stronger features of charismatic/ persuasive public speaking, cf. [5-9]. On the one hand, this correlation could stem from communicative skills related to content, i.e. clarity of expression and structure, which, in turn, have an effect on the analyzed prosodic parameters. On the other hand, a persuasive speaker might not necessarily be significantly more proficient with respect to his/her general presentation skills. Instead, s/he may profit from the persuasive power of a charismatic voice [9,26,27]. According to several studies, a charismatic delivery in terms of acoustic features does not only play a key role in a charismatic impression but may also outweigh the linguistic content of a presentation [1-4]. Hence, the delivery of the same presentation may achieve better grades due to the persuasive nature of a charismatic voice.

Although the two explanations are not mutually exclusive, the second effect we found lends support to the first explanation: The PASCAL score shows a significantly positive correlation with the grade of the written report. The written report had the form of a scientific paper after the example of a proceedings paper. Accordingly, the criteria were clarity of expression and argumentation. Since we find a significant connection between scientific writing competences and acoustic persuasiveness, this supports the assumption that both acoustic charisma competence and general linguistic style competence are related and converge on a common communicative skill. Although significant, the effects for the written grade are much weaker than for the oral presentation. However, this is expected as it suggests that there is no immediate connection between writing and acoustic performance but rather an indirect relation as both are based on the same basic skill set.

For the DPA score we find two effects. Firstly, the DPA score correlates positively with time management and team work. Note that time management and team work were assessed through self-perception by the students. Accordingly, the DPA score did not correlate with an objective assessment of time

management and team work performance but with the students' impression of it. This suggests that teams consisting of students with a higher DPA skill (prosodic entrainment based on mean f0) perceived their communication and internal organization as being better. Research shows that higher degrees of cooperation, collaboration, rapport [12] and a higher success rate in different learning tasks [13-15] are correlated with higher degrees of prosodic entrainment. According to the *communication accommodation model* [28] and the *theory of alignment* [29], entrainment is not only coincidently related to cooperative communication but plays a major role in signaling social closeness [10,11], which, in turn, enhances and facilitates social bonds and increases dynamic group processes. We hypothesized that being able to perceive and adapt to fine changes in prosody is a necessary perquisite for being able to perceive and employ prosodic entrainment in natural conversations. Furthermore, we assumed that the ability to prosodically entrain in natural conversations and to be cooperative are generally connected in one of two ways. Either more communicative individuals develop a finer acoustic proficiency to entrain or a naturally higher acoustic proficiency makes someone more susceptible to subtle social cues like prosodic entrainment, allowing for the development of cooperative social skills.

Accordingly, we provide two potential explanations for the correlation between self-assessed time management, team work and the DPA score. Firstly, teams whose members showed higher DPA scores actually possessed stronger communicative skills and engaged in a more efficient cooperative communication, which then resulted in a better coordination among team members, i.e. a more balanced distribution of assignments, more sharing of information, etc. On this basis, these teams could have achieved better time management and a better overall team work. An anecdotal observation from the principal course lecturer supports this. He perceived teams whose members all had moderate-to-high DPA scores to quickly and extensively engage in conversations from the start, while teams with moderate-to-low DPA scores barely talked to each other at all at the beginning. Alternatively, since the team work was self-assessed, it is possible that students in the overall higher scoring DPA teams merely perceived their team work to be better. Since high degrees of entrainment correlate with social closeness, which is also related to conversational quality [30,31], mutual liking and encouragement [32], and generally positive impressions, members of teams showing relatively high degrees of entrainment may simply have perceived interactions inside their teams as more fulfilling and pleasant, hence evaluating their time management and team working as much more positive than the members of overall lower scoring DPA teams. This is also supported by anecdotal evidence from the principal course lecturer: Although the overall higher scoring DPA teams started to interact faster and livelier, he observed the conversations to frequently stray away from the weather station project, while the overall lower scoring DPA teams talked less but stayed more focused on the task at hand. Accordingly, higher scoring DPA students could be more communicative and talkative, without this having positive implications for team work.

Furthermore, we find that the DPA score also correlates with the objectively assessed quality and functionality of the finished product. So, the teams with the higher DPA scores achieved better results at the end of the 14-week weather station project. Again, there are two possible explanations. Firstly, prosodic entrainment may have played an immediate role in facilitating team work. That is, a higher DPA skill allows to perceive and employ prosodic entrainment better, which then leads to stronger cooperation and team work and, in consequence, to a better project output. The alternative explanation is that, similar to the PASCAL score, the ability to use prosodic entrainment could be linked to a general communicative competence. Individuals who have strong social and communicative skills in cooperation and social bonding also feature higher DPA scores. This would mean that social competence leads to better team work and, consequently, to a more successful work output; and DPA serves as an indicator for said social competence.

The latter assumption is supported by the fact that the correlation between DPA score and product quality was significant but weak. In general, we note that both effects for DPA were relatively weak compared to the effect for PASCAL and its measured oral presentation skills. However, besides the fact that the sample size of this pilot study was relatively small, the primary explanation would be that the oral presentation grade is closely linked to the communication quality measured by the PASCAL score, whereas the two DPA effects are not. The self-assessment of team work only captures the participants' impression of the situation, which is shaped by the actual quality of the team work but also several external factors. While the cooperation of the group is certainly a key factor to the final product quality, other factors ranging from intelligence over professional expertise and experience to external time constrictions and workload differences all contribute to the product quality. Accordingly, it would be necessary to find a measurement that actually captures team work competence as a social and communicative skill and then directly relate it to DPA, as was done for oral presentations and the PASCAL score.

Finally, we conclude with reporting an anecdotal observation made for both DPA and PASCAL scores during their application in the real world. Although it highly depends on the individual, there is an irrefutable tendency for some professions to rely more strongly on communicative skills than others and accordingly to favor individuals with higher proficiency in these skills. If DPA and PASCAL reflect those communicative competences, we expect differences in these scores between professions. This is confirmed by our experience of assessing DPA and PASCAL scores in business consulting. A sample of participants who studied to become teachers in German were found to show average and slightly above average scores for both DPA and PASCAL. Students of electrical engineering, however, showed very low PASCAL scores and even lower DPA scores relative to the teachers' scores. We also assessed 42 sales representatives of a large German bank and found their average scores to be 30-40 % above those of the teachers and 60-70 % above those of the electrical engineering students. Furthermore, several participants in the banking group reached unexpectedly high values that resulted in a readjustment of the score (esp. DPA).

One drawback of this study is the skewedness of the sample for speaker sex. Although both PASCAL and DPA take speaker sex into account and there were no specific speaker sex differences in the outcome, this issue has to be investigated in the future, especially with respect to entrainment. Secondly, our pilot sample consisted of L2 speakers from different L1s. Again, although no L1 specific effects could be observed, cross-cultural differences in charisma and entrainment should be investigated and considered in future research.

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