Psychophysiological reactions to persuasive messages deploying persuasion principles

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Psychophysiological Reactions to Persuasive Messages Deploying Persuasion Principles

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Abstract— Measurement of physiological reactions to persuasive messages can improve our understanding of psychological processes of persuasion, and potentially further enhance and personalize current persuasion interventions. However, little is known about the relationship between psychophysiology and persuasive processes. This study focused on four persuasion principles: scarcity, commitment, consensus, and authority, and people's susceptibility to them. Physiological measures included the cardiovascular, respiratory, and electrodermal system, as well as facial motor systems. Psychological measures consisted of self-reported attitude towards oral care and susceptibility to persuasion (STPS). We performed a randomized within-subject experiment in which fifty-six participants viewed persuasive messages deploying the aforementioned persuasion principles to improve their oral care. Results indicated different physiological patterns during persuasion versus rest. We found no different physiological patterns in exposure to distinct persuasion principles, nor a clear correlation with susceptibility to individual persuasion principles. However, mixed model analysis illustrated that overall STPS scores help explain variance in reactivity of skin conductance level and skin conductance response, and reactivity in the zygomaticus major: lower susceptibility relates to higher reactivity. Summarizing, we have found no conclusive support for distinct psychophysiological patterns associated with different persuasion principles, although overall susceptibility seems to be reflected in physiology to some extent.

Index Terms— Affective computing, arousal, persuasion profiling, physiological measures, valence

1 Introduction

Despite good intentions, most people struggle with changing their behavior towards a healthier or more sustainable lifestyle. A considerable body of research has therefore emerged around behavior change interventions, which provide support for people when trying to change their behavior. One way to increase effectiveness is by tailoring the intervention [1]–[4] to specific characteristics of the individual. For this approach, understanding the psychological processes underlying persuasion is essential for the success of tailored interventions [5].

Currently, the effects of persuasion on human experience and behavior are analyzed using self-report measures and observational data [4]. However, there are additional ways to gain insight, for instance using psychophysiology. As some psychological events cause changes in one's physiology [6], psychophysiological variables and their relationship with psychological events might tell us something about mental processes underlying persuasion. Psychophysiological measures can help in explaining behavior and human experience, reflecting deeply rooted physiological reactions as triggered by the nervous system. Thus, they can serve the same goal as self-report measures, but are less subject to biases that are inherent to self-report introspection processes [7]. Moreover, in comparison to self-report, psychophysiological measures have the advantage that they can be applied without interrupting the user and can be used continuously throughout a persuasive intervention. This may thus yield a measure that has higher temporal resolution, potentially picking up on subtle changes in experience in-the-moment, which might be missed using a retrospective summary measure such as self-report. Importantly, real-time measures of physiology could be applied to adaptive and personalized interventions, as the interactive application may take such psychophysiological indicators explicitly into account (see e.g. physiological responses in affective loops improving dynamic game balance [8]). Psychophysiological information could therefore enhance behavior change interventions by allowing physiology-contingent selection and tailoring of persuasive content, and unobtrusive optimization of persuasion interfaces.

Thus far, only few studies have investigated the psychophysiology of persuasion [9]–[11] and a firm link between persuasion and physiology has not yet been established. This paper will give a brief overview of previous literature on psychophysiological processes during persuasion. The next section will describe the psychological processes of persuasion. Then we discuss the meaning of physiological reactions and their link to psychology. Next, we explain why a link between bodily processes and psychological susceptibility to persuasion is expected. The remaining part of the paper discusses a study exploring physiological reactions of the peripheral nervous system to messages employing various persuasion principles.

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2 Related Research

2.1 Overall processes of persuasion

Changing behavior involves a complex interaction of internal and external motivations. Persuasion is an external motivator with the goal to change one's intention and attitude towards a certain topic, while still having the free will to think or do otherwise [12]. If the persuasion is successful, the resulting change in attitude and intention can potentially change behavior [13]. A way to model the impact of persuasion on intention and attitude is the elaboration likelihood model (ELM, [14]). This model centers on the probability that a person considers the communicated message. Therefore, the impact of persuasive cues can vary in correctness, motivation and elaboration of a person [14]. These variations result in the prevalence of either a central or a peripheral route during persuasion: the *central route* provides conscious evaluations of the communication, whereas the *peripheral route* is based on simple inferences and affective associations tied to the persuasion context [15]. If both motivation and ability to process the message are high, the central route is more likely to prevail than the peripheral route [12], [14].

Given this, the prevailing processing route can be manipulated, e.g. hampering one's awareness of being persuaded by realizing situations where persons are not able to process a cue via the central pathway due to time constraints [10]. Professional persuaders use this in their benefit. Cialdini's *persuasion principles* describe six manipulations of this kind [16]:

- The *authority principle* implies that people comply more when the source is a legitimate authority.
- The *reciprocity principle* suggests that people feel obliged to return a favor or have the norm to do so.
- The *scarcity principle* describes how scarce things become more valuable.
- The *commitment and consistency principle* denotes people's tendency to follow pre-existing commitments and relates to the cognitive dissonance theory.
- According to the *social proof* or *consensus principle*, people tend to use others as an example when they are uncertain.
- The *liking principle* explains peoples' tendency to behave more positively to what they know or like.

Cialdini's principles effectuate persuasion via the peripheral route by manipulating peripheral cues, e.g. source credibility, instead of argument quality [16].

2.2 Individual differences in susceptibility to persuasion

Although these principles have, on average, positive effects on compliance with persuasive requests, not every principle is equally effective for everyone [16]. Previous research indicates that individual differences in traits such as need for cognition [15] and involvement [5], [12] induce diverse compliance to persuasive strategies. For example, people scoring high in need for cognition and involvement are more likely to be persuaded via the central route than via the peripheral route [15]. This explains the differences in persuasion route effectiveness among different persons. These individual differences are used in personalized behavior change interventions to increase effectiveness [1], [5].

Besides differences in susceptibility to persuasive strategies, there are also differences in susceptibility to distinct persuasion principles that can be used for personalization [4], [17]. Kaptein et al. [4] developed a *susceptibility to persuasion scale* (STPS), measuring individual differences in susceptibility to Cialdini's persuasion principles. Doing so, these individual differences can be used as a relative advantage to persuade instead of a liability. The scale successfully profiles the expected compliance to a request when formulated by specific persuasion principles and enables personalized use of persuasion principles [4]. However, by explicitly assessing these persuasion profiles, the person has to consent with filling in the questionnaire. Therefore, he or she will be aware of the measure and might be able to imagine its influence on the intervention. Despite the successful use of meta-judgmental measures to tailor persuasion principles, there is controversy in literature about the precise underlying mechanisms [5]. Thus, although differences in susceptibility to persuasion are measurable and usable for personalization, other, and specifically implicit, ways to measure the impact of various persuasion strategies may yield additional insight in underlying psychological mechanisms. In the future, this knowledge may be used to further tailor persuasive interventions with implicit profiles.

2.3 Psychophysiology in persuasion research

The psychophysiological research domain is based on the observation that our experiences and physiology are integrated [6]. In other words, various cognitive or affective states are distinguishable in physiology, which makes psychophysiology an implicit measure of the mind, considering both conscious and unconscious psychological processes [6], [18]. Persuasion aims at changing psychological states such as intentions and attitudes that could result in behavior change [12]. For a person, it might not be easy to comply with persuasive cues, as changing behaviors and habits requires high levels of self-control, self-regulation, effort and attention. This strong appeal on a person's resources activates the prefrontal cortex [10] and potentially induces negative emotions. When being confronted with their 'wrong' behaviors people might experience feelings, such as frustration or annoyance, which might lead to psychological reactance [19], [20]. Therefore, persuasive messages might change a person's valence and arousal states. As affective states have physiological correlates [21], these states caused by persuasion might also result in detectable physiological signs.

Indeed, earlier research indicated changes in cardiovascular arousal due to narrative persuasion, i.e. successful persuasion was characterized by lower heart rate variability [9]. This indicates that psychophysiological metrics during persuasion might reflect the effects of persuasive cues. Furthermore, there is a growing amount of papers on the neural correlates of persuasion [10], [11], [22], of which some claim that neural correlates indeed predict the effectiveness of persuasion even better than self-report measures [22], [23]. Since the same neural correlates also relate to peripheral physiology such as cardiovascular arousal [24]–[26], this again appears to hint at a psychophysiological impact of persuasion. However, a direct link between distinct persuasion strategies and the peripheral nervous system has not yet been established. Therefore, this paper sets out to assess this link by exploring reactions of the peripheral nervous system to different persuasion principles.

2.4 Physiology of affective states

As the relation of psychophysiological parameters with persuasion is still unknown, we took the broadly established valence-arousal framework as a research basis, also known as the circumplex model of affect [27]. The model states that emotions are not discrete singular states, but come from complex interactions between cognitions and neural structures emerging from two independent neurophysiological systems [28]: 1) the valence-neural circuit finds it basis in the mesolimbic system linked to dopamine release when processing valenced emotions, e.g. negatively valenced anger or positively valenced joy. 2) The arousal-neural circuit regulates the arousal level of the central nervous system through its connection with the limbic system and the thalamus, e.g. low arousal levels during boredom versus high arousal levels during anger [27]. The prefrontal cortex interprets and acts upon the signals from the valence and arousal circuits and, thereby, facilitates conscious emotions [28].

The valence-arousal framework connects affective states to neurophysiological systems [28]. Affective states have also been linked to changes in the peripheral nervous system (see [21] for full review). As these peripheral parameters are easily accessible with wearables and incorporable in persuasive technology, this paper focuses on responses of the autonomic and somatic nervous system. In the autonomic system, reactivity of the cardiovascular system (CVS), the electrodermal system (EDS) and the respiratory system (RPS) predominantly indicates arousal, and reactivity of the somatic nervous system facial muscle activity indicates valence. Each subsystem provides different information about cognitive and emotional processes. The main functions, important parameters, and the meaning of activity changes for the physiological system are described briefly in Table 1.

Earlier findings in psychophysiological persuasion research can be linked to the valence-arousal model: effective narrative persuasion resulted in lower heart rate variability (HRV) compared to absence of persuasion [9]. Activity in the medial prefrontal cortex (mPFC) correlates positively with behavior change [10], [11], [23], [33]. Research also indicated that activation of the mPFC can lead to decreased HRV and increased HR (for detailed information see [25], [26]). These findings suggest an increase in cardiovascular and neural arousal during persuasion, but proof for a specific persuasion valence-arousal pattern is still thin. Not all earlier results can be easily compared, as different persuasion strategies might have different effects, e.g. empathetic narrative persuasion [9] does not elicit the same psychological response as gain/loss-framed messages [10]. In similar vein, different persuasion principles will probably not elicit the exact same degree of valence and arousal. In addition, individual differences in susceptibility might also reflect in physiological reactions, e.g. someone with higher susceptibility to a certain principle will have a different valence-arousal pattern than someone with lower susceptibility to

TABLE 1
MAIN FUNCTIONS, IMPORTANT MEASURES AND INTERPRETATIONS OF ACTIVITY CHANGES FOR PSYCHOPHYSIOLOGICAL SYSTEM OF INTEREST

Cardiovascular system [6], [29] provides blood flow to all the tissues in the body, thereby, ensuring the supply of oxygen and depletion of waste. Both hormonal and autonomic systems regulate blood flow, making the CVS highly responsive to neurobehavioral processes. • **Heart rate (HR)** is the number of R peaks (heartbeats) within a minute. Increased heart rate indicates a state of higher arousal. • **Standard deviation normal-to-normal peaks (SDNN)** reflects all cyclic components responsible for variability in the time between heartbeats (interbeat interval, IBI) in the fixed whole period of recording. Decreased SDNN reflects prolonged higher states of physical and emotional arousal. • **Root mean square of successive differences (RMSSD)** is the variability in IBI differences, thus filtering out lower frequency variability. High frequency HRV is an index of parasympathetic cardiac control. It reflects sudden changes. Decreased RMSSD reflects sudden higher states of physical and emotional arousal.
Electrodermal system [6], [30] focuses on the sweat glands, as skin conductance varies with sweat gland activity. Arousal in the sympathetic nervous system results in increased electrodermal activity. Skin conductance is sensitive indicator of both psychological and physiological arousal. • **Skin conductance level (SCL)** is the tonic component of the skin conductance. • **Skin conductance responses (SCR)** are rapid phasic components.
Respiratory System [6] has as primary task to supply oxygen and deplete carbon dioxide in the blood. Automatic regulation operates via the brainstem. Voluntary regulation involves different cortical areas. • **Respiration rate (RR)** is measured via mechanical movement of the diaphragm and rib muscles. Changes in RR relate to task difficulty and cognitive problems. Higher respirations rates indicate increased arousal.
Facial muscle activity [31], [32] can provide quantitative information about affective states and expression. Activity is measured with electromyography where the waveform of the signal reflects the contributions made by all active muscle motor units in the area of interest. • **Zygomaticus major** (**EMG-ZM**) muscle is located in the cheek and activity associates with psychological states of positive valence. • **Corrugator supercilii** (**EMG-CS**) muscle is located in the eyebrow and activity associates with psychological states of negative valence.

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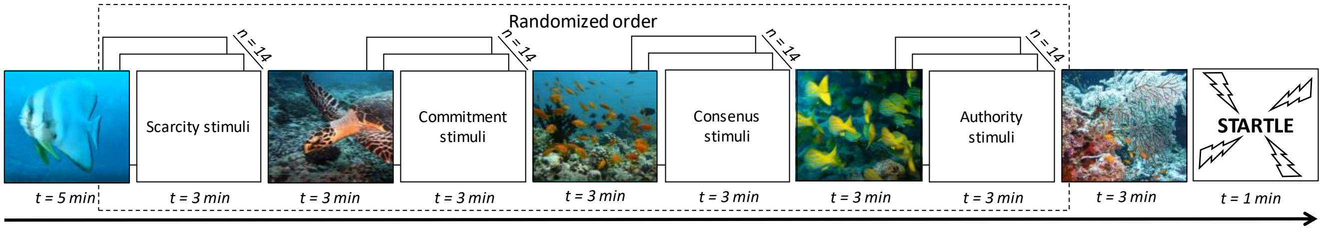

Fig. 1. Visual representation of the experiment conditions. Each manipulation condition consisted of 14 persuasive messages and lasted 3 minutes. The manipulation conditions occurred in randomized order alternated with short sea life clips. A longer clip was presented at the beginning for baseline recordings and a short acoustic startle was presented at the end to elicit a maximum range of physiological values.

the same persuasion principle. By analyzing physiological reactions during persuasion in perspective of the valence-arousal model, it might be possible to classify and/or group the impact of various persuasion principles. This could create extra insight in the underlying processes of persuasion.

2.5 Study Aims and Hypotheses

This paper investigates whether physiological reactions to persuasive messages provide additional insights into the individual susceptibility to persuasion in general and to various persuasion principles specifically. It aims at finding a relation between scores on self-reported susceptibility to persuasion and physiological arousal during exposure to persuasion principles. Most earlier studies do not consider individual differences and compare results between groups of participants [9], [23], even though comparison of reactions to different persuasion principles within one individual is equally informative. Especially when individual differences in physiological reaction reflect differences in individual susceptibility to persuasion principles, it might be possible to make implicit persuasion profiles based on psychophysiological data. If it is established how the cardiovascular, electrodermal and respiration system respond to different persuasion principles and what this represents in terms of susceptibility to persuasion, this information can be used to implicitly profile and further personalize future persuasion interactions, and thereby enhance behavior change interventions [5].

Given the background described in the introduction, we formulated the following hypotheses: 1) There is a difference in physiological responses in exposure to persuasion principles compared to rest state. 2) Different persuasive principles elicit different physiological patterns, as the principles target different psychological aspects. 3) The difference in physiological responses during persuasion relates to self-reported susceptibility to persuasion – higher susceptibility to a certain principle is expected to evoke more physiological arousal in exposure to that principle.

3 Methodology

3.1 Design

This study has a within-subject design with persuasion manipulations employing four (out of six) persuasion principles, as formulated by Cialdini [16]: scarcity, authority, commitment and consensus. Liking and reciprocity proved to be difficult to implement in our non-interactive setting [4], [34]. The manipulation messages promoted oral care by increased tooth brushing behavior, since this is a preventive health behavior associated with considerable general health indices [35]. Participants' individual susceptibility to persuasion was measured to predict the effectiveness of the persuasive cues and relate it to physiological responses. The study has six blocks - one baseline of physiological state, four randomized persuasion blocks and an acoustic startle. The difference in arousal between baseline and startle illustrates the range of participants' physiological reactions and helps interpret the differences in physiological reactions to the persuasion principles applied in the study. Physiological arousal and valence will be assessed by different parameters of the nervous and affective system - the cardiovascular, electrodermal, respiration and facial motor system.

3.2 Participants

Sixty healthy participants (average age 48 years, s.d. = 9.6, range = 18 – 60), who indicated to usually brush their teeth less than 2 minutes per session, participated in a 1-hour experiment. Individuals with a history of cardiovascular diseases and pregnant females were excluded from participation. To enhance commitment to the study, participants were led to believe they would participate in a 1-week trajectory to improve their oral care, starting with a laboratory study.

3.3 Manipulation

The four blocks of the manipulation were based on the persuasion principles scarcity, authority, commitment and consensus [16]. Per principle, 14 messages aiming at increasing teeth brushing time were constructed (examples in Table 2). Messages were based on earlier research employing persuasion principles [4], [16] and presented in the native language of the participants (Dutch) to control for language biases. Important parts of the sentences appeared in bold. Each block consisted of an equal number of messages directly focusing on the behavior to change, i.e. *'dentists advise to brush your teeth two minutes per session'*, and messages containing peripheral cues effecting behavior change, e.g. *'dentists advise to participate in his study'*. Based on several pilot trials, exposure to a single message lasted 8 seconds to standardise the speed of information processing across participants. Messages were alternated with a fixation point lasting 3 seconds. Participants were exposed to all messages in each block. Block and message order was randomized by OpenSesame software [36]. Each block lasted around 3 minutes (Fig 1).

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TABLE 2
SUBSET OF THE PERSUASIVE MESSAGES DEPLOYING PERSUASION PRINCIPLES

Principle	Message
Authority	*Try brushing your teeth well. According to* ***the College of Dental care,*** *this is an easy way to lead a healthy life.*
Authority	***Doctors*** *say that dental health relates strongly to your overall health. Therefore, participate in this experiment.*
Scarcity	*Changing your oral care habits in the future will not reverse teeth decay.* ***Now is your chance*** *to work on healthy teeth.*
Scarcity	*Your dentures give you* ***a unique appearance****. Do not ruin this and brush your teeth twice a day for two minutes. Starting now.*
Commitment	*Try to achieve your goal to live a healthier lifestyle by brushing your teeth twice a day for two minutes.* ***Stay committed****!*
Commitment	*You participated in this study to improve your oral care.* ***Finish what you started*** *and give your teeth the care they need.*
Consensus	***Everyone agrees:*** *Brushing your teeth twice a day for two minutes improves multiple aspects of your life in terms of health and appearance.*
Consensus	*You are not alone:* ***95% of the preceding participants of this study*** *have already increased their healthy brushing behavior.*

Sentences are translated from Dutch; Number of words per sentence mean = 20.29; s.d. = 4.37; range = 12 – 30

3.4 Self-report measures

In addition to questions about demographics, participants' relation to oral health care was assessed with questions regarding past behavior and attitude. Past behavior focused on the quantity and quality of teeth brushing. Based on the theory of planned behavior, five questions reflecting the observed quality and instrumental nature of the behavior provided insight in the participant's attitude towards the targeted behavior [13]. Furthermore, the Ten-Item Personality Inventory (TIPI), a 10-item measure of the Big Five personality dimensions, was administered [37]. To determine participants' individual susceptibility to persuasion, the Susceptibility To Persuasion Scale (STPS) by Kaptein et al. [4] was administered. The STPS is a self-report measure assessing susceptibility to each distinct persuasion principle (all six principles were included, including the two we did not use as manipulation). The scale has 26 items fitting the underlying latent variables (7-point scale ranging from *"completely disagree"* to *"completely agree").* All questionnaires in this study were validated in previous research and were analyzed as instructed [4], [13], [37].

3.5 Physiological measures

For cardiovascular measures, three sticky Kendall H124SG ECG electrodes measured electrocardiography (ECG): one electrode on the right side of the torso below the collarbone, a ground electrode on the left side below the collarbone, and one electrode on the left side of the torso underneath the ribs. Two dry electrodes fastened on the thenar eminences of the palms measured electrodermal activity (EDA) [6, p. 163]. Respiration rate (RR) was measured with a piezoelectric belt transducer around the chest [6]. Facial electromyographic (EMG) measures consisted of four reusable Ag/AgCl surface electrodes attached with disposable adhesives to the skin on top of the zygomaticus major (EMG-ZM) and corrugator supercilii (EMG-CS) [31]. The physiological parameters of interest were recorded simultaneously using a NeXus-10, i.e. a multi-channel ambulatory system with bipolar electrophysiological inputs and a maximum sample rate of 1024 Hz.

3.6 Procedure

Participants were instructed to refrain from drinking caffeinated beverages in the 2 hours preceding the experiment. To enhance engagement, instructions emphasized that the lab task prepares the participants for a successive week in which oral health care would be monitored and coached. Participants were attached to the NeXus-10, seated in front of a computer screen and given a closed headset. Custom OpenSesame software with a Legacy-backend [36] executed the experiment by a script starting with the self-reported measures, excluding the STPS. While a recording of their physiological arousal was performed as a baseline measure, participants watched a 5-minute fragment of the neutral sea life video 'Coral Sea dreaming' with classical music, since a relaxing video is known to lower physiological arousal [38]. Afterwards, the manipulations were displayed on the computer screen. Alternating the four manipulation blocks, different 3-minute emotionally neutral sea life videos were put on display allowing the physiological system to return to baseline levels prior to each manipulation (see Fig. 1). Each stimulus block lasted around 3 minutes to allow HRV analysis [29]. To evoke a startle response, a loud unexpected 1000 Hz sine tone and white noise mix accompanied with a big red cross appeared after the last block. The STPS was taken at the end just before debriefing to eliminate the possibility that its questions would influence participants' perception of the manipulation.

3.7 Signal processing

The first step to signal processing of the psychophysiological data was signal quality enhancement by elimination of those observations that are artifacts or outliers. A 50 Hz notch filter was applied to all signals. R-peaks in the ECG signals were detected using EDFBrowser [39], and inter-beat intervals (IBIs) were derived. Inter-beat intervals outside 0.4-1.4s were manually checked and interpolated if the value seemed an artifact. EDA was filtered with a 0.5 Hz low-pass Butterworth filter. The signal was down sampled to 2 Hz. A low pass cutoff frequency of 0.5 Hz was applied to the respiration signal. EMG outliers were removed using a limit of 10^{-4} mV on a normalized histogram. Both EMG signals were filtered with a 20 Hz high-pass filter. The full-wave EMG signal was rectified [31].

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The second step was parameter extraction from filtered data for each experimental condition: baseline, manipulation blocks, rests in between blocks and startle response. From filtered IBI data, mean heart rate (HR) was computed as well as heart rate variability (HRV) by means of standard deviation of the normal-to-normal peaks (SDNN) and root mean square of successive differences (RMSSD) [29] for each segment. From EDA, mean skin conductance level (SCL) and the number of skin conductance response peaks per second (SCRs) were calculated. The mean rectified voltage of the EMG in the zygomaticus major (EMG-ZM) and corrugator supercilii (EMG-CS) were calculated. Respiration rate (RR) was determined as the number of respiration cycles per minute [6]. Each of the above-mentioned parameters was calculated per segment or condition. Reactivity was quantified as the parameter value during a manipulation block minus the average of parameter values during the preceding and successive rest-phases. As there was no rest-phase after the startle stimulus, startle reactivity was calculated by subtracting the value during the last minute of the rest-phase preceding the startle stimulus from values during the startle stimulus. For all parameters, three times the standard deviation was operated as cut-off point.

3.8 Statistical analysis

The third step is statistical analysis with a multivariate approach. To answer hypothesis 1) and 2), a repeated measure MANOVA was used to find if reactivity in physiological parameters during persuasion was different from zero and between experiment parts. For hypothesis 3), a multivariate correlation was performed between susceptibility self-report measures, i.e. the subscales and total score of the STPS, and physiological reactivity during exposure to the (matching) persuasion stimuli. In addition, linear mixed models (LMM) were used to assess the interplay between subjective and physiological data taking into account individual differences. For analysis, R Studio [40] with packages *tidyverse* [41], *psych* [42], and *lme4* [43] was used.

4 Results

The final dataset contained self-report and physiological reactivity data of 56 participants, since four sets had to be discarded due to insufficient conductance properties of the skin.

4.1 Self-report data

Self-report data had no outliers and was normally distributed with the exception of brushing quality and quantity. Considering our recruitment criteria, this was in accordance with expectations. Most participants reported to brush their teeth at home for a duration of 1 - 1.5 minutes per session. Their attitude towards brushing was relatively positive (mean = 5.11 on a 7-point Likert scale, s.d. = 1.21, range = 3.2 – 6.4).

Descriptive statistics of the TIPI and STPS subscales and the overall STPS score were calculated (Table 3). Based on the observed alpha-values, the STPS items are considered to have sufficient internal reliability, in line with previous research [1], except for Liking. However, this is not a real problem, since we did not present a matching persuasive message. The insufficient internal reliability of the TIPI subscales is not surprising since the number of items is small.

TABLE 3
DESCRIPTIVE STATISTICS SUSCEPTIBILITY TO PERSUASION SCALE AND TEN-ITEM PERSONALITY INVENTORY

Scale	mean	s.d.	alpha	# items
Authority	3.82	1.10	0.76	4
Scarcity	3.91	1.10	0.67	5
Liking	5.17	0.84	0.32	3
Commitment	5.49	0.86	0.74	5
Reciprocity	4.90	0.99	0.77	5
Consensus	4.21	1.03	0.61	4
overall STPS	4.58	0.61	0.82	26
Agreeableness	4.33	0.96	0.26	2
Conscientiousness	5.28	1.17	0.49	2
Emotional stability	4.88	1.27	0.49	2
Extraversion	4.58	1.35	0.75	2
Openness	5.27	1.12	0.63	2

4.2 Physiological data

In the physiological reactivity dataset, only HR data was normally distributed. Various data transformations, i.e. log, log10 () + 1, Cube root and Tukey's Ladder of Powers, did not improve normality. We proceeded to analyze without data transformation, since 56 participants is a reasonable sample size [35].

Reactivity for all conditions is visually represented in Fig. 2. To test if people's physiology reacted to the startle response, multiple t-tests compared the reactivity parameter values during the startle stimulus to zero. RMSSD and SDNN were omitted as the startle response was recorded for only 60 seconds [29]. Results indicate that almost all parameters were significantly different from zero ($p < .05$, $d = 0.427 – 0.882$), indicating a physiological reaction to the startle stimulus, and proper measurement of physiological activity. Only EMG-CS was not significantly different from zero ($p = 0.058$).

Intercept terms of the one-factor Pillai's trace MANOVA with Bonferroni correction revealed that average reactivity to persuasion was significantly different from zero in multivariate statistics ($F(1,143) = 6.376$, $p < .001$, $\eta^2 = 0.044$) and univariate statistics for HR ($F(1,143) = 8.987$, $p = .003$), SDNN ($F(1,143) = 14.752$, $p < .001$), SCR ($F(1,143) = 8.676$, $p = .004$), EMG-CS ($F(1,143) = 11.648$, $p < .001$) and EMG-ZM ($F(1,143) = 5.589$, $p = .020$). Univariate reactivity intercepts for RMSSD, breathing rate, and SCL were not significantly different from zero. There was, however, no significant effect on reactivity of the factor condition (4 levels: authority, scarcity, commitment, consensus).

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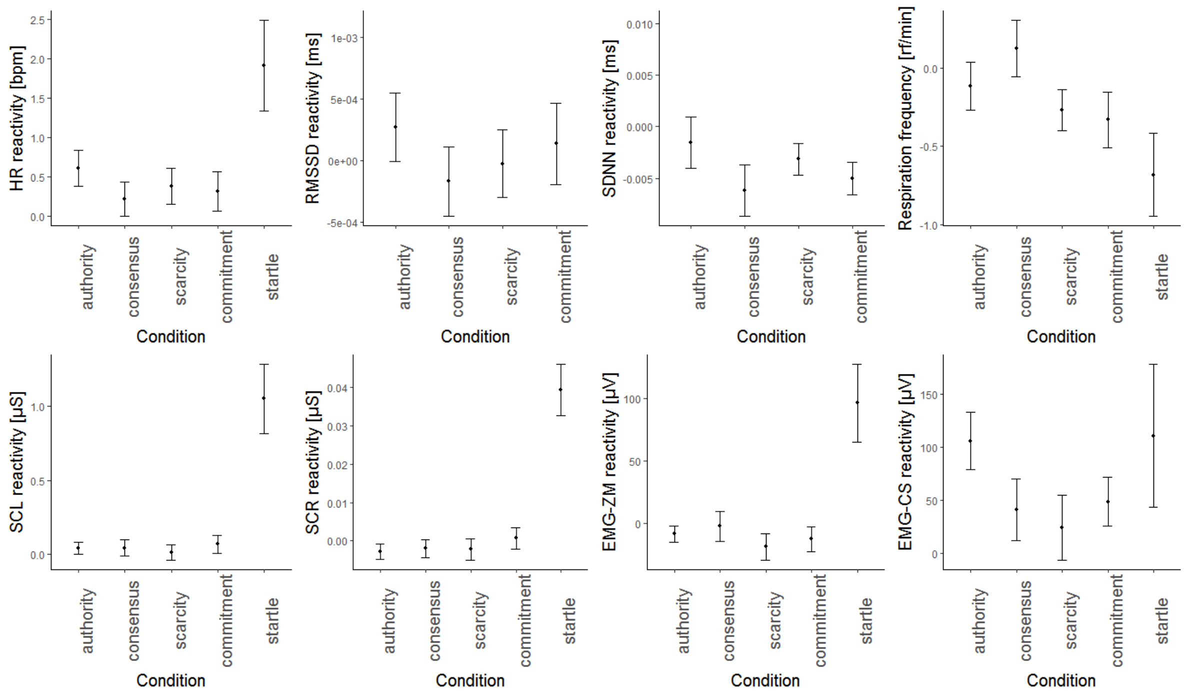

Fig. 2. Physiological reactivity per condition with error bars representing standard errors of the mean. Reactivity during persuasion stimuli was significantly different from zero for heart rate, SDNN, SCR, and facial muscle activity in the corrugator supercilii and zygomaticus major. Startle data for SDNN and RMSSD were omitted, as the response was recorded for only 60 seconds.

4.3 Relation between self-report and physiological data

Five multivariate Pearson correlations, with Benjamini & Hochberg' correction for multiple testing, calculated the relationship between physiological reactivity and self-report data, i.e. one test per STPS subscale and one for overall susceptibility. Self-reported susceptibility to the scarcity principle (scarcity subscale) proved not to be correlated to physiological reactivity during the block with persuasive messages deploying the scarcity principle. In a similar way, no significant correlations were found for the other three persuasion principles, nor for the correlation between overall STPS susceptibility and physiological reactivity during all persuasive blocks.

4.4 Mixed model approach

In addition to above-mentioned statistics, we performed a linear mixed effects analysis to understand the relationship between self-report measures and physiological reactivity. Mixed models consist of fixed and random effects. Fixed effects are constant across measurements, whereas random effects vary for example due to individual differences. This approach enabled us to create subject-specific models, account for missing data, and characterize the unexplained or residual variation in the response on multiple levels [34], [36]. To avoid overfitting, we started with a simple model and compared a series of increasingly complex fits using the Akaike Information Criterion (AIC) [36]. Only if the added factor significantly explained more variance and added predictive power to the model, this effect was retained. Parameter specific p-value estimations were based on conditional t-value with the Satterthwaite approximation for denominator degrees of freedom [36]. In the dataset, the first level are the individual participants and the second level are the repeated measures of physiological reactivity to the four persuasion principles within the subject. The first fit (model A) consisted of manipulation condition as fixed effect and subject as grouping variable. In the second fit (model B), the overall STPS score was added as fixed effect. The third fit (model C), contained scores on the STPS subscales related to physiological activity during the corresponding manipulation as fixed effect. As fourth (model D), the different factors of the TIPI, i.e. extraversion, emotional stability, conscientiousness, openness, and agreeableness, were added as fixed effects and evaluated one by one in model D. This iterative model-building process was performed separately for each physiological response parameter.

Results indicated that for most physiological parameters the fixed effects of overall STPS or STPS subscale, did not significantly explain variance. In other words, model A, a subject-specific model focusing on reactivity of physiological outcome parameter based exclusively on manipulation condition, was the best fit for HR, RMSSD, SDNN, and RR reactivity. Exceptions are SCL and EMG-CS reactivity, for which the overall STPS scores significantly explained more variance in physiological responses to the persuasion manipulations. Consequently, model B proved to be the best fit for SCL and EMG-CS (Table 4). Higher overall STPS scores indicated lower reactivity and vice versa. Results show EMG-CS values drop 44.67 mV with higher overall STPS score. However, a large amount of variance in EMG-CS reactivity is still unexplained. For SCR, a model containing both overall and subscale STPS scores in addition to

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TABLE 4
SUMMARY OF THE BEST MIXED LINEAR MODEL FIT FOR SKIN CONDUCTANCE LEVEL, SKIN CONDUCTANCE RESPONSE AND ELECTROMYOGRAPHIC ACTIVITY IN CORRUGATOR SUPERCILII AND ZYGOMATICUS MAJOR

	SCL		SCR (·10²)		EMG-CS		EMG-ZM	
	B (CI)	*p*	*B (CI)*	*p*	*B (CI)*	*p*	*B (CI)*	*p*
Fixed Parts								
Intercept (authority)	0.58 (0.12 – 1.04)	**.017**	1.26 (-0.82 – 3.33)	.241	299.11 (88.05 – 510.17)	**.007**	-52.15 (-96.83 – -7.47)	**.026**
manipulation (commitment)	-0.01 (-0.12 – 0.11)	.920	-0.29 (-0.87 – 0.29)	.332	-45.45 (-107.24 – 16.35)	.154	-8.55 (-27.48 – 10.37)	.379
manipulation (consensus)	-0.03 (-0.14 – 0.09)	.644	-0.08 (-0.54 – 0.39)	.749	-65.73 (-127.78 – -3.68)	**.042**	-0.80 (-19.72 – 18.13)	.935
manipulation (scarcity)	-0.03 (-0.14 – 0.08)	.593	-0.20 (-0.67 – 0.27)	.408	-88.18 (-150.23 – -26.13)	**.007**	-10.35 (-29.17 – 8.47)	.286
STPS total	-0.12 (-0.21 – -0.02)	**.024**	-0.53 (-1.03 – -0.03)	**.043**	-44.67 (-89.34 – 0.00)	.053		
STPS subscales			0.23 (0.01 – 0.44)	**.045**				
TIPI Extraversion							9.53 (0.55 – 18.51)	**.041**
Random Parts								
σ^2	0.092		1.243		26058.294		2489.606	
$ICC_{subject}$	0.235		0.304		0.129		0.384	
Observations	222		175		209		214	
R^2 / Ω_0^2	.430 / .367		.492 / .439		.312 / .254		.552 / .515	
AIC	159.196		595.316		2756.533		2361.951	

B = estimates, CI = confidence interval, p = p-values (presented in bold if significant), σ^2 = subject variance, ICC = intra-class correlation coefficient, R^2= r-squared statistics, Ω_0^2 = adjusted Omega-squared values, AIC = Akaike Information Criterion

manipulation as fixed effect and subject as grouping variable proved to be the best fit. Similarly, higher overall STPS scores indicated lower reactivity and vice versa. In contrast, higher STPS subscale scores indicated higher reactivity. Probably the effect of average scale score is influenced strongly by the psychophysiology of commitment, as only this scale has a larger, negative relationship with SCR reactivity. The other subscales have a smaller, positive relationship with SCR reactivity. A version of model D with a fixed effect of manipulation and as random effect TIPI subscale extraversion was the best fit for EMG-ZM reactivity. Results show EMG-ZM values rise with 9.53 mV with higher scores on TIPI subscale extraversion.

5 Discussion

As affective states have physiological correlates, changes in state caused by persuasion might also have detectable physiological patterns. Finding and understanding these physiological patterns during persuasion might increase our understanding of the underlying mechanisms. This might enable future applications by allowing physiology-contingent selection, content tailoring and unobtrusive optimization of interventions that are less subject to introspection and with higher temporal resolution than those based on questionnaires. Therefore, this study analyzed the relationship between reactivity of the peripheral nervous system to persuasive cues with self-reported susceptibility to persuasion. Physiological data were collected during exposure to persuasive messages using scarcity, consensus, authority, and commitment as persuasion principles. Measures of the peripheral nervous system included the cardiovascular, respiratory, electrodermal system and facial motor activity. The physiological data was related to self-reported susceptibility to persuasion (STPS). Building

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on earlier research, we expected differences in physiological arousal in exposure to persuasion in general and to various persuasion principles. We also expected this reactivity to correlate with the self-reported persuasion profiles – i.e., people with higher susceptibility to a certain persuasion principle also showing more pronounced physiological reactivity during that specific condition.

Results appeared to support hypothesis 1, that is reactivity during presentation of persuasion stimuli was different from reactivity during baseline for heart rate (HR), standard deviation from normal-to-normal peaks (SDNN), skin conductance response (SCRs), facial motor activity in the corrugator supercilii and zygomaticus major (EMG-CS and EMG-ZM). There were no differences in reactivity for root mean square of successive differences (RMSSD), skin conductance level (SCL) and respiration rate (RR). However, results provided no evidence in support of hypothesis 2, that is no differences in reactivity between different persuasion principles were found. Regarding hypothesis 3, no correlations between susceptibility to persuasion and physiological reactivity to the corresponding persuasion principle were found. Nevertheless, when a mixed model approach was used to explain the differences in physiological reactivity between conditions, self-report measures (i.e. STPS scores) and subject specificity, results do indicate that self-report measures (i.e. overall STPS alone or with STPS subscales and extraversion) explained SCL, SCR, EMG-ZM and EMG-CS data. This was not the case for the remaining physiological variables. Multiple explanations for these main findings are possible.

5.1 Physiological activity in persuasion differs from rest state

Starting with hypothesis 1, results showed that activity during presentation of persuasion stimuli was different from physiology in rest state for HR, SDNN, SCR, EMG-CS and EMG-ZG. This indicates that information processing during persuasion is characterized by different physiological arousal than during baseline. However, it is unclear if the persuasiveness of the information elicited the physiological arousal. It is possible that the physiological responses to the persuasive messages come from a more generic orienting reaction to the stimuli. For example, the difference in physiology might actually come from reading texts instead of persuasive content. Thus, although the results appear to be supportive, one could question if hypothesis 1 was correctly formulated. Future research should establish if the persuasive character of the information is what arouses the physiological responses, by comparing physiological reactivity during persuasive messages to an additional control block with unrelated, fact-stating texts.

Moreover, the difference in physiology during rest state and persuasion stimuli is hard to interpret. Results show higher HR values and lower SDNN values during persuasion indicating higher sympathetic arousal in the cardiovascular system, which represents the energization of the body [6]. In contrast, however, we found on average fewer SCRs during persuasion. This finding indicates more frequent sympathetic responses in the electrodermal system during baseline, while we expected this pattern during persuasion. Earlier research demonstrated that the cardiovascular and electrodermal system are, alongside nervous system control, differently subject to a range of physiological subsystems, such as humoral influences and other neurobehavioral processes. It is possible that, in a part of the participants, some of these subsystems were activated during baseline, which resulted in elicitations of SCRs without influencing the overall level of electrodermal arousal. This would be in line with the finding that SCL during persuasion was predominantly similar to baseline. In a broad sense, the findings across these two physiological systems seem to contradict each other in terms of peripheral nervous system arousal. We currently do not have enough information to interpret this unexpected finding.

Concerning the somatic nervous system, results indicate more EMG-CS and less EMG-ZM activity during persuasion compared to baseline. Roughly, this indicates that participants enjoyed the sea life movies during baseline better than the oral care information up to the extent that they disliked the latter. This could mean that, alongside just reading and thinking about the information, the persuasion indeed induced negative emotions by appealing on a person's resources or confronting them with their 'wrong' behavior. This could be explained with the theory of psychological reactance [19], [44], which states that people might be motivated to reject the content of a persuasive message when they view it as threatening. This results in a resistance to influence of others and a motivation to regain their freedom. Reactance is seen as a state of arousal that can involve physiological reactions. This indicates the complexity of multiple intertwined psychological processes at play.

5.2 Similar physiological reactivity to persuasion principles

Although we found reactivity during persuasion, there was no difference in activity between the persuasive principles (i.e. hypothesis 2). Because the different persuasion principles target other psychological aspects, we expected different persuasion principles to elicit different degrees of valence and arousal resulting in distinct physiological patterns. One reason for this finding could be that individual differences in susceptibility to persuasion were not considered in this analysis. Because we also expected that differences in susceptibility to a principle would reflect in physiology, it could be that the mixture of high and low susceptibility levels averages out the physiological responses.

An alternative explanation for the lack of differences in reactivity to different persuasive stimuli could be that - in contrast to the startle sound - the persuasive manipulation was not strong enough. A weak manipulation lessens the reactions to the different principles, making them too frail to be distinctive. The persuasive stimuli were based on earlier research that successfully used comparable messages deploying these persuasion principles [4], [16]. Still, our messages were not identical to those messages, mainly because the target behavior differed. An additional reason for lower manipulation strength might be that the experimental set-up with physiological measurement devices might have decreased ecological validity. Physiological

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measurements benefit greatly from static postures and reliable timing [6, Ch. 34]. Consequently, the participants had to sit perfectly still, and a preprogrammed script was used to run the experiment. This set-up might have decreased participants' belief in the stimuli, as persuasion heavily depends on human social interaction [16]. Additionally, it created a rather passive experiment set-up. This may have caused the participants to lose interest in the experiment, again lowering the manipulation strength.

Another source for leveled physiological responses could be carryover effects between conditions. It could be that the 3-minute timeslot was not sufficient to return to physiological rest state. We tried to minimize the chance of carryover effects by adding resting periods between conditions and randomizing the order of manipulation conditions and stimuli [6, Ch. 34]. This is in line with the finding that physiological reactivity during persuasion did differ from rest state, but not between the different principles.

Another reason for the lack of differences in reactivity between persuasion conditions might come from the strategy that was used to persuade participants. We chose Cialdini's persuasion principles [16] as influence strategy, because of the large amount of literature on the implementation of these principles and the availability of the STPS [4]. These self-reported indications of susceptibility enabled us to analyze subject-specific psychophysiological relationships. However, earlier research implemented these principles mainly in field experiments instead of lab experiments. This difference in experiment context might have decreased the ecological validity and, thereby, the effectiveness of these particular persuasion strategies. Given the short duration of our intervention, i.e. only one visit to the lab, it is possible that our participants did not translate the persuasive messages into their daily lives. Perhaps there are other, more appropriate, persuasive strategies to influence people in such a short timeframe. Similarly, longer termed interventions might yield different results. In similar vein, the target behavior might have not been the right one. Only people with bad oral care habits were included, it is highly plausible that not everyone is as invested with oral care. This could be a reason why these participants had unhealthy oral care habits to start with. Targeting behaviors around issues that people truly care about might yield different results. Therefore, future research should focus on powerful persuasive interventions that are able to influence someone's life profoundly.

5.3 Relating physiological arousal to self-report measures

The third hypothesis considered the psychophysiological relationship in persuasion. The multivariate correlation analyses indicated no relationship between self-reported susceptibility and physiological reaction to persuasion. This finding appears to confirm that reactions to persuasion principles do not have a clear psychophysiological signature. However, the mixed model approach indicated that adding overall STPS scores does help in explaining the physiological reactions to persuasion manipulations, at least for SCL, SCR and EMG-CS. Interestingly, this effect was in the opposite direction of what we expected, i.e., a higher overall STPS score indicated lower physiological reactivity and vice versa. In other words, participants low susceptible to persuasion principles overall were more physiologically reactive to messages employing persuasion principles. The results indicate that people with lower susceptibility scores were frowning more during persuasion. People tend to frown when they are, for example, thinking, paying attention or experience negative emotions. Lower susceptibility also indicated more electrodermal arousal during persuasion. Sweat glands are driven by arousal of the sympathetic nervous system. Potentially, other psychological processes are at play here, possibly psychological reactance [44]. This could explain why for example, less susceptible participants exhibited more frowning and more activity of the electrodermal system during persuasion. This important issue warrants future research.

The mixed model results also reveal lower SCL for people with higher STPS scores, even though on average the SCL arousal during persuasion did not differ from baseline. This appears to suggest that individual differences in susceptibility are important in explaining SCL arousal during persuasion. Interestingly the best model fit for SCR included both average STPS scores and STPS subscales scores. Further inspection indicates that overall susceptibility and susceptibility to particular principles had opposite effects on SCR; higher reactivity was associated with lower average and higher subscale scores. This might suggest that self-report susceptibility and physiological reactivity has a different relationship in commitment persuasion compared to scarcity, authority or consensus persuasion. Furthermore, the mixed model approach revealed extraversion as a predictor of zygomaticus reactivity. This finding is well understood as the zygomaticus major is involved in large facial expressions, such as laughing, and extravert people are known to exhibit more facial expressions.

5.4 Implications and further research

Taken together the findings of this study are not conclusive. A main reason for difficulty with interpretation of the results is that it is unclear whether the participants actually were persuaded. Consequently, although physiological arousal during persuasion was different from baseline, persuasion might not have been the instigator. It could also come from a difference in action, e.g. watching a video versus reading a text. On the other hand, the relations found between physiology and susceptibility to persuasion do suggest processes relevant to persuasion were indeed triggered. Future research would benefit from adding a measurement of intention and/or attitude towards the target behavior after the persuasion manipulation. A change in intention or attitude would indicate effective persuasion and give more meaning to the physiological responses. Adding behavioral measures could reveal if the persuasion resulted in prolonged behavior change. Comparing physiological response during these persuasive versus control stimuli would provide more meaningfulness to the psychophysiological response. To ensure that physiological reactivity comes from persuasion, future research should create an experiment set-up involving powerful persuasive stimuli, targeting learning behaviors that people are interested in but experience trouble with achieving, and comparing those physiological responses to those during neutral information

Despite these ambiguities, self-reported susceptibility to persuasion did explain variations in SCL, SCR and EMG-CS reactivity partially. It does suggest a relationship between susceptibility to persuasion and physiology. If susceptibility to persuasion is measurable in physiology, this could have great applicability to behavior change interventions and persuasive design systems, even if only small changes in physiology are obtained. For example, a behavior change intervention can be created with a built-in affective loop drawing upon physiological and emotional interactions between the user and the system. With wearable technology, such as a smart watch, physiology could be measured while someone receives a persuasive text. Combined with other indicators, this physiological response could indicate how the persuasive text is received by the user. Thereby, the behavior change intervention can adapt to a specific user continuously without interrupting the intervention. Physiology enables real-time measurement with higher temporal resolution and fewer introspection biases than summarizing measures. Physiology-based tailoring could be a refreshing addition to current personalization techniques. However, more research is needed before we can be sure that a system like this can work.

The findings of this study opened up new questions that need to be addressed in future research. Some of the findings were unexpected, which made us question the underlying processes of persuasion. It could be that a single persuasion principle does not activate one clear, delineated psychological process, but a mix of interacting cognitive and emotional processes. This diffusion might also be reflected in the underlying physiology, leading to ambiguous results and multi-mapping problems [6], [45]. This justifies the potential role of the reactance phenomenon some participants, but also implies the possible presence of other internal processes. The current study explored the peripheral path of the ELM, and hypothesized possible links in affective state to physiological reactivity. However, earlier research [45] questioned if peripheral processing influences affect and concluded that emotions can also serve as persuasive argument when elaboration likelihood is high. Indeed, the ELM is a descriptive model integrating both contextual and individual variables to process persuasion, but it does not effectively model the psychological process of persuasion [45]. As a result, it is unclear how these persuasive processes may vary and result in different outcomes.

These ambiguous findings highlight the difficulty in the psychophysiological research area. In future investigations, it might be possible to test the psychophysiology of isolated persuasion processes. For this purpose, it might be necessary to not only make a distinction between persuasion strategies, but also between the underlying psychological aspects that are targeted. The predominant targets of the present study were health beliefs in oral care. However, persuading people to change their moral beliefs or perceived behavior control could result in different physiological patterns. Especially the latter, perceived behavior control, might be important for people that have trouble with adjusting their behaviors. Furthermore, people might be more aroused when persuasion targets behaviors that they are invested in more. Comparing the physiological reactions in different persuasion settings might provide better understanding of how psychological constructs underlying behavior, such as intentions, beliefs, attitude, perceived behavior control, are connected.

5.5 Concluding

Altogether, no distinct psychophysiological patterns in exposure to different persuasion principles were found in this study, nor a clear correlation with individual susceptibility. This means that this experiment did not provide support that physiology might be appropriate for implicit profiling of susceptibility to persuasion principles. However, we did find that some of the variance in physiology was explained by self-reported susceptibility to persuasion scores. Although the findings of this study are not conclusive, they open up many new questions. In that sense, this study provides a first notion of this relationship: it is a complex relationship. Apparently, research on the psychophysiological nature of persuasion is still in its infancy, and implicit personalization with physiology remains a promising way to increase effectiveness of behavior change interventions. However, further research is needed to conclude whether different psychophysiological relationships are present and sufficient for implicit reactance-to-persuasion profiles.

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