Understanding User Acceptance of Electrical Muscle Stimulation in Human-Computer Interaction

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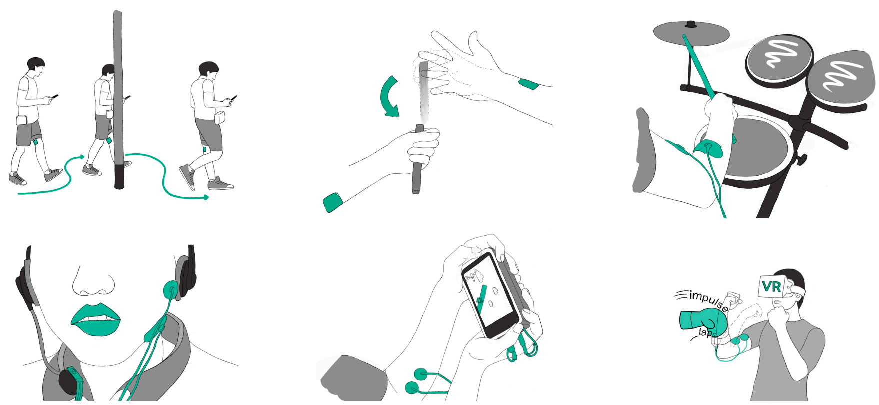

Figure 1: Electrical Muscle Stimulation (EMS) has been used to realize multiple application scenarios. The illustrations from left to right in the top row display EMS systems that direct users while walking [62], accelerate a user's reaction time [34], and aid percussion learning [15]. In the bottom row, the illustrations display EMS systems that can change chewing food texture [58], add haptic feedback to mobile games [47], and generate a realistic haptic sense of being hit in VR [48].

ABSTRACT

Electrical Muscle Stimulation (EMS) has unique capabilities that can manipulate users' actions or perceptions, such as actuating user movement while walking, changing the perceived texture of food, and guiding movements for a user learning an instrument. These applications highlight the potential utility of EMS, but such benefits may be lost if users reject EMS. To investigate user acceptance of EMS, we conducted an online survey ($N = 101$). We compared eight scenarios, six from HCI research applications and two from the sports and health domain. To gain further insights, we conducted in-depth interviews with a subset of the survey respondents ($N = 10$). The results point to the challenges and potential of EMS regarding social and technological acceptance, showing that there is greater acceptance of applications that manipulate action than those that manipulate perception. The interviews revealed safety concerns and user expectations for the design and functionality of future EMS applications.

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CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; Empirical studies in HCI;

KEYWORDS

Acceptability; Social Acceptability; Electrical Muscle Stimulation

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1 INTRODUCTION

Electrical Muscle Stimulation (EMS) radically deviates from how human-computer interfaces traditionally implement system feedback because *EMS appropriates the human body to stimulate movement*. It enables system feedback that is displayed through a motion of the user's own body, which appeals to the user's proprioception [72]. Prior work has made use of EMS to manipulate a user's walking direction [62], change their perception of food texture, namely elasticity and hardness [58], and speed up their reaction times [34]. EMS has the ability to actuate the human body, which has also been taken advantage of in the medical [18, 26, 52, 67, 78] and fitness [1, 25] domains. To this end, an EMS system conveys electrical impulses imitating a signal sent by the human brain via electrodes into the user's body, where the EMS system can elicit muscle contraction. Henceforth, bodily motion is subject to *external actuation*, which makes the user no longer the sole initiator of action. Therefore, systems involving EMS have the potential to violate the user's internal locus of control [77], which may cause concerns over pain and loss of bodily control in addition to the social factors of on-body electrodes.

EMS applications are quite well-established in the research community [15, 16, 30, 34, 47, 48, 58, 62]. Although a number of applications, predominantly from the health[1] and fitness domains[2,3], have already found their way into consumer markets, resulting concerns, even before consumers have experienced EMS, have been underexplored. With EMS substantially changing the dynamics between the user and system (i.e., the user's actions being altered instead of the user altering the system's state) and, consequentially, the user's perception of it [22], an in-depth understanding of user concerns is of utmost importance for future system design. This is especially critical for potential new users because reservations about EMS might even prevent prospective users from even trying it. Hence, negative attitudes towards EMS paired with a lack of insight into the nature of these concerns may pose a significant entry hurdle for the adoption, acceptance, and applicability of EMS technology as a feedback paradigm – or, as put by Knibbe et al., EMS might be *"too awful to ever be an acceptable paradigm for HCI"* [38].

Building upon this strand of work, this paper explores user attitudes, expectations, and concerns regarding EMS, with a particular focus on *user acceptance*. User acceptance encompasses user expectations and attitudes even before initial experiences with a technology [11, 13], which represents a particular challenge for EMS. This focus on user acceptance complements work on experiential aspects of EMS [38], exploring the entry hurdles that might prevent users from accepting EMS at all. To this end, we make use of Davis' *Technology Acceptance Model (TAM)* [11] as a theoretical foundation. The aim of this well-established model is to *predict* the adoption and use of technology by individuals [33]. TAM and its expansions [31, 84, 87] share that they aim to explore an individual's willingness to start using a specific technology before having gained actual experience with it [3]. In this work, we focus on potential user acceptance given that EMS is often poorly understood [38] by including two different perspectives: prospective users of EMS without prior exposure and more experienced users with some first-hand EMS exposure. This choice of theoretical foundation is well suited for the topic of investigation due to the novelty of EMS as a feedback paradigm and the high entry hurdle caused by concerns and reservations towards EMS. Notably, TAM and related models differ significantly from *user experience* models. User experience models (e.g., as proposed by Hassenzahl and Tractinsky [29]) aim to capture the experiential and hedonic aspects of technology use [33] after the user has come into contact with the technology. Therefore, prior insights into user experience [38] are orthogonal to the question answered by the present work: *What are the precise factors that contribute to users refraining from using EMS?*

To address this question, we follow a two-step approach. First, we conducted an in-depth analysis of the users' acceptance of EMS using an online survey ($N = 101$) that explored eight existing EMS applications. We carefully selected the applications, which we portrayed as videos, to cover the fields of HCI, sports, and medicine. By extracting constructs from previous work [11, 31, 84, 87], thoughtfully examining overlaps, and filtering for relevance, we created a questionnaire that assesses nine different aspects that influence user acceptance. Since the online survey results pinpointed the influence of prior experience with EMS, we followed up with in-depth, semi-structured interviews ($N = 10$, $mean = 1{:}15$ *hrs*) with a subset of respondents, balanced with and without prior EMS experience. This provides further qualitative insights into the reasoning behind their given answers. From an in-depth analysis of the survey and interview data, we distill key potentials and challenges for the application of EMS in human-computer interfaces. We consider the roles of use-case, social factors, anxiety, safety, agency, and trust for designing future EMS applications with increased user acceptance.

In short, we contribute (1) a detailed analysis of the interplay of factors shaping people's willingness to accept and adopt EMS. Most significantly, our results show that the purpose and necessity of EMS use in a specific application scenario is a deciding factor for user acceptance. We also contribute (2) an in-depth understanding of the reasons behind the responses from the online survey based on semi-structured interviews. Consequently, we derive (3) design recommendations to address the aversion to EMS, taking into account social values, safety concerns, and fear of loss of control that result from a lack of exposure to EMS.

2 BACKGROUND

We outline relevant models of user acceptance and technology acceptance, and a background of electrical muscle stimulation (EMS).

2.1 User Acceptance and Technology Acceptance Models

Multiple theories and models aim to provide a better understanding of the diverse factors influencing user acceptance (e.g., Brown et al. [8], Davis et al. [12]). According to Dillon, *"user acceptance"* refers to the *"demonstrable willingness within a user group to employ information technology for the tasks it is designed to support"*[13]. User acceptance models typically do not only reflect on the actual status of technology but also project the challenges and opportunities that the technology will have to face in the long run. User experience and user acceptance are two approaches used to define

[1] https://www.physiosupplies.de (last accessed on February 26, 2024)
[2] https://www.compex.com (last accessed on February 26, 2024)
[3] https://visionbody.shop (last accessed on February 26, 2024)

how a user would adopt a new technology [33]. One can think of them as related constructs. However, each of them provides insights obtained from two different points in time. On one side, the user acceptance targets the user's expectation from the system, on the other side the user experience targets the users' opinion based on actual interaction with the system. Surveys have been used in the past to assess user acceptance, for example, for data glasses [40] or smart kitchens [53]. Shahu et al. [74] offered an initial glimpse into the acceptance of EMS technology using an online survey, highlighting that various scenarios have an impact on user acceptance. Surveys provide the advantage of high experimental control, while capturing misconceptions about a novel technology, and allow for the inclusion of a broad range of scenarios and diverse respondents. This breadth also comes at the cost of the participants not gaining actual experience with the technology during the study. This is because EMS, being haptic and unfamiliar to many participants, cannot be fully experienced in a video. However, this limited exposure is also a benefit: it allows to showcase the to-be-evaluated scenarios in a manner approximating market entry when prospective users get first in contact with technology via media reports, advertisements, and accounts of peers.

2.2 Interacting through Electrical Muscle Stimulation

EMS does not only affect the perception channels of humans like traditional output methods (e.g., displays or audio) [73] but also actuates the human to execute certain actions (e.g., move the arms) [22]. While applications of EMS already exist in fields such as fitness training (e.g., strengthening the muscles [25]) or health (e.g., overcoming certain health conditions [27]), it was not until recently that the HCI field started to explore this technology [80]. Over the last decade, within HCI, research has started to look into different use cases where EMS could be integrated as part of an user interface [72]. Faltaous et al. [21] grouped EMS application in action manipulation and perception manipulation:

2.2.1 Electrical Muscle Stimulation for Action Manipulation. Researchers use EMS to improve or augment the users' skills. This could be achieved by using EMS to teach the users how to use certain objects [49], to accomplish a certain task [56, 71], or to accelerate reaction times [34]. EMS could also teach them how to learn a certain skill in sports [19, 28, 60, 83, 85], improve using musical instruments [15, 55, 59, 81], or learn new gestures [23]. Studies explored the possibility of directing the users while walking in real-world settings [62] or in virtual realities [2], as well as pointing at a target by actuating their arms' muscles [36, 80–82].

2.2.2 Electrical Muscle Stimulation for Perception Manipulation. EMS can also be used to manipulate users' perceptions. Examples of this include gaming-feedback in mobile devices [47], in real life (e.g., [9, 20, 35, 41, 76]), or in mixed reality applications [24, 51]. EMS can have an interesting role in virtual reality applications, where users receive EMS feedback when they interact with virtual objects [63, 65, 66] or virtual characters [48]. Other examples use EMS to change the way users perceive the texture of certain objects in virtual reality (e.g., object stiffness and hardness [42, 88]) or in real life (e.g., food texture & taste [57, 58, 69]).

3 SURVEY

To understand users' current acceptance of EMS, we conducted an online survey using eight EMS scenarios. Our results explore how nine factors, drawn from technology acceptance models, influence user acceptance when considering the unique constraints of EMS.

3.1 Scenario Selection

In a first step, we selected scenarios from existing EMS applications across HCI, health, and sports. In particular, we selected ten out of the most-cited[4] research articles using EMS, which implies interest for future work as indicated by the number of citations. Additionally, we selected two baseline scenarios, showcasing products available on the market for application in the medical or sports domain. Thus, both scenarios do not show research prototypes but actual applications of EMS which might already be known to users. The first scenario is a commercial fitness application, where EMS is used to strengthen muscles. The second scenario is a rehabilitation scenario, where EMS is used to aid the treatment of a stroke patient who has difficulty walking. Both baseline scenarios describe applications in which EMS is currently successfully applied on the market in contrast to the research prototypes.

We analyzed these potential scenarios by conducting a pre-test to assess their suitability for the online survey format. For this, we prepared a 30-second video and a brief textual description for each scenario. The video and textual description both present the goal of each project and show the benefits of the EMS technology in each scenario. We based our videos on videos uploaded to YouTube and other video platforms and changed the length to 30 seconds to have a comparable level of detail. We showed the potential videos in combination with the textual description to 3 pilot participants. These participants had no prior experience with EMS. After each participant, we iteratively improved the descriptions and videos to make sure that the overall concepts and benefits could be understood by survey respondents. This resulted in six scenarios focusing on EMS research in HCI (cf. Table 1): three targeting action manipulation and three targeting perception manipulation.

3.2 Question Design

We based our design on four main technology acceptance models: Technology Acceptance Model (TAM) [11], Unified Theory of Acceptance and Use of Technology (UTAUT) [84], User Acceptance of Wearable Devices (UAWD) [87] and Almere model [31]. We started by taking TAM as the base for the model that we would apply to our research, extending it with the above-mentioned three additional models. After combining overlapping constructs, we filtered out all the non-relevant constructs that could not be applied at this early stage of the EMS technology (e.g., brand name) and that could not be generalized to every use case (e.g., visual attractiveness). This approach leads to nine constructs affecting the user acceptability of EMS: social value, perceived usefulness, perceived enjoyment, anxiety, trust, intention of use, functionality, compatibility, and attitude. Table 2 lists the constructs and questions. Each question is formulated as a statement and uses a 7-point Likert item stating to which degree the respondent agrees or disagrees.

[4] We used the citation count on Google Scholar in May 2022.

Table 1: HCI Scenarios used in the survey grouped by Action and Perception.

Type	Label	Name	Reference
Action	Action 1	Cruise Control for Pedestrians: Controlling Walking Direction using Electrical Muscle Stimulation	Pfeiffer et al. [62]
	Action 2	Preemptive Action: Accelerating Human Reaction using Electrical Muscle Stimulation Without Compromising Agency	Kasahara et al. [34]
	Action 3	Building a Feedback Loop Between Electrical Stimulation and Percussion Learning	Ebisu et al. [15]
Perception	Perception 1	Study on Control Method of Virtual Food Texture by Electrical Muscle Stimulation	Niijima and Ogawa [58]
	Perception 2	Muscle-Propelled Force Feedback: Bringing Force Feedback to Mobile Devices	Lopes and Baudisch [47]
	Perception 3	Impacto: Simulating Physical Impact by Combining Tactile Stimulation with Electrical Muscle Stimulation	Lopes et al. [48]

Table 2: Questions and related constructs asked in the questionnaire.

Construct	Model	Question
Social Value	UTAUT [84]	I will not use the EMS technology when I am home alone. I will not use the EMS technology when I am home with friends/family. I will not use the EMS technology when I am in a public place alone. I will not use the EMS technology when I am in a public place with friends/family.
Perceived Usefulness	TAM [11]	I think it is inconvenient / not useful to have EMS on my body.
Perceived Enjoyment	UAWD [87]	I think this application would not be enjoyable to use.
Anxiety	Almere [31]	I am afraid to hurt myself while I am being actuated. I am afraid to hurt others while I am being actuated. I think this application would be comfortable to use.
Trust	Almere [31]	I trust being actuated by the EMS system.
Intention of Use	TAM [11]	I think I will use EMS in the near future.
Functionality	UAWD [87]	I think this application provides a realistic functionality.
Compatibility	UAWD [87]	I think this application is compatible with my existing activities.
Attitude	Almere [31]	I think I will use the EMS technology.

Table 3: Results of the ART ANOVA for the factors Scenario and EMS Experience as well as the interaction effect Scenario x EMS Experience. The tests are presented for each construct (mean over all questions if there is more than one question – cf., Table 2) and overall (mean over all constructs). Statistically significant results are marked: '*': $p < .001$; '**': $p < .01$; '*': $p < .05$. Effect sizes (η^2) are calculated without the random effect of respondent.**

	Scenario	EMS Experience	Interaction Effect	η^2		
Construct	**F(7,693)**	**F(1,99)**	**F(7,693)**	**Scenario**	**EMS Exp.**	**Interaction Effect**
Social Value	16.445 ***	6.928 **	2.238 *	.074	.034	.011
Perceived Usefulness	29.064 ***	5.386 *	1.706	.149	.021	.010
Perceived Enjoyment	16.125 ***	0.560	1.769	.084	.002	.010
Anxiety	18.334 ***	10.583 **	1.220	.079	.054	.006
Trust	28.316 ***	9.718 **	1.622	.121	.047	.008
Intention of Use	20.421 ***	3.615	2.388 *	.114	.013	.015
Functionality	40.070 ***	3.272	1.465	.210	.011	.009
Compatibility	12.992 ***	1.112	2.311 *	.071	.005	.014
Attitude	25.383 ***	4.966 *	2.220 *	.137	.018	.014
Overall	37.541 ***	6.803 *	2.880 **	.169	.031	.016

3.3 Survey Protocol

The online survey is structured as follows. First, we collected demographic data (age, gender, country), tech-savviness, and prior experience with EMS applications. We next introduce the basic principles of EMS using a short video and textual description. Afterward, we provided each respondent with all 8 scenarios: 6 HCI-related scenarios, a sports scenario, and a health scenario. All scenarios were presented one after the other. The order of presentation is randomized to prevent confounding effects from boredom or fatigue. We used a single page per scenario. For each scenario, we presented the textual description and the video and asked all 14 questions (cf., Table 2) using 7-point Likert items. At the end of the questionnaire, we asked for participants' email addresses in case they were willing to participate in follow-up interviews or the voucher raffle. We implemented the survey using the LimeSurvey platform[5]. We designed and conducted the survey according to our local ethical guidelines.

3.4 Respondents

We recruited respondents through mailing lists and social media. Participation was incentivized with ten Amazon vouchers of € 25, which were raffled to respondents after the survey closed. Overall, 101 respondents filled in the questionnaire completely (mean time 29.58 mins). Respondents self-identified gender, our results include 57 male, 38 female, 2 other gender, and 4 preferred to not specify. Respondents specified their age, averaging 30.3 years (min: 18; max: 75; sd: 11.10). Overall 91% of the respondents came from Germany, Egypt, and the United States.

3.5 Pre-processing

We measured response time to check for outliers completing the survey too quickly or slowly. We used the Tukey method of the 1.5 quartile distance for survey completion time. All respondents met the inclusion criteria based on completion time, we did not exclude any respondents. To create a uniform scale from positive to negative, we inverted the polarity of the negative Likert items (i.e., stronger agreement equals a positive attitude towards the scenario). Where multiple questions applied to a single construct, we grouped these responses as shown in Table 2.

3.6 Analysis

The survey data was analyzed using quantitative techniques for ordinal Likert data responses. We applied the Aligned Rank Transform (ART) procedure [86] to our data before performing repeated measures analyses of variance (ANOVA) for each of the questions with the within-subject factor scenario (8 levels) and the between-subject factor previous experience with EMS (*EMS Exp.* – 2 levels). For previous experience with EMS, we grouped respondents into two groups: respondents who did not use EMS before (58) and respondents who used EMS once or more often (43) based on their self-reported prior experience with EMS. In addition to the rating, participants described their experience. About twelve participants already participated in user studies involving EMS, seven explored EMS themselves (e.g., as a medical student), four used it as medical treatment (e.g. after knee surgery), four used it in the sports domain as a training tool, three conducted research with EMS themselves, and 13 did not specify their experience in detail.

We explored significant effects for all comparisons in more detail using Holm-Bonferroni-corrected post-hoc pair-wise t-tests. We conducted the evaluation based on the individual scenarios as well as with categorization of action and perception (cf., Table 1).

We also did a control analysis in which we checked the control factors of tech-savviness (low vs. high – split in half based on median), gender, country (Western vs. Middle East), and age. We found one statistical difference for country. Respondents from Western countries ($Med = 4.33$, $Mad = 1.48$) are less anxious than respondents from middle eastern countries ($Med = 3.33$, $Mad = 1.48$), $F(1, 97) = 14.082$, $p < .001$. We found no further statistically significant main and interaction effects.

3.7 Results

Figure 2 gives an overview of the nine survey constructs for each of the eight EMS scenarios. Table 3 gives an overview of statistical comparisons for each construct based on the scenario and previous experience with EMS as reported by respondents including the effect size of each factor. In the following, we provide an overview of the analysis of the survey results highlighting the main findings.

3.7.1 Overall Rating. We averaged the responses over all constructs and found statistically significant differences for scenario and previous EMS experience (cf., Table 3 and Figure 3). We also found interaction effects between scenario and previous EMS experience.

Averaged over all constructs, respondents rated the health ($M = 5.03, SD = 1.00$) scenario significantly better than all other scenarios (all $p < .05$). In contrast, they rated Perception 1 ($M = 2.91$, $SD = 1.42$) (all $p < .05$, except for Action 1: $p = .46$) and Action 1 ($M = 3.29$, $SD = 1.52$; all other $p < .05$ except for Perception 2: $p = .19$) worst. Action 3 ($M = 4.35$, $SD = 1.41$) was rated second highest (Perception 2: $p = .03$, all other $p > .05$) followed by Action 2 ($M = 4.24$, $SD = 1.46$), Perception 3 ($M = 4.17$, $SD = 1.47$), Sports ($M = 4.11$, $SD = 1.49$), and Perception 2 ($M = 3.75$, $SD = 1.41$) where we could not find any further statistically significant differences (all $p > .05$).

3.7.2 Trust. Respondents rated the health scenario particularly high with regards to *Trust* independent of experience (cf., Figure 4). Those with previous experience have significantly more *Trust* in EMS than those without. Although, *Trust* in health-related applications is uniformly high across both groups. Particularly Action 1 and Perception 3 are rated higher by experienced respondents compared to non-experienced respondents.

Comparing the scenarios, we found that health ($M = 5.33$, $SD = 1.39$) was rated better than all other scenarios ($p < .05$). On the other hand, Perception 1 ($M = 3.15$, $SD = 1.85$) is rated lowest (all comparisons $p < .05$ except for Action 1: $p > .05$) followed by Action 1 ($M = 3.30$, $SD = 1.89$) that was rated second lowest (all other comparisons $p < .05$ except for Perception 3: $p = .09$). Furthermore, all other comparisons did not show statistically significant differences ($p > .05$).

[5] https://www.limesurvey.org/

Figure 2: Stacked bar charts of the responses of the online survey ($N = 101$) for each of the nine constructs listed in Table 2. Note that constructs with multiple questions are averaged per scenario.

3.7.3 Social Factors and Acceptability. Figure 5 (left) shows a summary of responses to questions about social factors for EMS applications. Overall, Health ($M = 4.33$, $SD = 1.79$) is rated highest followed by Action 3 ($M = 4.03$, $SD = 1.85$) and Action 2 ($M = 3.97$, $SD = 1.91$). Perception 1 ($M = 2.66$, $SD = 1.76$) is rated lower compared to all other scenarios ($p < .05$) except for Action 1 ($M = 3.07$, $SD = 1.79$; $p > .05$). Action 1 is additionally rated lower then Health ($M = 4.34$, $SD = 1.76$; $p < .001$), Action 2 ($p = .010$), and

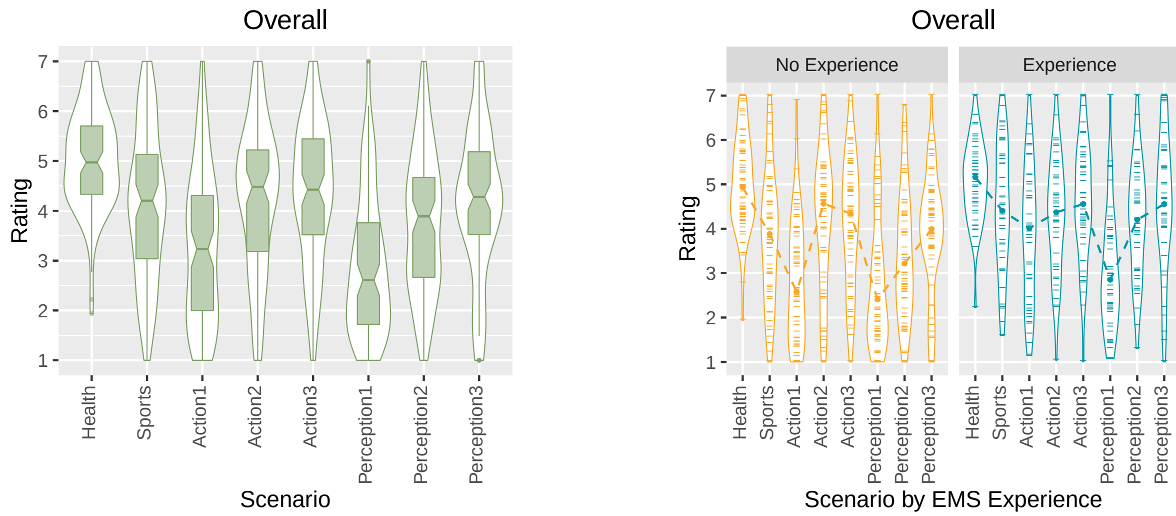

Figure 3: Boxplot and Violinplot of the responses averaged over all constructs per scenario (left) and split by experience (right).

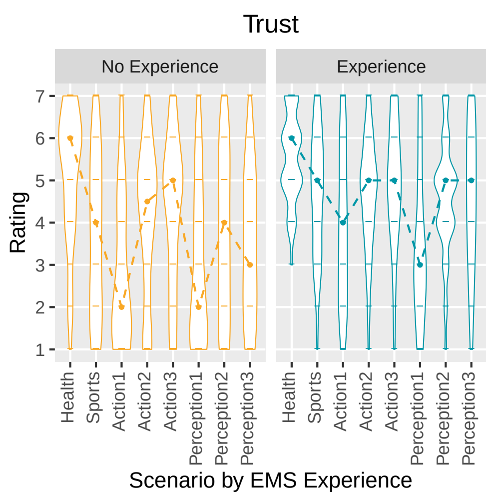

Figure 4: Respondent ratings for *Trust* related to the different scenarios. Respondents with previous experience with EMS respond significantly differently, with higher ratings for *Trust* than those without.

Action 3 (p = .004). Health is also rated higher than Perception 2 (M = 3.46, SD = 1.84; p = .012) All other comparisons could not show statistically significant differences (p > .05).

The experienced respondents (M = 3.99, SD = 1.88) rated scenarios on average higher compared to non-experienced ones (M = 3.32, SD = 1.83). Further, we observed an interaction effect of EMS experience on scenario. Experienced respondents rated all scenarios except for Perception 1 similarly whereas non-experienced respondents rated Action 1, Sports, Perception 2 and Perception 3 lower (cf., Figure 5 – left).

Comparing the questions about EMS usage home alone (cf., Figure 5 – center) and EMS usage in public alone (cf., Figure 5 – right), we found that experienced respondents (M = 4.31, SD = 2.14) compared to non-experienced respondents (M = 3.22, SD = 2.17) tend to be more willing to use EMS home alone ($F(1, 99)$ = 12.867, p < .001, η^2 = .063). In contrast, we could not find a statistically significant effect for experienced (M = 3.74, SD = 2.09) compared to non-experienced (M = 3.36, SD = 2.05) respondents for the same question in public with friends (cf., Figure 5 – right; $F(1, 99)$ = 1.554, p = .216, η^2 = .008). The only exception in the rating of experienced respondents is Perception 1 which was rated low independent of the location and experience of the respondent.

3.7.4 Anxiety. Figure 6 shows a summary of responses to questions about *Anxiety* towards using EMS applications grouped by previous experience with EMS. Experienced respondents have significantly less *Anxiety* towards EMS compared to non-experienced respondents.

Looking into the specific scenarios, Health, Action 2 and Action 3 are rated significantly better compared to all perception scenarios (p < .05). In contrast, Action 1 was rated significantly worse compared to every other scenario (p < .05) except for Perception 1 (p = .10). Health is rated better than sports (p = .01). All other comparisons could not show statistically significant differences (p > .05). We also found that respondents in general are more anxious about hurting others (M = 4.48, SD = 1, 63) than hurting themselves (M = 3.71, SD = 1, 94) (cf., Figure 6 – center and right).

3.7.5 Further Influence of Experience. We also found that previous experience has a significant effect on *Perceived Usefulness* with experienced respondents (M = 4.28, SD = 1.95) rating higher compared to non-experienced respondents (M = 3.75, SD = 2.07). The *Attitude* towards the EMS scenarios also changed with the experience. Experienced respondents (M = 4.25, SD = 1.99) had a more positive *Attitude* compared to non-experienced ones (M = 3.77, SD = 2.10). The experience also influenced the rating for the different scenarios concerning *Intention of Use*, *Compatibility*, and *Attitude*.

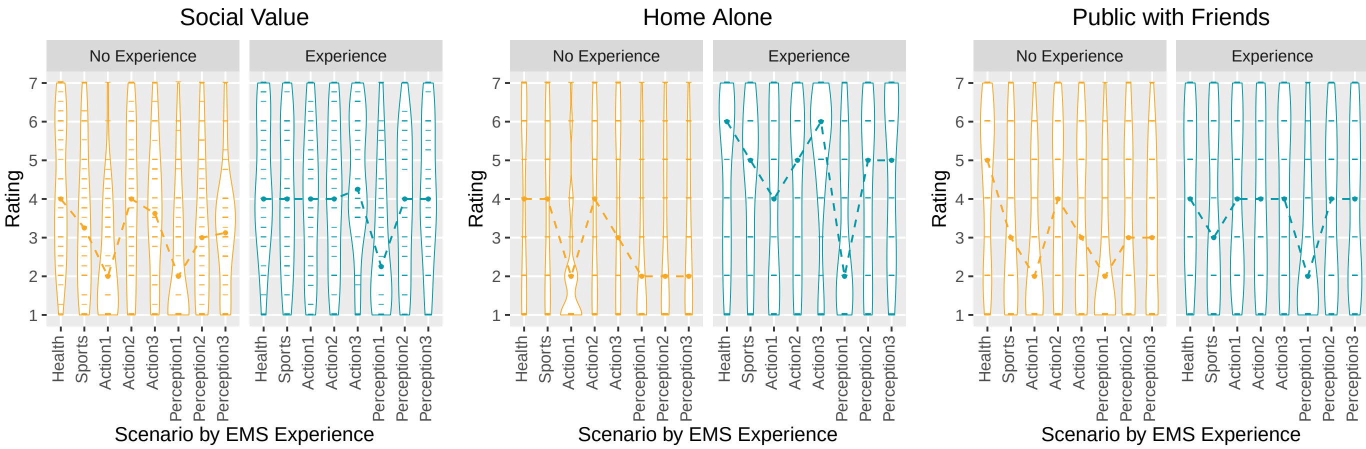

Figure 5: Respondent ratings for social factors related to EMS applications in sports, health, action, and perception. Respondents with previous experience with EMS responded significantly differently, with more positive attitudes, than those without.

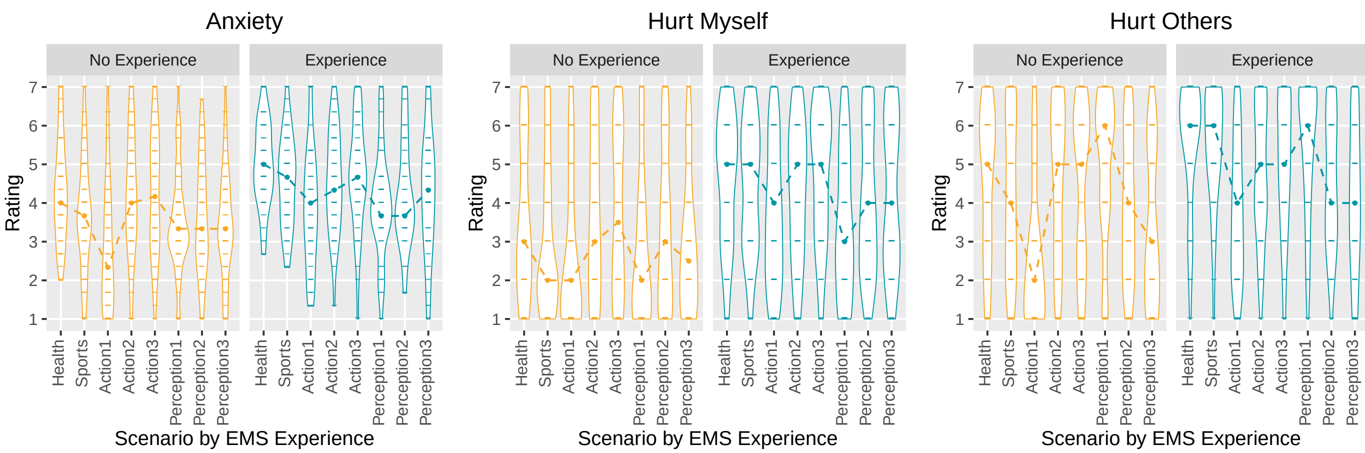

Figure 6: Respondent ratings for *Anxiety* related to EMS applications. Overall, respondents with previous experience with EMS respond significantly differently, with lower levels of *Anxiety*, than those without (left). Similarly, the ratings of the questions whether they would think they would hurt themselves (center) or others (right).

4 INTERVIEWS

Following the results of the online survey, we conducted 10 semi-structured in-depth interviews to gain further insights into users' attitudes, motivations, and acceptance of EMS technologies.

4.1 Method

We started each interview by presenting the chosen scenarios again and highlighting that they represent different application domains, namely, health, sports, action, and perception. Next, we systematically went through the constructs and revisited each question to shed light on the reasons behind their answers.

4.1.1 Recruitment. We recruited interview participants from the respondents of the online survey. Overall, 25 respondents from the survey volunteered, out of which we selected 10 interview participants (cf., Table 4). To further understand our survey findings on the impacts of previous experience with EMS and acceptance, we selected five participants with no experience and five participants with experience using EMS. Participants' main experience with EMS varied from using it for fitness training (1 participant), overcoming health problems (e.g., physiotherapy – 2 participants), researching EMS in HCI (2 participants). We optimized the selection of the experienced participants to include all different experiences.

4.1.2 Procedure and Asked Questions. We conducted the interviews partly via video conferencing software (i.e., Zoom) and in physical meetings (e.g., in our lab environment). Interviews lasted on average seventy-five minutes and were audio recorded. The interview protocol explored the nine constructs from the survey with a focus on eliciting the reasoning and motivation behind participants' answers. At the beginning of the interview, we reminded the participants of the eight presented scenarios (HCI, sports, and medicine) and that these are potential scenarios illustrating how EMS could be used in the future. Then, we asked questions about each construct from the survey (cf., Appendix A). At the start, we mentioned the questions as presented in the survey, then we extended these questions to get more insights. For example, in the *Perceived Enjoyment* we repeated the question as in Table 2. We proceeded by asking them what would they expect as *Perceived Enjoyment* and what benefit would the users need so that they would enjoy using the system. We applied the same strategy with all the constructs with a varying number of questions for each construct and asking for more insights whenever possible. We designed and conducted the interviews according to our local ethical guidelines.

4.1.3 Qualitative Analysis. We analyzed the interview transcripts following thematic analysis as after Braun and Clarke [7], an approach that allows for both inductive and deductive theme generation. The flexibility of thematic analysis was important because we aimed to uncover the reasons and patterns behind the results of our earlier, larger-scale survey. A deductive orientation allowed our existing construct to act as a ‘lens’ to interpret the collected qualitative data in light of the earlier survey. Simultaneously, inductive theme generation allowed us to account for unanticipated patterns and more closely examine the factors that contextualize the participants’ perception of EMS. After a phase of familiarization, the initial codes were extracted by the first author and then iteratively discussed and refined in collaboration with the team of authors. We started out from code clusters (candidate themes) that were then developed further, revisiting the original interview excerpts where necessary. In this process, a thematic map, including a mapping of patterns across the interview data, was created using a Miro board[6]. Along this process, code cluster were contextualized and contrasted with the constructs asked in the questionnaire (cf., Table 2) which lead to overarching themes, spanning multiple of the original constructs (e.g., Urge to Use, Causes of Anxiety), as well as more nuanced, refined notions covering two distinct aspects of one single construct (e.g., *Social Value* relating to External Image and Design Requirements). In total, we generated six themes that provide essential background information to our survey results and derive and motivate design recommendations for future EMS applications.

4.2 Results

Since we conducted semi-structured interviews to uncover the rationales behind the answers given in the survey, our questions were aimed at gaining further insights into the nine used constructs. However, for clarity, we named the themes in a way that is distinct from the constructs avoiding any overlaps in terminology. For readability consistency, we link each theme to the answers obtained from the interview (cf., interview questions – Appendix A).

4.2.1 Urge to Use. Participants often highlighted that their responses depended heavily on the use case and the reasoning *“why it is useful”* [P10]. This came as a reply whenever asked about *Perceived Usefulness*, *Perceived Enjoyment*, *Intention of Use*, *Functionality*, *Compatibility* and *Attitude* questions. P8 clarified that he would be using the system *“if a system, is clever and helps on achieving a specific goal"*. Analyzing the answers, it became clear that the Urge to Use would be highly individualized. For example, P2 said *“I would use it in doing faster housework definitely"* or for a different interest as P4 mentioned *“I would use it to enhance my experience in gaming in a meaningful way."*

[6]https://miro.com/

Table 4: Characteristics of the participants in our interview sample. They were split between “no prior experience with EMS” and “with prior experience” with a variety of common EMS applications. The sample was gender-balanced.

Id	Age	Gender	Previous Experience	Technology Interest
P1	38	Male	No experience	high interest
P2	37	Female	No experience	medium interest
P3	31	Female	No experience	low interest
P4	35	Male	No experience	high interest
P5	37	Female	No experience	low interest
P6	30	Female	Sports training; Participation in HCI studies	high interest
P7	57	Female	Medical Treatment; Participation in HCI studies	medium interest
P8	39	Male	EMS usage & development in sports	high interest
P9	29	Male	Medical Treatment; EMS usage & development in HCI	high interest
P10	29	Male	EMS usage & development in HCI	high interest

When asked to categorize the applications according to their potential use cases, participants indicated that the health-related applications are the most important, with focus on medical applications as they have a strong motivation to use it. P2 reflected that by saying *“I would use it, if I have a disability and I know that there is a system out there that could help."* P6 reflected on a critical situation, for example *“if I am in a desperate need and normal measures don’t work."* P5 who had low interest in using new technologies in general elaborated *“I am not a tech fan, I will not use it unless it is used for rehabilitation or physiotherapy."* Overall, the Urge to Use is the participants’ main motive and it differed from one participant to the other. However, all of them agreed on using it in health-related applications.

Participants also discussed their acceptance of the action and perception use cases, again highlighting the importance of individual scenarios. P10 commented *“it can generate some feedback that cannot be generated by the other systems or prevent me from danger"*. This participant’s preference of the use case was dominant, with more focus on the outcome. P4 had an interest in gaming and discussed gaming specific scenarios (i.e., entertainment), while P3 had less interest in technology and preferred to applications for learning music (i.e., artificial trainer). Participants also related the

Intention of Use to their feeling towards the use case as P1 expressed it *"I think it is an emotional point of view, but I would feel comfortable using it whenever I have interest."* The Urge to Use could be summarized in P6 quote *"if the desire is big enough to use new technology, you will find a way to work around"*.

4.2.2 Design Requirements. Answering the *Social Value* construct questions, the participants indicated both functional as well as hardware requirements. P10 highlighted that the system should be interactive as *"you can't get good control and natural movements of overlapping muscles without having a full image of the body state"*. This point was also confirmed by P6 who said that she would like to see an *"adaptive system"*. Others indicated that they would like to have an easily controlled system that they could *"fine tune"* [P1] to reach certain *"control levels"* [P3]. All of the participants wanted an easy system to use that would not be *"cumbersome"* [P10].

Participants also reflected on the hardware requirements, with all of them highlighting the necessity of small size and familiar look as P5 described *"it would look weird to have electrodes and wires, it would make me feel nervous. If it is like a glove it would be better"*. While all the participants' comments related the positioning of the electrodes and safety measures, P7 mentioned it from an outlooking perspective. She said *"I would think about the electrodes at the head from a beauty aspect. It is easier to have them on the body."* Two participants compared EMS to a smartwatch, a technology that one can wear and easily operate [P4, P10]. Other general design aspects were then presented like: size, mobility, battery life, reusability, and hygienic use.

4.2.3 External Image. Participants expressed worry about the community perceived image of users of EMS-based systems, which is captured by the survey's *Social Value.* When elaborating during the interviews, all participants indicated that EMS should be integrated into other objects such as clothes or accessories as a way to avoid the impression of being controlled by a computer. As P1 explained *"appearance sells, the more it is not obvious the better in order not to feel different. Everyone wouldn't like to go around with wires"*. Whereas P10 noted: *"In public I won't use it as long as it is visible to others unless it is integrated into clothes then it is ok."* Further, participants were afraid of attracting attention by behaving non-human like. P10, for example, mentioned that *"if my movements would be robotic-like, people would look at me, even when I have the option to override it, still I would look weird to others if I am suppressing the EMS signal."* While all participants expressed their concerns of using EMS in public, they discussed their acceptance when it comes to others using EMS. P6 explained *"Usually I don't pay attention except to odd stuff. If the kit is visible, yes I would look [...] again curiosity of the use case, but I wouldn't see it as inappropriate"*. In particular, *"if people with disabilities are using the system, it would look like a medical device and then it is a design question"* [P8]. In general, the participants feared being perceived odd by the surrounding community either because of their appearance using EMS or the EMS influence on their movements.

4.2.4 Causes of Anxiety. Participants mentioned concerns regarding using an EMS-based system as they replied to the *Anxiety* and *Trust* constructs questions. They discussed the positioning of electrodes & they expressed their fear of approaching the head, neck, private, and vital parts of the body. P1 further elaborated *"we don't know everything about the body. I know people with nerve problems and don't know the impact on them"*. The fear of damaging nerves was also brought up by P6 as she said *"I would not use anything that directly targets the nerve ending, I don't want to have them electrocuted."* Other participants expressed their concern of long-term side effects. P4 mentioned the need for further *"debates regarding long-term effects and implications"*. P1 highlighted his fear of long-term effects as he wondered *"what would happen when the strength of the signal going to the muscle tricks the brain to send different actuation strength"*. Another group of concerns targeted the perceived safety level while being actuated. P4 started by giving an example based on the food texture. He said: *"Sometimes when I eat something old, I feel that because of its texture. If I used the chewing system I would not be able to do that."* P9 gave an example relating the cruise control scenario with a system failure, where a user might be erroneously guided to a dangerous area. P8 used the same scenario, to highlight that the system could make him stumble as a result of actuating his feet. However, he mentioned that the user has an active role as well, as he further elaborated *"this is something that you have to adapt to the system and change your behavior to be able to use it. Like modifying my gait while walking."* P6 mentioned: *"I would keep distance and I would warn those in a close range."* Both P3 and P8 mentioned that the lack of knowledge of how far the system can go would prevent them from using it. Even when we informed participants that muscle strength can overcome EMS actuation, participants still raised the concern that overcoming actuation might look *"weird"* [P10], *"be accompanied with pain"* [P6] and might not be at the *"right moment"* [P4]. All in all, the participants were mostly concerned about the consequences of a system failure and the side effects of using EMS on their body as well as perception.

The participants proposed solutions that could overcome the challenges of *Anxiety* and safety. Most of the proposed solutions could be grouped as characteristics of a smart system. All of the participants highlighted the importance of having an emergency safety switch that would instantly disengage the system. One of the participants further commented *"I would assume it is there by default"* [P5]. Out of our ten participants, eight indicated a higher sense of safety if the system was recommended by a person with experience or if they could use it in presence of an expert (e.g., medical doctor), but this raised the question *"who would you consider as an expert?"* [P8]. Another aspect is the adaptivity to the body state as described by P10: *"A smart system would detect the user parameters, for example, user's sweat level and heart rate and would stop in case of reaching certain measures."* This would also prevent the user from *"overexerting the muscles by knowing the maximum limit"*, P6 further explained. Another safety measure that affected the participants' acceptance was the system transparency. P5 explained: *"I would need a manual with a clear description, relevant to my use case [...] with rules, regulations, and limitations."* Another direction of safety addressed the research field more generally. P1 said that *"the system should be widely tested, along a well-prepared introduction with numbers and safety aspects presented to the public"*.

4.2.5 Agency. When asked about their responses related to the constructs of *Anxiety* and *Trust*, our participants expressed a desire for a sense of control over their own actions. One described how they perceived EMS to be *"playing a game with your body"*. In total nine of the interview participants commented on Agency and expressed similar concerns. Furthermore, all of the participants commented on the cruise control scenario. As P6 expressed her concern with this particular scenario, mentioning that *"I need to have enough autonomy on my body."* Others also expressed their non-acceptance of being controlled. P5 elaborated: *"I don't like the idea of being pushed to do something. I hate the idea of the system agency, it would make me nervous."* P10 expressed his worry of the system's decision in critical situations. For this he used the preemptive action example (i.e., Action 2). He elaborated: *"The system has to know what to do, which is tricky. If the system would speed up my reaction time to catch a coffee cup instead of a pen, I wouldn't trust using it."*

4.2.6 Ethical Perspective. Participants' concerns extended beyond just safety, for example worry of legal issues and regulations. These comments were mentioned when the participants talked about the *Anxiety* construct. P4 expressed his worry, saying: *"Who is responsible for the errors, do we have risk management? I doubt we have a holistic view of the whole chaotic environment."* P9 and P10 expressed their worries using examples like regulations for autonomous vehicles. For example, P9 said: *"In the cruise control, it is like GPS or system failing to guide someone, like dangerous autonomous cars GPS failing experience"*. Four participants showed their concern that EMS could be used to control other people. P1 said: *"I don't judge but I won't accept it if it is a mother controlling her child [...] I will not perceive it negatively unless it is touching the negative ethical point"*.

5 DISCUSSION

5.1 EMS Constraints on Muscle Contact and Power Need to Blend into the User's Appearance

The need for EMS that combines functional electrode placement and socially acceptable wearable technologies is clear from our results. Social aspects play an important role in EMS acceptance as indicated by our participants in the ratings of the *Social Value* construct (cf., Section 3.7.3) and their comments regarding External Image in the interviews (cf., Section 4.2.3 – External Image). While experience influenced the participants' willingness to use the technology alone at home, this influence was not observed in public. Multiple participants mentioned that cables *"coming out of the body"* (i.e., from electrodes on the body) might not be appropriate in a public space. This is in line with Dunne et al. [14] work on the social acceptability of wearables, where they found that users are afraid that their wearables attract (negative) attention. Throughout the interviews, we received multiple suggestions to integrate the electrodes into clothing or accessories. Our results support what has been hypothesized by Knibbe et al. [39], that future EMS devices should fulfill wearability criteria, including aesthetics and social acceptability. While the technology is not there yet, there are some approaches to include EMS in smart textiles [64]. However, not all parts of the body are always covered with clothing. Moreover, the position of the muscle is defined by human physiology and constrains electrode placement [64]. Thus, the design space with regard to electrode placement is limited, which requires more adjustable systems (e.g., Chen et al. [10]). Our results highlight the social constraints that must be considered when developing EMS in terms of electrode placement and user appearance.

5.2 Action Elicited by EMS Needs to Be Compatible With Existing Human Dynamics

Besides having a device that is designed to look natural on the body, EMS also uses the human body as an output device. This induced movement should still look like existing human movements and dynamics. How the body moves when stimulated by EMS is important for factors like the *perceived social image* of the user, as elaborated by our participants in the interviews (cf., Section 4.2.2 – Design Requirements). EMS could be integrated into acceptable wearables, but this might still lead to unnatural looking movements that attract (negative) attention. Social appearance anxiety, described as *"fear of negative evaluation of one's appearance"* [44], is a particular threat to acceptance when the technology can produce un-natural looking movements. While EMS in general mimics the signal of the brain and therefore provides similar input to the muscle than the users themselves, the fine-grained control of muscles is still an open challenge. Particularly muscles that are covered by other muscles cannot always be actuated precisely (if at all) with electrodes placed on the skin. The actuation should be designed in a way that the movements look as close to user initiated movements as possible. For example, the work by Takahashi et al. [79], where they explored new EMS electrode placement for increasing dexterity. Another issue is the *Trust* shown to the user's actions and movements are perceived as robotic, sudden, or random. In some situations, where the application is stationary and the interface is clearly visible (e.g., in VR) the spectator's experience [70] will differ from scenarios where the user is using it in public in an unobtrusive way (e.g., cruise control [62] hidden by long pants). As a result, the spectator's *Trust* and caution towards the EMS user might also differ. For this reason, we recommend evaluating the perceived visual appearance of behavior elicited by actuation and perceived trustworthiness when evaluating acceptance of EMS. Although exploratory work in EMS may results in actuated movements that do not match human dynamics, refinement towards more natural movements is important to improving acceptance of EMS in everyday life.

5.3 EMS Needs a Safety Net or Emergency-off Switch and a Clearly Communicated Status

Beyond visual appearance and perceived awkwardness, users were afraid of specific issues like control, pain, and agency. Prior work noted that their participants' felt that EMS feedback was uncomfortable [2], unnatural [54], weird [61], induced numbness as well as tingling [10, 42, 48] and unfamiliar sensationas [23, 37]. Furthermore, research showed that participants have fear of losing control [38, 61]. This observation is further supported by our findings. Fearing that a system failure might hurt them directly or even hurt others, causes a high level of *Anxiety*. Participants were particularly afraid of failure in safety measures, for example not being able to override the EMS signal and lose their sense of agency. This is particularly clear in our survey results for the non-experienced respondents, whi were more anxious to hurt themselves compared to experienced respondents (cf., Section 3.7.4 – *Anxiety*). Furthermore, it is in line with prior research exploring the users' desired sense of Agency when interacting with technology [45] and their fear of control loss [62, 74]. Even if the safety of an EMS system can be ensured through technical security measures in software and hardware, the EMS system would still need to provide options for manual interrupt or override to support the user's sense of Agency and – in consequence – feeling of comfort. How to design interventions that can address Anxiety and Agency in wearable EMS is an open research challenge.

Safety measures for EMS should be introduced first, before exploring the user experience. We have found that potential users would refrain from using such a system just by thinking of consequences based on speculation. Unlike traditional user interaces (e.g., clicking a wrong button), a failure in the case of EMS not only produces the wrong action or result but also potentially unexpected sensations directly actuated on the body. EMS raises interesting challenges in the context of interface guidelines of Shneiderman et al. [77], for example that systems should provide an easy reversal of actions. While this is easily implemented in conventional computing systems, EMS actuates the human body in the real world and reversal of action may not be possible.

5.4 EMS Applications Should Target Specific Use Cases That the Users Deem Necessary

The interviews demonstrated that *Urge to Use*, such as a necessary use case, is the main motivation to use EMS (Section 4.2.1 – Urge to Use). Novelty alone seems not to be enough to drive an Urge to Use. This is further supported by the survey results, where scenario tends to influence the responses more than previous experience with EMS. We also found that the *Perceived Usefulness* is influenced by the users' prior experience with EMS. EMS provides unusual feedback and sensations directly to the body, and unfamiliarity makes judging utility more complicated for users.

For all constructs, we found that scenario significantly influenced the ratings of the respondents (cf., Figure 3). This was especially pronounced in the *Functionality* construct, where the participants perceived the health-related scenarios as providing realistic purposes. In the interviews, all participants mentioned that the value a scenario adds should be directly relevant to their personal benefit. For example, if they are planning to learn a new musical instrument and EMS might support them by guiding their finger movements, this would be valuable enough that they would accept the technology. In contrast, some scenarios did not provide enough value (e.g., changing the food texture [Perception 1]) to encourage acceptance. These results are in line with previous work where participants shared about their opinion in four different EMS applications in HCI [74] (i.e, motor skill learning [15, 80], virtual reality applications feedback [50, 51], interacting with media player [46] and road safety [62]). They found it non-essential to integrate the EMS experience in these situations.

Future applications of EMS with high utility could change acceptance of EMS. For example, EMS that can give users "superhuman powers." If EMS could improve human reaction times (e.g., preemptive action scenario), this would be a high utility scenario and complex social and ethical implications. Participants also discussed ethical challenges of EMS (i.e., Section 4.2.6 – Ethical Perspective) is similar terms to autonomous vehicles [32]. For example, if a system failure resulted in hurting someone other than the user, who would be legally responsible for the resulting action? Although it was clear in our results that the use-case plays the most significant role in acceptance, ethical and legal aspects need to be further investigated as use cases increase their utility.

5.5 Simple Applications May Help Overcome High Entry Hurdles of EMS

Throughout the survey data analysis, we found that respondents with previous experience provided more favourable responses to EMS compared to respondents without previous experience. A core reason for this difference is users' *Anxiety*. In the survey responses (cf., Table 3) and throughout the interviews (cf., Section 4.2.4 – Causes of Anxiety), non-experienced participants emphasized that they were afraid of hurting themselves. This impression is also solidified by non-experienced participants mentioning that they would prefer the help of professionals while using EMS and, consequently, not feeling comfortable using it home alone. In contrast, experienced participants prefer home usage due to social reasons. The insecurity of the non-experienced participants was tied to having never perceived EMS. They were, for example, afraid that the EMS device could force them to move beyond their normal limits. While the latter might be addressed by providing explanations and reassurances, the lack of knowledge about how EMS actually feels creates a significant entry hurdle.

This high entry hurdle has practical relevance: while user acceptance (as in TAM [12]) describes the willingness to *start using* a product or system, user experience [29] is decisive for whether a user *will continue* using it. As our results demonstrate that user acceptance is lower with non-experienced users, we identified targeted actions such as specifically designed demo cases to lower the entry barrier. An initial positive user experience can increase the willingness to use with experienced participants: some even mentioned that with a negative experience (e.g., tickling) in the beginning, they would still be willing to continue using EMS. This highlights how our work's focus on *user acceptance* complements existing work on EMS' user experience [38] by adding an orthogonal perspective.

5.6 EMS Applications Should Provide Suitable Means to Share Control Between User and Computer

EMS has the ability to take control of the users' body if the users are willing to share them, asking users to hand over some control over their own bodies to the computer. The challenge of sharing the control was a recurring theme in our results. Nine of the interview participants reflected on the fear of losing control and not having enough *autonomy* (cf., Section 4.2.5 – Agency). One aspect that was mentioned is not knowing the extent to which the system would be actuating them. Particularly, non-experienced participants expressed concerns about how they would maintain their control and were unsure if they could easily overpower EMS actuation. Similar issues were discussed in the field of autonomous vehicles, for example handing over and regaining control from driving systems. The issue of sharing control and when would it be suitable for humans to take over control from a vehicle has been extensively investigated [6, 17, 68]. While there are differences between the two cases (e.g., nature of interaction, system failure consequences, etc.), control sharing still needs to be researched for EMS. For example, while driving it is clear how the user is required to intervene (e.g., driving wheel). Control sharing metaphors for EMS are still an open challenge. While classical interface guidelines such as Golden Rules by Shneiderman et al. [77], which suggest that the user should maintain control of the system (i.e., be the initiator of action), it raises the challenge of how that should be done in cases where users want to hand over control.

5.7 Limitations

We acknowledge the following limitations to our work. Firstly, we recruited participants for the online survey through social media and mailing lists. Although previous research has shown this method to be feasible [4, 5, 43], we acknowledge that it can introduce biases in our sample composition. We in particular acknowledge that a high number of participants in our sample have prior experience with EMS. Although the number of participants who had prior experience with EMS through participating in HCI-related studies was relatively high (12 of 43), participants had various other experiences with EMS (physiotherapy, sports, studying medicine – see Subsection 3.6). We believe that this reflects a state in the future where people have tried EMS-based applications with friends or medical personnel and, thus, have experienced it a few times in real life. Further, we gave all participants an introduction to how EMS would be used to ensure equal grounds. The goal here was to make sure that, even if participants used EMS differently (i.e., in medical treatment without actually inducing a signal that makes limbs move), they understood the potential of EMS as it is currently used in HCI. Although we iteratively in a human-centered approach improved the videos and descriptions of the used applications, it remains possible for users to have a misunderstanding of one of the applications or EMS in general. This is, however, a similar situation as in the future when users get to know EMS systems through advertisements or explanations of family and friends. We addressed this limitation by explicitly distinguishing between novice and experienced users. The selection of interview participants might also influence the qualitative results. We chose both novice and experienced users (i.e., participants that used EMS multiple times during sports training, medical treatment, or participating or conducting research in HCI using EMS) from the survey sample to ensure that both groups are represented since we found that the experience has a strong influence (cf. Table 3). However, this limited our pool of potential volunteers. Nevertheless, particularly among the experienced users, a diverse set of participants volunteered for the interview, with previous experience in using EMS for medical treatment or as output technology in HCI research.

Secondly, we utilized an online survey to gain an initial understanding of user acceptance of EMS. We thereby aim at the intended behavior of the users without any prior experience with EMS. Although the intended behavior differs from potential future behavior [75], the insights generated in our study play an important role in understanding the different components of user acceptance (cf. Table 2). This makes our work complementary to the work on EMS and user experience [38].

6 CONCLUSION

In this work, we provide a set of design recommendations for EMS applications. We conducted an online survey. We then analyzed the responses to the survey ($N = 101$) plus around twelve hours of in-depth interviews ($N = 10$). On the one hand, our results show differences between experienced and non-experienced users, indicating that the entry hurdle is one of the biggest challenges. On the other hand, we found that the scenario in which EMS is applied highly influences acceptance. Overall, even for experienced participants, we conclude that the design of EMS experiences should include consideration of aspects that affect the users' comfort, trust, and appearance. In the future, as the technology spreads and experience with EMS becomes more common, further investigations should be conducted to examine developing user attitudes.

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A SEMI-STRUCTURED INTERVIEW QUESTIONS

Interviewer: [welcomes participants, asks for consent, explains the purpose of the interview and the link to the conducted online survey, and explains (again) the basic principles of EMS]. We had 8 scenarios [interviewer presenting the photos as in Table 1 as well as photos of the two baselines]. Please always refer to the EMS technology in general. If one of the scenarios differs from the others, please let us know!

A.1 Social Value

Interviewer: [reading items from the original survey as in Table 2, then proceeds]
Q1. When would you use such a system? Does the location influence your willingness to use? Why?
Q2. How would you think of people wearing such electronic devices (think about playing games, interacting with a system, health, and sports)? Why? When/where would that be acceptable in your point of view?
Q3. What if such a device is embedded in clothing or smartwatch – would that change your opinion and make it more acceptable?
Q4. How important is appearance for you in general? How about such a device?

A.2 Perceived Usefulness

Interviewer: [reading items from the original survey as in Table 2, then proceeds]
Q1. What application scenario would you consider useful?
Q2. When would you agree to use EMS?

A.3 Perceived Enjoyment

Interviewer: [reading items from the original survey as in Table 2, then proceeds]
Q1. Can you indicate what you expect as perceived enjoyment?
Q2. What benefit would you need so that you would enjoy using it?

A.4 Anxiety

Interviewer: [reading items from the original survey as in Table 2, then proceeds]
Q1. Why are you afraid to hurt yourself/others? Does the fact that you can override the technology help that you feel safe?
Q2. What about receiving feedback vs. feeling being actuated why?
Q3. What needs the system to do in order to provide a higher security level or more assurance for you? Would a safety switch or communication of intent help to trust the computer?

A.5 Trust

Interviewer: [reading items from the original survey as in Table 2, then proceeds]
Q1. Why or why not do you trust EMS? If wearing EMS would convey a better experience, performance, or treatment, for which scenario/experience would you be certain of using it? (Which not?) Why?
Q2. Would you trust being actuated with EMS for each of sports, action, perception, and health? Why this specifically?
Q3. EMS provides the control over parts of your body to a computer. This rarely happens in other occasions. What would you need to accept that a computer partly controls your body?
Q4. Is it different in health? Why? What about Doctor prescribing for example the navigation system to let you walk a longer way home to have a healthy and active lifestyle?

A.6 Intention of Use

Interviewer: [reading items from the original survey as in Table 2, then proceeds]
Q1. What negative implication do you expect? How to overcome them?
Q2. Do you think in general there is a scenario where you would like/can use EMS in your daily life? How would it look like? How should one of the scenarios change so that you would use it?
Q3. Does the location of the electrodes influence your rating? Would putting them on your head differ from limbs or from rest of the body?

A.7 Functionality

Interviewer: [reading items from the original survey as in Table 2, then proceeds]
Q1. Why do you (not) think that EMS could provide realistic functionality? More details?

A.8 Compatibility

Interviewer: [reading items from the original survey as in Table 2, then proceeds]
Q1. What everyday task you do that might benefit from EMS?

A.9 Attitude

Interviewer: [reading items from the original survey as in Table 2, then proceeds]
Q1. What would you make using the EMS technology? How should technology be/not be? Would you rather use perception or action scenarios?
Q2. Do you have experience with EMS? What? Did your opinion towards EMS change after trying it out?