big data and cognitive computing

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Social Acceptability in Context: Stereotypical Perception of Shape, Body Location, and Usage of Wearable Devices

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Abstract: Assessing social acceptability is vital when designing body-worn mobile devices. Previous research found evidence that using stereotyping content model (SCM) mobile devices can systematically predict ratings of the warmth and competence of their wearers. However, it is currently unknown if other contextual dimensions of mobile device usage can also systematically affect those ratings. In two studies, we investigate if and how shape and body location of a body-worn mobile device as well as the activity in which the device is being used can systematically influence stereotypical ratings. Our results suggest that this is evident in some but not all cases. We conclude that people further differentiate between the placement of the device, particularly devices in the user's hand, and during an activity in which the device can contextually be misused. This indicates that users further differentiate the context and that more contexual information is helpful while operationalizing the SCM as a measure for social acceptability.

Keywords: social acceptability; social context; mobile devices; wearables; stereotyping

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Citation: Sehrt, J.; Braams, B.; Henze, N.; Schwind, V. Social Acceptability in Context: Stereotypical Perception of Shape, Body Location, and Usage of Wearable Devices. *Big Data Cogn. Comput.* **2022**, *6*, 100. https://doi.org/10.3390/bdcc6040100

Academic Editor: Min Chen

Received: 29 July 2022
Accepted: 20 September 2022
Published: 23 September 2022

1. Introduction

Finding objective measures for the underlying cognitive process of stereotyping and perceiving social acceptability of users with wearable devices is important for designing products that are supposed to be worn in public settings. Particularly for mobile devices, assessing social acceptability is important as judgments in social settings do not only influence how the device is being perceived by other people but also whether and how such a device is being worn and utilized by its user. There is evidence that a number of factors influence the social acceptability of mobile devices. In particular, humans themselves are responsible for the social perception of the mobile devices they are wearing. For example, bystanders assume that smart glasses are more accepted when used by persons with disabilities [1] or when a person is marked as being disabled [2]. Therefore, research in human-computer interaction (HCI) seeks reliable models able to evaluate social acceptability in different contexts.

In empirical research, the evaluation of the social acceptability of mobile devices often follows a simple paradigm: the device is presented in a neutral and controlled way and then evaluated using questionnaires by the researchers [3–5]. Although the neutral notion of mobile devices can be valid for many cases, it has also been demonstrated that the social acceptability of devices does not only depend on the design [6] but also on where the device is being worn on the body [7] or on the situation of the device usage [8]. For example, when in a situation in which people are supposed to socially interact with each other (such as in a cafe), wearing headsets or head-mounted displays (HMDs) is considered to be problematic in terms of social acceptability [8]. In addition, not only the user's activity but also the location of the device on the body of the user seems to affect their social acceptability [5,6,9]. Dunne et al., for example, present a body map and define areas where a user should place a wearable device for increased social comfort [7]. Consequently, researchers such as Koelle et al. criticize that *"social acceptability is mostly evaluated in highly to moderately controlled settings"* [5] and ask for more discussions regarding *"what constructs it might comprise"* [5]. Thus, considering more contextual factors when measuring social acceptability seems necessary, but how to incorporate all the factors of contextual usage when evaluating mobile devices remains unclear.

One solution to take multiple contextual factors of social acceptability into account is the stereotype content model (SCM) by Fiske et al. [10]. The SCM is based on the assumption that the cognitive process of *stereotyping* assesses people in two *"universal dimensions"* [11]—other people's intent and their capability to pursue it. Individuals or groups not competing for the same pool of resources are considered as *warm*, and those who can carry out their intentions are considered as *competent* [10,11]. Following a binary view on those two dimensions, they lead to various emotions: paternalistic (high warmth, low competence), admirable (high warmth, high competence), contemptuous (low warmth, low competence), or envious (low warmth, high competence) [10,11]. While the over-generalization of groups and individuals through the cognitive process of stereotyping likely leads to unconscious prejudices or biases [11–13], the mechanism is beneficial for quickly simplifying one's worldview and reducing the mental effort to assess other individuals [10,14,15].

Research in social psychology has shown that the SCM is not only a robust and valid method but also stable across cultures [15] and, interestingly, also applicable to non-human entities such as brands [16], consumer products [17], and mobile devices [18–20]. Research by Schwind et al. [19,21] found strong evidence that ratings of warmth and competence highly correlate with ratings of social acceptability of mobile devices and, thus, validate the model as a method to assess the construct for mobile devices. By taking an influential contextual factor into account—namely the *stereotypical user*—the SCM leads to surprisingly predictable measures of social acceptability of mobile devices across multiple studies [19,21]. The authors also found evidence for the potential reason for their results: wearers of mobile devices are anticipated to be part of stereotypical groups that are likely to use the device [21]. Our research is based on the assumption that not only the user but more contextual aspects do systematically contribute to the stereotypical perception and, therefore, to the social acceptability of mobile devices. This would be in line with previous work indicating that non-human factors can also be stereotyped [16,17,21] and would consequently indicate that a device's social acceptability is "just" the sum of all the stereotypically perceived contextual factors related to the mobile device's usage.

In two online surveys, we investigate if and how the body location of a body-worn mobile device as well as the activity in which the device is being used can systematically influence ratings of warmth and competence as suggested by the SCM. Our results indicate that only some—and consequently not all—contextual factors do systematically "attract" ratings of warmth and competence. We conclude that people further differentiate (or also do require more contextual information) to stereotypically assess body placement of the device, particularly in the user's hand or at their wrist, or during an activity, in which the device can potentially be used out of its context. This shows that the SCM cannot always be operationalized to predict social acceptability and that likely more contextual dimensions must be taken into account in order to precisely assess the social acceptability of body-worn devices.

Our research highlights that not only people [10], products [16], or other physical entities [19], but also abstract concepts or locations as contextual information can be subject to the cognitive process of stereotyping. Thus, we provide evidence for internalizing contextual information from different situations into the stereotypical perception and, thus, into a construct of social acceptability of users with wearable devices. The contribution is threefold: (1) We present the results of two user studies investigating the contextual stereotypical perception of wearable devices on different body locations, shapes, and in different activities. (2) We further validate the SCM and bring forward research for a reliable standard and systematization in measuring the social acceptability of wearable devices.

(3) As people differentiate a context, prediction models of social acceptability reach their limits. We illustrate these limits and discuss some possibilities and applications of the SCM to measure social acceptability.

2. Related Work

A growing corpus of work in HCI is concerned with the social acceptability of wearable computing devices and particularly looking at the social acceptability of interactions using gestures or head-mounted displays. As already indicated, studies in HCI and social psychology also found that the SCM can be an effective method for assessing and understanding ratings of social acceptability.

2.1. Social Acceptability in HCI

Researchers studying the social acceptability of mobile and wearable devices are particularly interested in figuring out why people accept (or reject) body-worn artifacts and in which situations interacting with wearable devices is problematic for any users or bystanders. Such interactions may include speech, gestures, body expressions, and the device itself [22–24]. Montero et al. [25], for example, differentiated between the user's and spectator's social acceptability and how culture, time, and interaction type influence social acceptability of interaction gestures. They found that the spectators' perception of other people depends on how well they can interpret the device manipulation and that an important factor in determining the social acceptability of gesture-based interaction techniques is the user's perception of others' ability to interpret the potential effect of the manipulation. In addition, Williamson and Brewster [26,27] as well as Väänänen et al. [28] showed that location and type of audience are important factors for the users' willingness to perform gestures in social settings. Moreover, assessing the social acceptability of different input modalities, Williamson and Brewster [24,27] further highlighted the importance of avoiding confusion about why users are gesturing or speaking, as such actions might be misunderstood by spectators. Looking specifically at on-body gestures, Profita et al. [9] revealed that gender and cultural background have an effect on users' willingness to perform the gestures in public.

Wearing devices or using them is a form of inter-human communication. Thus, researchers are not only wondering where to locate wearable devices for best interaction but also where users place and do prefer to wear their artifacts on themselves [29]. As the study was conducted in public, it implies aspects of social acceptance and reports that the wrist is the most popular location. In an exploratory study with designers conducted by Inget et al., the participants distinguished between private and public areas of the body. The study derived four additional dimensions for, e.g., smart jewellery devices: health-related, expression, social-, and utility-related [30]. The derived dimensions are interestingly similar to categories of devices used in other studies of social acceptability [1,19,21,31]. A study by Harrison et al. focused on the usability of displays on different body locations and how the displays can be obscured in different postures [32]. Contextual information about technological properties and the necessity to wear the device at a certain location for proper functioning can also affect social acceptance. For example, positioning a fall detection sensor to detect accidents in an ambient assisted living environment works best on the chest [33]. Causing limited functionality in critical situations, the combination of location and device is likely to be perceived socially less accepted as the correct usage. Thus, we conclude that different areas of the body inform bystanders about the functionality of the device, the confidentiality, and the context of using the device.

HCI researchers are also interested in the social acceptability of devices that emerge from new technologies, such as head-mounted displays. For example, Profita et al. [1,31] found that the social acceptability of head-mounted displays also depends on the disabilities of the user when assessing different devices. In their study, smart glasses were socially more accepted when they were worn by blind persons. Moreover, Schwind et al. [8] pointed out that the social acceptability of virtual reality (VR) head-mounted displays depends upon both the activity and the environment in which they are used. According to Guggenheimer et al. [34], in particular, using head-mounted displays in shared and social spaces still poses a challenge to social acceptability. These discussions are accompanied by privacy concerns caused by integrated cameras [35], which must also be taken into account in other devices [36]. This is in line with Kölle et al., who found that social acceptability based on privacy issues with integrated cameras is a major design aspect that should be considered designing smart glasses [37]. Another important issue with such devices is that bystanders do not see the complete face and do not know what the user is actually doing with the device [8,37,38]. Additionally, Häkkilä et al. [38] highlighted that smart glasses are socially less acceptable because of their negative effects on face-to-face interaction with other individuals. Therefore, one approach in HCI to increase the social acceptability of such displays is to communicate the viewer's content on a display in front of the head-mounted display [39,40]. More recently, Koelle et al. stresses that researchers *"need to increase both user and bystander involvement and consider their views on social acceptability earlier, during phases of requirement analysis, design and prototyping"* [5].

Not only head-mounted displays but any wearable computing devices worn on different locations of the body are the subject of recent HCI research on social acceptability [5,9,41]. One way to overcome some of the issues regarding the social acceptability of mobile devices is bby using unobtrusive shapes or designs imitating non-computing devices, such as accessories or jewelry with familiar styles such as rings, watches, wrist bands, and glasses [5,6,42–44]. According to research by Fortmann et al., there are wearable devices where the form factor, design, or functionality is more important than the body location [6]; however, in having a choice in selecting body locations for smart artifacts, Holleis et al. [41] found that users prioritize hands and thighs instead of other body locations. To indicate *where* designers or users should place body-worn devices, Dunne et al. proposed a body map to ensure social comfort [7]. However, devices worn anywhere on the body may also have a fashion-related component, which has not been further addressed in HCI research. For wearable artifacts in general, DeLong [45] differentiates in her book between the physical wearability perceived by the user and the wearer's perception perceived by external viewers. Both views can highly fluctuate through their *"expressive"* and *"referential"* characteristics, which can point to something outside of the user as well as the artifact (brands, trends, other constructs) [45].

2.2. Methods and Models of Social Acceptability Assessments

Due to the importance of social perception of wearable and mobile device research, HCI is focusing on using standardized methods and tools for assessing social acceptability. Thus, previous work developed qualitative approaches [37,38], asked for specific situations [23], ranked input techniques [22], or used single Likert items [35,46] to assess social acceptability. Further, Profita et al. [1,31] developed a scale consisting of 13 Likert items to quantify social acceptability. In multiple iteration, Kelly et al. [3,4,47] developed the Wearable Acceptability Range (WEAR) scale, a quantitative questionnaire that consists of 14 Likert items in its latest version. The WEAR scale v.3 is based on the assumption that social acceptability comprises the two factors of aspirational desires and social fears and is currently the only validated quantitative method to directly assess the social acceptability of wearable devices. However, more work on standardized scale development, such as thtat by Kelly et al. [3,4,47], has neither sufficiently been re-used, re-evaluated or further extended by other researchers. Instead, Koelle et al. [5] further identified alternative methods from researchers that operationalized social acceptability based on other scales, e.g., using the international 10 item Positive and Negative Affect Schedule (Short Form) (PANAS SF) questionnaire [48]; however, these items "largely depend on self-defined, custom questionnaires, which impairs comparability, and—potentially—validity" [5].

Despite—or even because of—the difficulties with such measuring instruments, researchers also repeatedly take the context of use in their measures of social acceptability into account. For example, using custom items, Taniberg et al. [49] found that the physical context of device usage affects the social acceptability of gesture interactions for paired users. One method that takes aspects of the context inherently into account is Rico and Brewster's [23,50] "audience-and-location" axes measure based on a selection of predefined audiences and locations. However, according to Koelle et al. [5], many questionnaires and scales are often rephrased to match the target prototype or the context of use, and they conclude that such changes cause a lack of ecological validity. This issue is also related to the fact that there is currently no agreed upon way to ask for social acceptability at all [5]. Consequently, that means that the social acceptability of a mobile device determined for one specific context is poorly incomparable across other experimental conditions or even other studies when such devices can (or should) only be used in specific situations. Nonetheless, alienated use of mobile devices can provide interesting and important insights when measuring social acceptability, particularly when experimenting with novel devices and minorities of user groups [1].

Despite some methods for assessing social acceptability in HCI, Schwind et al. criticized the lack of standardized models to generally understand when and how a user with a device is socially being accepted [51]. Schwind et al. [19] suggested that the stereotype content model (SCM), a model from the field of social psychology, can be used to explore and even to predict when a social group is accepting a user-device combination. Basically, the SCM is based on the assumption that people assess strangers' intent to either harm or help as well as their capacity to act on that perceived intention. Thus, groups or individuals are considered to be warm and competent and shape stereotype content clusters. The model further distinguishes between in- and out-group perception and has been applied to different domains in social sciences to understand, for example, racism [52], sexism [53], and ageism [54]. Previous work showed that the SCM can not only be applied to understand the stereotypical perception of human stereotypes but also the stereotypical perception of other entities such as animals [55], products [17,56], or brands [16,57]. Findings by Schwind et al. [21] show that higher ratings in warmth and competence correlate with ratings of social acceptability of mobile devices. Moreover, they showed that the anticipated stereotypical users of mobile devices can reliably predict how well the devices are being socially perceived and assume that "stereotypical perception is still important when predicting if a potential user uses a device in a specific context" [21]. However, if a context of device usages is being perceived in a stereotypical way is currently unknown.

2.3. Summary

Despite the increasing need to include the context in assessments of social acceptability, there is no standardized method for assessing the construct, which is potentially caused by a basically unlimited number of potential factors influencing social perception [5,23,50,58]. The SCM provides a promising alternative through not directly assessing the social acceptance of devices for each possible context but the stereotypical perception of an indirect view on the user-device combination within all contextual dimensions that can possibly be stereotypical perceived as well [19,21]. We derive this assumption from previous findings that even non-human social concepts are being stereotypically perceived [16,17,54–57]. Thus, our research question is whether a context can be stereotypically perceived and systematically "attract" ratings of a device (such as mobile devices for human stereotypes [19,21]) when the device is supposedly used in a certain context. To answer the research question using full factorial study designs, we conducted two studies investigating basic components of contextual device usage as suggested in previous work: body location, device shape and device perception while doing an activity [6,7,41,45,49]. The research questions were investigated using two independent surveys, keeping the overall duration of conducting the survey for the participants reasonable and the design of the conditions understandable.

3. Study: Shape and Body-Location

Wearable devices that are visible and worn on the body are "inherently connected to the personal space of the wearer" [59]. In line with previous work in HCI research, the location on the body and where a mobile device is being worn is not only important for the design of the mobile device but also for its social acceptability [5,6,9,41]. As research also indicates that other factors such as the shape and how a device looks like can influence social perception [6], we investigated in our first study whether both the shape as well as the body location do have a systematic influence on the stereotypical assessments of the wearing users. To answer that research question, we conducted an online survey with LimeSurvey in order to obtain anonymously collected data from a larger population. LimeSurvey was hosted by our institution.

3.1. Study Design

We used a two-factorial within-subjects design with the independent variables BODY LOCATION and SHAPE. To cover a wide range of different BODY LOCATIONS, we included the levels *ankle*, *wrist*, *hand*, *chest*, *hand*, and *any location*, while *any location* was added to obtain the ground truth of social perception for the other independent variable. To explore the stereotypical bias on SHAPES, we used the four levels *squared*, *star-shape*, *cylindrical*, and *any device*.

3.2. Stimuli

In addition to the textual description of the location-shape combination, we used images to prevent participants from over-sawing or over-reading the condition while reading a question. To visualize the individual conditions in our survey, we created 24 rendered images using Blender 3.8, each showing shape and respective body location (Figure 1). The shapes *any*, *squared*, *cylindrical*, and *star* are based on four primitives as placeholders for the devices of those shapes. The body locations *ankle*, *any*, *chest*, *hand*, *head*, and *wrist* are typical for different wearable device placements and visualized using an abstract human-like character. All shapes had the same scaling. Body locations in the *any* condition were indicated through thin rectangles.

3.3. Measures

To assess the stereotypical perception of users with different device shapes on their body we used the SCM questionnaire as proposed by Fiske et al. [10]. Stereotypical ratings of the SCM were explicitly asked using the question: *"As viewed by the society, how ... are people with [SHAPE-d] wearable devices on the [BODY LOCATION]?"* for the nine corresponding 5-point items of perceived competence (*competent*, *confident*, *independent*, *competitive*, *intelligent*) and perceived warmth (*tolerant*, *warm*, *good-natured*, *sincere*) ranged from *not at all* (1) to *extremely* (5). To validate the proposed correlation with social acceptability, we additionally included the 14-item WEAR v.3 scale as proposed by Kelley et al. [4,47] and also suggested by Schwind et al. [21]. The SCM and WEAR-Scale v.3 questionnaires were used as suggested in the corresponding original work [10,47] and presented below the respective stimulus.

3.4. Procedure

The participants received a link to the online survey and were directed to the survey landing page. The landing page contained information about the purpose and goals of the study, contact information of experimenters and principal investigator, and more information on data protection according to the regulations of our institution (GDPR). After giving informed consent, the participants were pleased to enter their demographic data (gender, age, nationality, profession). After entering their demographic data, the participants gave an assessment of where they could imagine wearing a device on their body (*"To what extent do you agree with the statement that you can imagine to wear a wearable device at the following body locations"*) on a 7-point scale from *I strongly disagree* to *I strongly agree* including the following body parts: *head*, *eyes*, *chest*, *wrist*, *upper*, *arm*, *finger*, *foot*, *ankle*, *knee* and *back*. Then, the participants went through all of the 24 conditions in randomized order. Conditions were displayed on individual pages and showed the corresponding stimuli as well as the questionnaires below the stimuli. Participants were forced by mandatory fields to fill in all items. At the very end of the survey, participants received a generic confirmation code for their attendance.

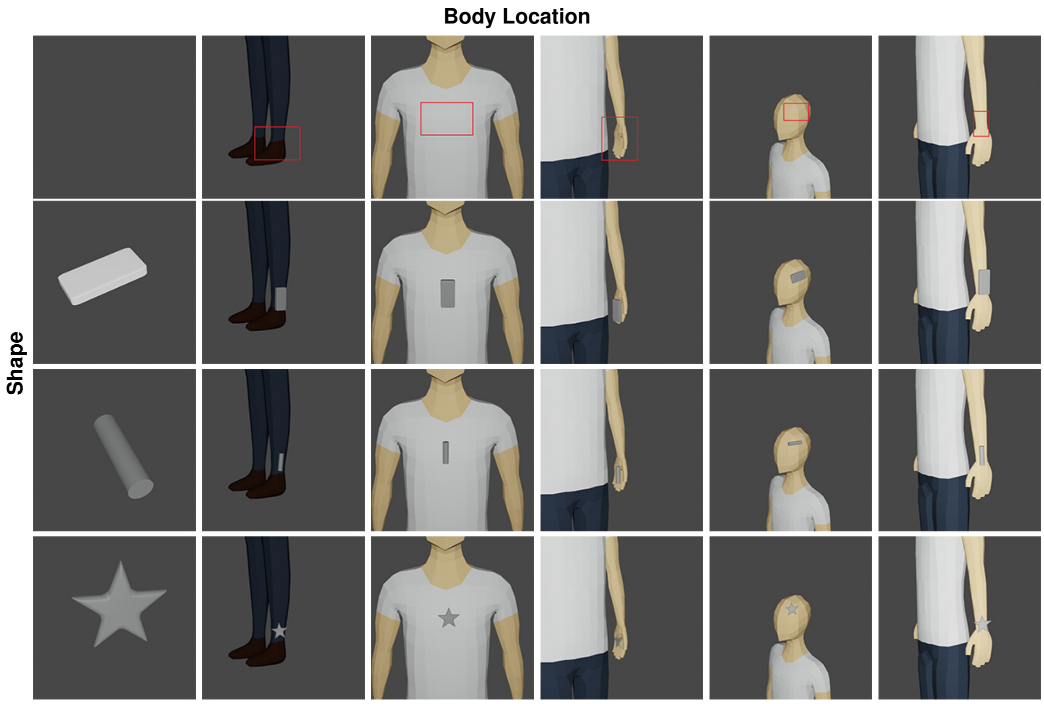

Figure 1. Stimuli in our study used to investigated the stereotypical perception of shape and body location: *any*, *squared*, *cylindrical*, and *star* as variations of shape (rows). *Ankle*, *any*, *chest*, *hand*, *head*, and *wrist* for different body locations (columns).

3.5. Participants

Participants were recruited via mailing lists of our institution and Amazon Mechanical Turk (AMT) with online workers located in Central and Northern Europe. The inclusion criteria were current location (Northern and Central Europe) and completion of the study. No further participants were excluded from the study. A total of 70 (of 169) participants (22f, 48m) completed the survey. Their age ranged from 21 to 60 years ($M = 31.014$ $SD = 9.257$). The majority of the participants studied or worked in the field of STEM (52.8%). Others came from the fields of selling and services (20.0%), law and order (18.6%), clerical (5%), or humanities (3.6%). Students were compensated with one credit point for the lecture. Crowd workers were compensated with $2.00.

3.6. Results

To confirm findings from previous work and in order to understand if means of social acceptability also do correlate with combined means of warmth and competence, we conducted a Pearson correlation analysis including the score of the WEAR v.3 Scale and the Euclidean length of the corresponding warmth-competence vector for all conditions. We found a significant and very high positive correlation, $\rho(22) = 0.903$, $p < 0.001$, which confirms the results by Schwind et al. [21] that social acceptability strongly correlates with the vector length of ratings of warmth and competence and, thus, can be operationalized using the SCM.

Mean ratings of the survey asking for the stereotypical perception in the two dimensions warmth and competence are shown in Figure 2. The results of the WEAR v.3 scale and the custom question at the beginning of our questionnaire are shown in Figure 3.

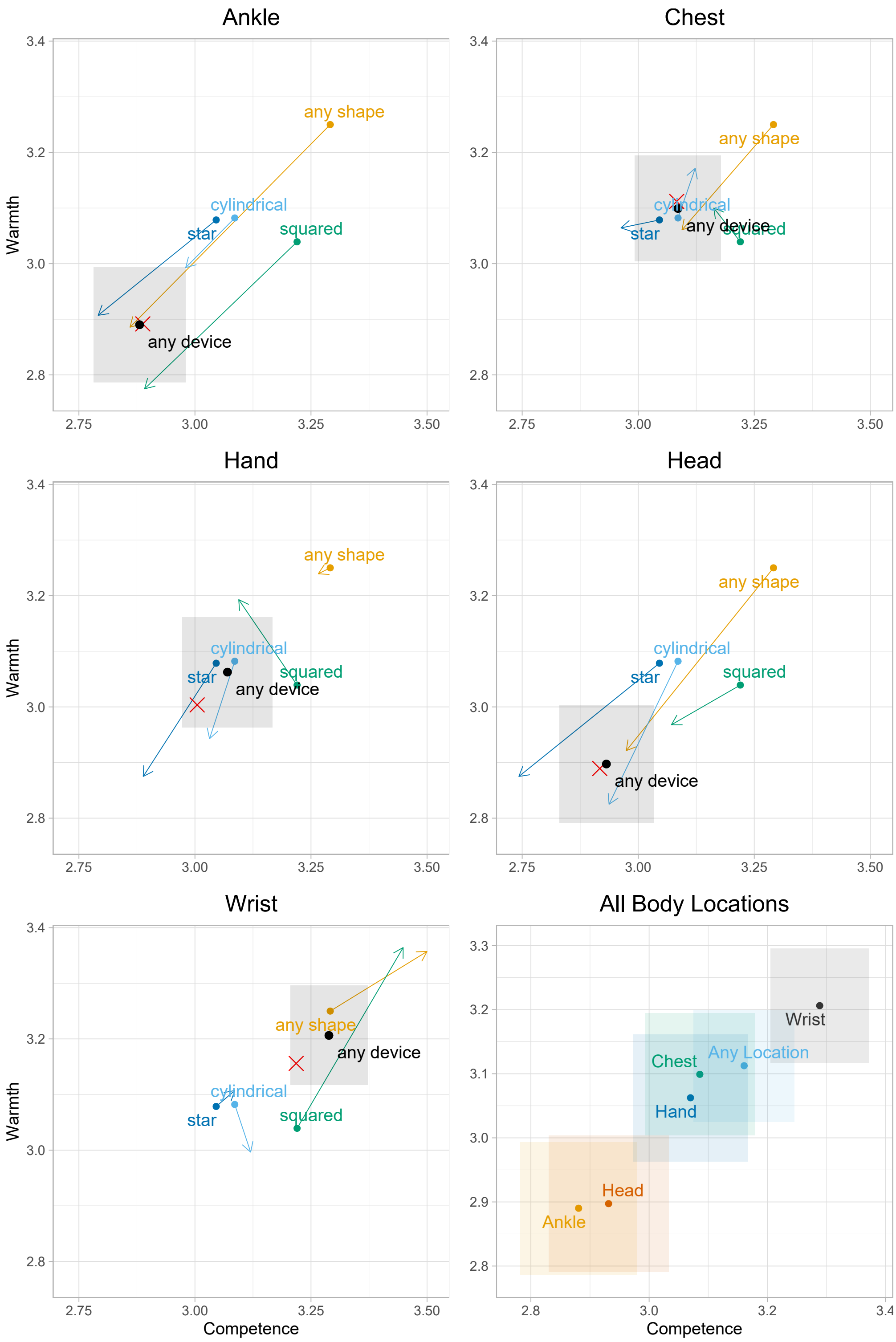

Figure 2. Effect of Shape and Body Location on the ratings of warmth and competence. As predicted, device ratings with different shapes tendentiously shift towards ratings of the body locations. Some ratings, e.g., of cylindrical or star shaped devices on the hand, wrist or chest partially diverge. Highest ratings were measured for wrist-located square devices or any devices. Last diagram below shows mean values of all body location measures. Rectangles show 95% confidence intervals.

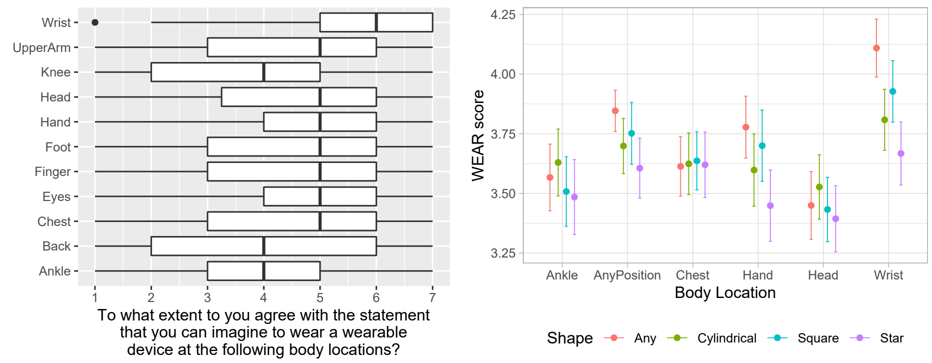

Figure 3. (**left**) Box plot with the ratings of the participants regarding to what extent they can imagine wearing mobile devices on other parts of their body. (**right**) Mean ratings on the WEAR v.3 scale on the individual conditions. The ratings indicate that the wrist seems to work out for the participants, and, in particular, the participants are likely to accept *any device* placed at wrist, while star-shaped devices attain the lowest acceptance ratings throughout the conditions.

We performed a two-way repeated measures analysis of variance (RM-ANOVA) to determine the effects of SHAPE and BODY LOCATION on warmth and competence using the R package rstatix. The within-subject factors violating the assumption of sphericity (equal variances between the conditions) were automatically adjusted using Greenhouse–Geisser correction [60] using the rstatix-package in R.

For warmth, we found a statistically significant effect of SHAPE, $F(2.50, 172.82) = 3.116$, $p = 0.036$, $\eta_p^2 = 0.043$, and BODY LOCATION, $F(3.51, 242.35) = 7.349$, $p < 0.001$, $\eta_p^2 = 0.096$, and a significant interaction effect of SHAPE $\times$ BODY LOCATION, $F(10.71, 738.98) = 3.108$, $p < 0.001$, $\eta_p^2 = 0.043$.

For competence, we found a statistically significant effect of SHAPE, $F(2.48, 171.20) = 9.471$, $p < 0.001$, $\eta_p^2 = 0.121$, and BODY LOCATION, $F(3.40, 234.41) = 9.257$, $p < 0.001$, $\eta_p^2 = 0.118$, and a significant interaction effect of SHAPE $\times$ BODY LOCATION, $F(10.49, 724.11) = 1.896$, $p = 0.040$, $\eta_p^2 = 0.027$.

To understand if the percpetual shift of the device shape is related to the BODY LOCATION, we performed multiple linear regression analysis. Scatterplots (not illustrated) of standardized residuals indicated that the data met the assumptions of homogeneity of variance, linearity, and homoscedasticity for both regressions. The regression equations of the mean ratings of all and any shapes were significant for competence, $F(1, 3) = 15.07$, $p = 0.030$, $R^2 = 0.834$, $R^2_{adj} = 0.778$, and warmth, $F(1, 3) = 35.45$, $p = 0.009$, $R^2 = 0.922$, $R^2_{adj} = 0.896$, and confirm that the SCM is able to estimate ratings for the individual body locations without considering the specific shape of the device. This is in line with previous work, which found that device ratings can be estimated without considering a specific stereotype [19].

We also analyzed the ratings of the WEAR v.3 score, which was significantly affected by SHAPE, $F(2.40, 165.91) = 6.282$, $p = 0.001$, $\eta_p^2 = 0.083$, and BODY LOCATION, $F(2.82, 194.68) = 11.259$, $p < 0.001$, $\eta_p^2 = 0.140$, and a significant interaction effect of SHAPE $\times$ BODY LOCATION, $F(11.14, 3.248) = 3.108$, $p < 0.001$, $\eta_p^2 = 0.045$. The WEAR v.3 score has been computed according to original work [47] and is the average between the two subscales, absence of social fears and aspirational desires [3,4,47]. Both showed significant main and interaction effects of SHAPE and BODY LOCATION (all with $p < 0.032$), as well. Interestingly, for all measures, except for competence with a marginal difference, the main effect sizes for BODY LOCATION were higher than for SHAPE.

Finally, we evaluated the ratings to which extent the participants can imagine wearing a wearable device (see Figure 3). Friedman analysis of variance (ANOVA) revealed a significant effect of BODY LOCATION, $\chi^2(10) = 39.035$, $p < 0.001$, Kendall's $W = 0.056$. Pairwise Wilcoxon signed-rank sum test revealed significant differences between *ankle* and *wrist* ($p < 0.001$), *back* and *wrist* ($p = 0.004$), *chest* and *wrist* ($p = 0.021$), as well as between *knee* and *wrist* ($p < 0.001$). Thus, the results support the assumption that it is more likely that people tend to accept wearable devices at the wrist more than on other body locations.

3.7. Discussion

In our first study, we conducted an online survey to investigate the effects of body location and device shape on stereotypical perception of wearable mobile devices. The results revealed significant effects with significant regression equations able to predict the ratings of any device on different body locations when taking multiple shapes into account. The results suggest that the SCM is a good predictor of warmth and competence; however, a closer look into the results suggest there are important differences between the other body locations and for hand or wrist. First, wrist- or hand-worn devices on average received the highest ratings, which was confirmed by ratings of the WEAR scale as well as our own question item and is in line with earlier studies [41].

However, not all device shapes seem to be equally preferred and there are the some divergences between squared or e.g., cylindrical or star-shaped devices. Interestingly, ratings for any shape and squared devices were higher than the ratings for any device, while other shapes showed no changes. This may seem contradictory at first glance but the concept of a wrist-worn device is likely to include a watch or fitness tracker as these devices are typically square-shaped. Our rendering of a wrist-worn cylinder did not match with the typical flat shape of a watch and, therefore, the rating remained unchanged. Cylindrical or star-shaped devices on the hand scored significantly lower than any devices, while square ones received higher scores for warmth but lower scores for competence.

As already mentioned, ratings of *any* shape were consistently high. Consequently, behind the concept of any shape there apparently were notions of devices that are socially more accepted than the other shapes presented. One might have expected any shape to move into the center of the shapes presented by the renderings of the other primitives, but the mental concept of (existing) appropriate devices for the respective body regions is potentially stronger than the visual representations of the shapes tested. In addition, the ratings for any shape in the hand were consistently higher in contrast to other body locations where other shapes shifted when being worn on a certain location.

Another finding of our study is that the effect sizes of most measures, excepting competence, were higher for body location than for shape. This partially contradicts findings by Fortmann et al. [6], where the authors reported that form and function were considered to be more important than body location. The difference can potentially be explained as participants in their study were mostly asked about the use of smart jewelry, which may have conceptually limited the concept of where the wearable device is supposed to be worn.

We also assume that the body location influences the stereotypical perception of wearable mobile devices when the devices typically worn in these locations share a common positive or negative image. Smart glasses or any headsets, which are often not socially accepted as they, e.g., cover the face [37,38], negatively influence all other potential shapes. The same applies to devices worn on the ankle, where bracelets are typically worn for surveillance purposes and the device could be anticipated with prosecuted people. In those cases, the SCM shows its methodological strengths as it makes it easy to determine and predict how well devices will be perceived on the relevant body location. However, as the results suggest, the perception becomes more undifferentiated for some body locations or for shapes where many concepts coincide, causing the uncertainty of the model to become supposedly higher.

4. Study: Activity and Device

Through our first study, we learned that body locations of the user and device shapes can be perceived stereotypically, validating the SCM further. However, to understand the stereotypical perception of wearable devices that are used in different situations, it is also important to take the context of usage in which a user utilizes the wearable device into account [23,25,28,49]. Thus, we investigated the stereotypical perception of the contextual usage of wearable mobile devices while *doing something* using the factors ACTIVITY and DEVICE. Based on the finding that devices are mediators of their typical users [19,21], we assume that some activities, typically performed by specific human stereotypes, can systematically change the stereotypical perception and social acceptability of wearable mobile devices. Thus, the focus in our second study is whether the device and activity combination are also stereotypically perceived and if the activity can affect or even predict the perception of a device. This study differs from related work that already takes the location or the number of bystanders in public settings into account [8] and specifically examines the effect of an undertaken activity on the stereotypical perception of mobile devices.

4.1. Study Design

Based on the assumption that activities can systematically influence how a device is stereotypically perceived, we again used a two-factorial within-subjects design with the independent variables ACTIVITY and DEVICE and the dependent variables warmth and competence of the SCM. To cover different stereotypical ACTIVITIES, we included actions that are typically undertaken by specific groups of people only lasting for a certain amount of time (a few hours). Thus, we included *any activity* to obtain the ground truth for each device, *babysitting* (high warmth, low competence), *gaming* (medium warmth, medium competence), *hacking* (low warmth, high competence), *partying* (low warmth, low competence), and *teaching* (high warmth, high competence). We included the following DEVICES for which stereotypical perception have already been determined by previous work [19,21]: *any device*, to obtain the ground truth for each activity; *e-readers* (high warmth, high competence), *hearing aids* (high warmth, low competence), *LED glasses* (low warmth, low competence), *smart glasses* (low warmth, high competence), and *VR headsets*. The combination of all levels lead to 36 conditions.

4.2. Stimuli

Similar to our first study, we used images in addition to the textual description to prevent participants from over-reading the user-device combination. Activity images (see Figure 4) for use case visualizations were downloaded from pxhere.com (accessed date: 2 September 2022) and are licensed under public domain. The exemplary photos were selected using keyword search and through discussion. Images of the devices were taken from recent work by Schwind et al. [21]. Thus, we combined the images to anticipate and visualize a certain context as proposed by previous work [19]. Additionally, every condition received an image description: *"Imagine the following context: Persons, who are using [*DEVICE*] while [*ACTIVITY*]/"Persons, who are [*ACTIVITY*]/Persons, who are using [*DEVICE*]/Any persons"*. Based on the findings by Schwind et al., we assume that these images have a negligible effect on stereotypical perception [19].

4.3. Measures

As in our first study, we measured the two dimensions of warmth and competence as proposed by Fiske et al. [10]. Stereotypical 9 item ratings of the SCM were asked based on the question: *"As viewed by society, how ... are persons using such wearable mobile devices while doing this activity?"* (referring to the stimuli above or to none if any activity or device were shown). For the sake of surveying more conditions, we did not further include the measures of the WEAR scale, and thus refrained from re-validating the SCM as a measure of social acceptability.

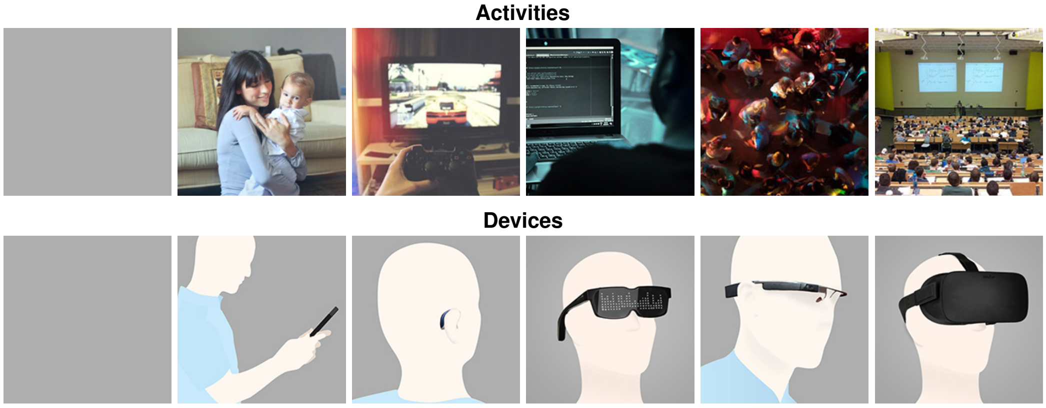

Figure 4. First row shows the images of the different activities presented in our study: *any activity*, *babysitting*, *gaming*, *hacking*, *partying*, and *teaching* (Images source: https://pxhere.com/ (accessed on 19 September 2022), licensed under public domain). Second row shows illustrations of the used devices: *any device*, *e-readers*, *hearing aids*, *LED glasses*, *smart glasses*, and *VR headsets* (image sources: [19,21]).

4.4. Procedure

Before starting our online survey, participants gave their informed consent and were then asked to provide their demographic data (gender, age, nationality, profession) as in our first study. Then, the participants went through all 36 conditions in randomized order. At the end of the survey, they received their confirmation code for their participation.

4.5. Participants

Participants (60f, 89m, 1d) were recruited via mailing lists of our institution and AMT with online workers located in Central and Northern Europe. A total of 150 (of 203) subjects finished the survey. Their age ranged from 21 to 64 years ($M = 33.228$ $SD = 9.894$). Similar to the first study, the majority of the participants studied or worked in the field of STEM (55.3%). Others were studying or occupied in the fields of management (25.3%), services & sales (18.6%), humanities (0.01%), or others (0.79%) As in our first study, students of our institution were compensated with one credit point for their lecture and crowd workers with $2.00. Inclusion criteria were current location (Northern and Central Europe) and that participants completed all conditions. None of the participants were further excluded from the study. None of the participants from the first study took part in the second one.

4.6. Results

A two-way RM-ANOVA was performed to determine the effects of ACTIVITY and DEVICE on the measures of warmth and competence. Within-subject factors violating the assumption of sphericity were adjusted using Greenhouse–Geisser correction [60] with the rstatix-package in R.

Considering the measure of warmth, we found statistically significant effects of ACTIVITY, $F(3.59, 532.02) = 7.419$, $p < 0.001$, $\eta_p^2 = 0.048$, and DEVICE, $F(4.20, 622.10) = 8.720$, $p < 0.001$, $\eta_p^2 = 0.056$, and a significant interaction effect of ACTIVITY × DEVICE, $F(17.29, 2558.25) = 4.021$, $p < 0.001$, $\eta_p^2 = 0.026$.

For competence, we also found statistically significant effects of ACTIVITY, $F(4.11, 607.84) = 4.716$, $p = 0.001$, $\eta_p^2 = 0.031$, and DEVICE, $F(4.46, 660.79) = 6.225$, $p < 0.001$, $\eta_p^2 = 0.040$, and a significant interaction effect of ACTIVITY × DEVICE, $F(17.25, 2553.51) = 2.775$, $p < 0.001$, $\eta_p^2 = 0.018$.

In contrast to the results of our first study, the regression equations of the mean ratings of all and any devices—independent from their contexts—were neither significant for competence, $F(1,3) = 2.037$, $p = 0.248$, $R^2 = 0.404$, $R^2_{adj} = 0.205$, nor for warmth, $F(1,3) = 1.484$, $p = 0.310$, $R^2 = 0.330$, $R^2_{adj} = 0.107$. Thus, the linear regression models were not able to predict ratings for the devices as they do not systematically follow the different activities in the SCM in our study. This becomes evident through visual inspection of the mean ratings shown in Figure 5 where some ratings (e.g., *smart glasses* and *hearing aids* while *babysitting* or *hearing aids* and *smart glasses* while *teaching*) highly diverge from the mean rating of the activity itself. In other words, the activity itself is not a good systematic "attractor" for the stereotypical ratings of warmth and competence.

4.7. Discussion

The second study investigating the effects of the context on social acceptability of mobile devices provides more insights into contextual perception but also illustrates some of the limits in the predictability of social acceptability using the SCM. Particularly, we found that different social activities are stereotypically perceived (see Figure 5, "All Activities"). The finding that certain activities are perceived in that way stems from the assumption that they are typically performed and anticipated to be done by certain groups of people that are stereotypically perceived, as well. However, the activity as a mediator of the information of who is typically doing the activity is only conditionally reliable in predicting how a user is perceived doing an activity *with* a wearable mobile device.

We assume that in perceiving a user undertaking an activity, observers further differentiate the user-device combination and that too much leeway in interpreting a context leads to higher variance, which can no longer be explained by linear models. The possibility that the usage of devices can be interpreted differently means that another cognitive process takes place between perception and stereotypical classification, which distinguishes between the intention and competence of the wearer's actions and what the device is typically used for. We can only speculate as to which cognitive process this is as processing a stranger's behavior requires the conscious allocation of (other) attentional resources [61]. Moreover, the activities presented in our study are only partially comparable with the actual perception of behavior. However, it is known that the influence of an automatically activated stereotype can only be inhibited if the person is both aware of their potential propensity to activate it and motivated to put in the time and effort to suppress it. According to Devine, this decision-making must first undergo a non-stereotypical assessment [62].

Inspecting the mean ratings, we found diverging assessments; for example, when it comes to the activity of babysitting, smart glasses and e-readers lose their social acceptability, while hearing aids seem to be beneficial in this context. Similar results were found for the teaching activity, where, however, e-readers and even LED glasses gain social acceptance. While gaming, hearing aids reduce warmth but not competence, and smart glasses or e-readers receive decreased ratings of warmth and competence, as well. For hacking and partying, the measures went more clearly and less differentiated in the direction in which the activity has been rated. It is noteworthy that any device does not significantly change its location in the SCM, except for hacking and partying, within the contexts. This supports the assumption that observers of devices stereotype the activity but look at the device differently in some contexts in order to possibly understand what else it can be used for.

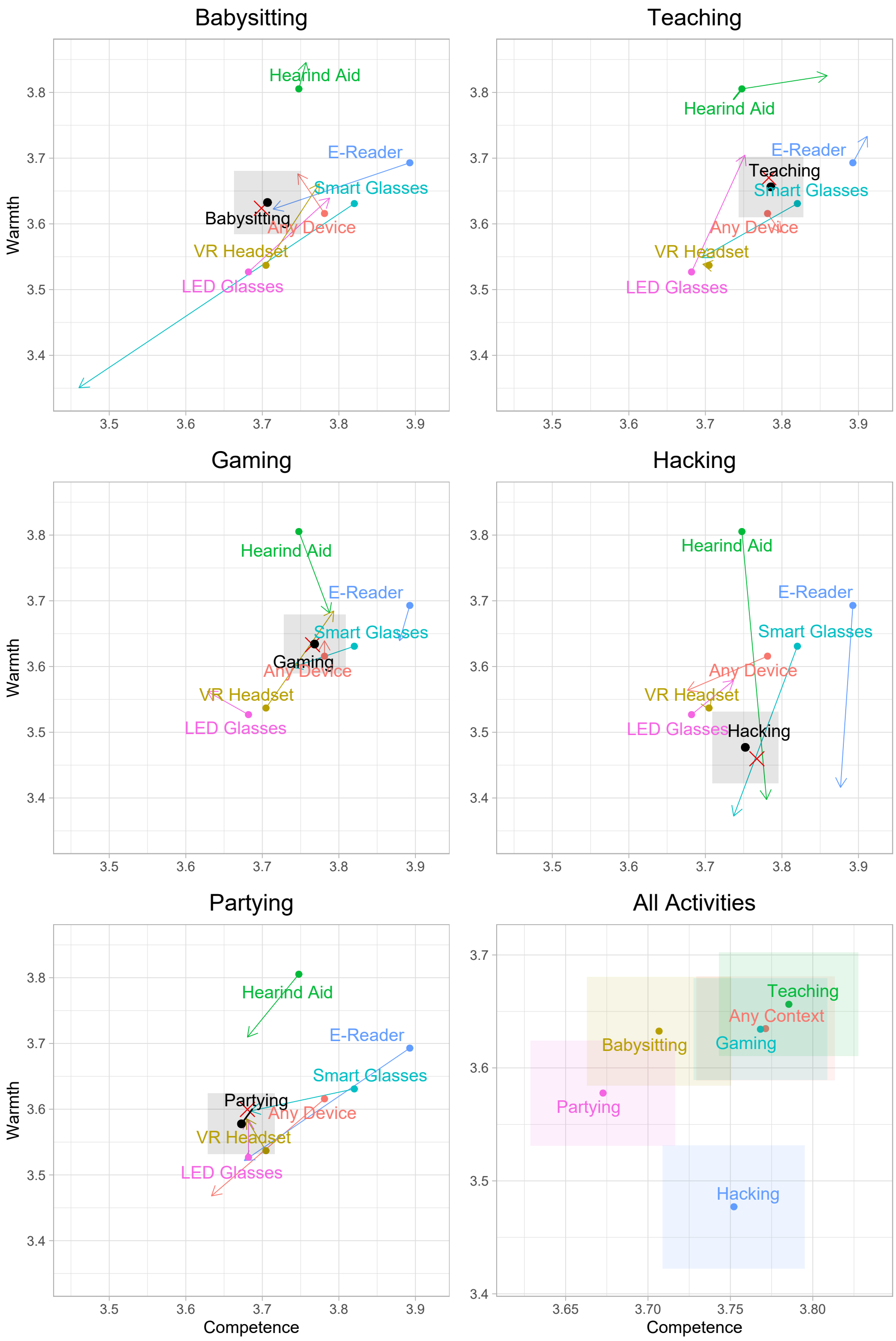

Figure 5. Mean ratings of warmth and competence for different wearable mobile devices and activities. Ratings of the activities babysitting, teaching, or gaming do not systematically "attract" ratings of users doing an activity with a body-worn mobile device. Rectangles show 95% confidence intervals.

5. General Discussion

In two studies, we investigated if contextual information of mobile device usage used can systematically influence stereotypical ratings of users with mobile devices. We used and further validated the stereotype content model (SCM) proposed by previous work to measure the warmth and competence of user-device pairs [10,19,21]. In our first study, we investigated the stereotypical perception of different shapes and body locations of a body-worn mobile device. In our second study, we measured the stereotypical perception of contextual usage with different devices. In both studies, we selected a wide range of stimuli that might be associated with stereotypical emotions as proposed by Fiske et al. [10]. In our first study, we compared ratings of warmth and competence with ratings of the WEAR scale by Kelley et al. [3,4,47] and found that those ratings strongly correlate with standardized ratings of social acceptability, which is in line with the results by Schwind et al. [21].

In addition to the actual results of both studies, we were mainly interested in whether perception behaves systematically, i.e., is systematically "attracted" by the contextual factors, as is evident with the perception of mobile devices with human stereotypes [19,21]. In line with Schwind et al., an attraction is considered to be evident if the average ratings of body-worn mobile devices tested behave similar to asking for *any* devices [19,21]. We first found that average ratings of device shapes are systematically influenced by body regions and correlate with those of any shape. Body regions in which potentially many concepts of different device types coincide—particularly on the hand or wrist—can diverge from the stereotypical perception of the body region. Similar results were also found in a previous work on smartphones by Schwind et al. [19,21], which are interestingly mainly used in the hand. While other body-worn device types could reliably be predicted, there are wide alternatives and a "tree" of possible alternatives in the imagination of what a smartphone actually is. This results in a higher variance and shows that wider concepts are potentially being influenced by other factors (e.g., the brand [16]).

We refer to diverging contexts as being contextually "fuzzy" when a context potentially includes multiple notions and makes a systematic prediction of the context difficult. This is evident in our second study, where we examined systematic ratings of device-use activity across different devices. While the data show systematic shifts for some activities (partying, hacking), there are also activities where contextual assessments have diverged and are unpredictable with linear models. For example, when teaching and babysitting, a hearing aid is socially more acceptable than the context itself. In contrast, smart glasses are socially less accepted while doing those activities, and their ratings of warmth and competence decreased below the context. We assume that these results cannot be explained solely by the aforementioned "fuzzy" concepts but by an emotional and affective response. These hypothetical cases of emotional responses are particularly interesting for measuring social acceptance because they occur with devices that are obviously not only used for activities of their actual purpose.

5.1. Implications

Even when cases of emotional responses contribute to an unpredictability of stereotypical ratings in our study, we conclude and highly recommend using the SCM to visualize and identify strong deviations caused by such contextual (and conceptual) artifacts of body-worn mobile devices in different stereotypically perceived contexts. As indicated by hearing aids and smart glasses in the contextual use, these deviations can "overshoot" the actual stereotypical perception of contextual use, both positively and negatively (c.f. babysitting, teaching). This still allows developers and designers to assess intense social responses of prototypes at an early stage and recognize what possible anticipations they have to reckon with their devices. This could also be of interest to marketers and advertisers who specifically want to avoid displaying devices outside of unpopular contextual uses or to positively emphasize positively perceived use cases of their products.

5.2. Limitations

The main limitation of our study is the lack of qualitative feedback as a supplement to the objective findings on social perception. Moreover, our sample was drawn from participants in Central and Northern Europe, limiting the generalizability of the findings to other regions in the world. We are currently lacking an overarching framework and transparent statistical solutions to ensure correct inclusion of all contextual factors and its weightings indicating to which extent a factor will influence ratings on social perception. Other contextual factors can also have a significant impact on the results and potentially threaten the generalizability of the herein-presented approach. This is particularly important when considering the required samples to answer specific research questions since the participants and their backgrounds themselves may be contextual components of perception. Correctly assessing related contextual factors is the basis for internal and, thus, external validity and must be considered in future studies, particularly when it comes to taking qualitative feedback and approaches for its deeper exploration into account. As more factors are likely to be involved in the perception of activities, qualitative responses from wearers and bystanders would help to understand the context or related factors. The follow-up question then is how these factors contribute to the stereotypical perception. This limitation also relates to the methodology of data collection using online studies, which have also been used in the past but have not yet been validated in the field or in situ.

5.3. Future Work

We see the need for more research to explore the stereotypical perception of contextual device usage. In our studies, we only researched some aspects of contextual use of mobile devices. Due to the unpredictability of some applications, the operationalization of social acceptance through the SCM allows many further research questions. Location, time, bystanders, public access, duration of use, etc. are other factors that can further define the context in order to better sharpen results of stereotypical perception and social acceptability. Therefore, we recommend doing a meta-analysis that precisely differentiates and defines the contextual use of mobile devices in order to obtain a concrete overview of the dimensions of the contextual use of mobile devices.

5.4. Conclusions

To the best of our knowledge, we conducted the first study measuring the stereotypical perception of human activities. In our research, we also contributed a validation study of the SCM with context-related dimensions of location, shape, and activity. Our contribution not only further validates the SCM and the contextual usage of mobile devices while doing different activities but also suggests that activities are potential mediators transporting information of the anticipated human group stereotype. However, some of the contextual assessments have diverged from a systematic relationship and are unpredictable with linear models. This could be a subject of further investigation not for HCI-related research but also for other disciplines such as social sciences. As previous work suggests, an important factor repeatedly found to be socially problematic is that people surrounding a head-mounted display do not know what the user is doing with the device [8,37,38]. Based on our findings, these questions can be further investigated using the herein presented approach and in an exploratory (qualitative) study to study more factors and the likelihood of an anticipation of those factors with related human stereotypes.

Author Contributions: Conceptualization, J.S. and V.S.; Methodology, B.B. and J.S.; Project administration, V.S. and N.H.; Stimuli, B.B. and V.S.; Writing—original draft, J.S., B.B.; Writing—review & editing, J.S., B.B., V.S. and N.H.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study received ethical clearance according to the guidelines of our institutions.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

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