



Article

Smartphone and the Self: Experimental Investigation of Self-Incorporation of and Attachment to Smartphones

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Abstract: Smartphones are a constant companion in everyday life. Interacting with a smartphone calls for a multimodal input and often leads to a multisensory output. Combining research in human-computer interaction (HCI) and psychology, the present research explored the idea that a smartphone is more than a smart object but represents an object to which people feel emotionally attached to and which is even perceived as a part or an extension of a person's self. To this end, we used an established rubber hand illusion paradigm to experimentally induce body ownership experiences in young adults ($n = 76$) in a 4-level mixed-design study. Our results revealed that in contrast to a neutral control object participants indeed felt attached to a smartphone, perceived it as a part of themselves and felt the need to interact with the device. This was specifically pronounced when hedonic characteristics were evaluated as high and when its usage for social communication was highlighted during the experiment. Psychological mechanisms of the incorporation of technologies are discussed and connected to positive and negative effects of smartphone usage on human behavior, its implications for technology design and marketing.



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Keywords: smartphone; self-incorporation; self-relevance; hedonic product quality; attachment; rubber hand illusion

1. Introduction

Since the introduction of the first iPhone on the market in 2007, smartphones have constantly become a bigger part of people's everyday lives. In 2019, more than 3 billion people worldwide were using smartphones [1]. Average smartphone users spend about 2.5 h each day on their smartphones and about 20% of that time on the instant messenger service WhatsApp [2]. While combining a multitude of technologies, the smartphone provides various opportunities of interaction to its user. For example, it offers multimodal input via clicking, texting, speaking by merely holding the device, as well as multisensory output such as auditive cues, speech, text, graphics and animations and vibration. Besides its offerings on the level of motor-actions, namely the how of interaction (e.g., [3,4]), the smartphone also fulfils a multitude of functions on a psychological level, namely the why of interaction. Smartphones are an important tool for communicating with the own social network by messaging, calling, and through social media—defined as social usage [5,6]. Additionally, smartphones are used for picture taking, entertainment and relaxation through games, movies or music, as well as information searching. This productive usage is known as process usage [5,6].

According to Belk [7] contact information, calendar entries, text messages, as well as posts on social media are memory markers that allow access to a person's individual and collective autobiographical memory. Autobiographical memory is important for the formation and maintenance of a person's sense of self. A recent study suggests that people extended their episodic memories onto their smartphones including the social contacts that were part of these experiences [8].

This potential link to a person's autobiographical memory implies that smartphones are not only an integral part of daily living but represent products with high self-relevance. From developmental and consumer psychology we already know that people tend to extend themselves with places, possessions and products [7,9–11]. For example, children describe themselves through their possessions [12]. Adults refer to pictures, presents and souvenirs to make them remember past experiences and social contacts that were involved [7,9–11,13–15]. The findings of self-extension through products were transferred to smartphones and for the first time experimentally tested by varying different smartphone conditions.

The present study aimed to find out whether and in how far young adults perceive a smartphone as a part of themselves and whether they feel emotionally attached to it. Thereby it adds new insights into the relationships between experiences, artifacts and technologies. From a design perspective, this is particularly interesting with regards to the specific role of self-related hedonic product qualities and their relevance for self-incorporation and attachment. We investigated self-incorporation through an established body ownership illusion (BOI) assuming that a smartphone is incorporated in a mental representation of one's body. Furthermore, we assessed in how far the possible incorporation of a smartphone depends on an individual's perception of self-related hedonic product qualities and the experimentally varied the focus on the usage of a smartphone for social communication. Besides theoretical advancements, the present research bears a deeper understanding of the role that technology can take in people's lives and the psychological mechanisms that become activated in human-computer interaction (HCI) if an object is perceived as a part of the self. People might feel more attached to these self-relevant technologies, enjoy the interaction to a larger extent and rely more on the product, and might show repeated purchase behavior and brand loyalty.

In the following paragraphs, we present related work, highlight the novel contributions of our study and derive our hypotheses. After that, we present our experimental study design, discuss our study findings and limitations as well as potential implications for HCI, technology design, marketing and future research.

1.1. Theory and Hypothesis

1.1.1. Rubber Hand Illusion Paradigm to Investigate Self-Incorporation

The unique ability to identify one's own body and behavior as one's own appears natural to us [16,17]. This so-called sense of body ownership and its plasticity has extensively been studied using the so-called rubber hand illusion (RHI) paradigm. In the original experiment [18] participants illusionary attribute a rubber hand to their own body when they view stimulation of the fake hand being placed in front of them while feeling congruent, synchronous stimulation of their own unseen hand. The RHI paradigm is a well-established method to investigate individual self-perception of the body [19] which has long been recognized as one pre-requisite for minimal or core selfhood [16,17,20]. Minimal self-hood is typically not only interpreted in terms of body ownership but also in terms of a sense of agency referring to the experience of control over actions and self-efficacy [16]. In contrast, the reflective part of the self contains autobiographical [20] or narrative [16,17] knowledge and thereby also represents the social self in regard to a person's social network.

In the present study, we adapted the classical rubber hand illusion paradigm to test whether or not the body ownership illusion can also be transferred to smartphones. To validate the basic effect, we assessed whether our participants are sensitive to illusionary body ownership experiences over a fake hand as compared to a non-corporal object. We hypothesize:

Hypothesis 1 (H1): *The rubber hand will evoke indicators of a body ownership illusion compared to the neutral control condition.*

1.1.2. Self-Incorporation of Smartphone

Liepelt et al. [21] were the first to include a smartphone and computer mouse in their experiment on the rubber hand illusion to explore to what extent technical devices become incorporated into representations of the body. Interestingly, the smartphone was incorporated, but not the computer mouse leading to the assumption that smartphones might be more self-relevant to users and, therefore, incorporated. Firstly, we aimed to replicate the results by Liepelt et al. [21] with a larger sample size. Secondly, we sought to evaluate the extent of socio-emotional attachment, a construct originally known as the emotional bond between an infant and its caregiver [22] and expanded to describe the relationship between an individual and a material object [23], to the test object following the experience of a body ownership illusion:

Hypothesis 2 (H2): *Overall smartphones (smartphone plus activated self-relevance and smartphone neutral) will evoke indicators of a body ownership illusion and a higher level of attachment than the neutral control condition.*

Thirdly, we aimed to further investigate the potential underlying mechanisms of Liepelt et al.'s [21] finding. Specifically, we expected self-relevance, as well as social communication to impact the incorporation of a smartphone since both can be linked to (pre-) reflective parts of the self.

1.1.3. Self-Related Product Qualities: Subjective Perception and Evaluation of Product Quality

One way to operationalize self-relevance is through the subjective perception and evaluation of product quality. The model hedonic and pragmatic product perception [24] states that people perceive products in two dimensions: pragmatic and hedonic. Pragmatic refers to functional tasks, i.e., usefulness and usability of a product, in contrast, hedonic to subjective aspects such as visual design and feel, aspects that are self-related [24,25]. Research has shown that hedonic product qualities can be self-related and influence attachment and psychological need fulfillment through products [26]. Based on these findings, we assume that there is a connection between the perception of a product as hedonic and the incorporation into the self.

Hypothesis 3 (H3): *The perception of a smartphone as of high hedonic product quality (in contrast to low hedonic perception) will evoke indicators of a body ownership illusion and a higher level of attachment.*

As the perception and evaluation of product quality is difficult to manipulate experimentally [25], we decided for a post-hoc categorization in high and low.

1.1.4. Self-Relevance through Social Communication

Another concept that might affect self-incorporation of a smartphone is the importance of smartphones for social communication [2,5,6,8]. Smartphones are commonly used for instant messaging such as WhatsApp and social networking sides such as Facebook and Instagram [27]. Average smartphone users spend about 30 min on WhatsApp every day [2]. Research has shown that smartphones can be perceived as an attachment object that releases stress and provides comfort similar to a pacifier for children [28–30], which might also be related to the smartphone's potential for social connection. Additionally, surveys showed that greater use of social networking sides is associated with increased social capital and reduced loneliness [31]. This product attachment can reach a degree where people feel negative emotions and stress if separated from their smartphones because of a perceived potential loss of their connection to their social contacts [8,32].

We assume that the smartphone's feature for social communication additionally activates self-relevance and thereby has an impact on object self-incorporation and attachment.

This is operationalized using a prototypical WhatsApp chat overview to manipulate self-relevance and the salience of the importance for the social network.

Hypothesis 4 (H4): *Smartphone plus activated self-relevance will have a higher level of attachment and evoke more indicators of a body ownership illusion than the neutral control object (H4a) and more than smartphone neutral (H4b), whereby Smartphone neutral will evoke more indicators of a body ownership illusion than the neutral control object (H4c).*

Additionally, we assume an interaction of the subjective perception and evaluation of product quality and self-relevance.

Hypothesis 5 (H5): *Smartphone plus activated self-relevance and high hedonic product perception will evoke more indicators of a body ownership illusion and a higher level of attachment than the condition smartphone neutral and low hedonic product perception.*

2. Materials and Methods

2.1. Procedure

2.1.1. Experimental Design

A 4-level mixed-design with the within-subject varied conditions rubber hand and neutral control object and the between-subject varied conditions smartphone plus activated self-relevance and smartphone neutral. The manipulation of self-relevance was operationalized using a prototypical WhatsApp chat overview. Each study participant was confronted with three different experimental conditions, whereby rubber hand and neutral control object (wooden block) represented the control conditions to be compared against the two smartphone conditions. In addition, the individual perception of the smartphone as rather high hedonic or low hedonic was studied as a quasi-experimental factor within the smartphone conditions.

2.1.2. Sample

The total sample consisted of $n = 76$ participants (63 female, 12 male, 1 without gender assignment). The age range was between 19 and 30 years ($M = 23.24$, $SD = 2.81$). The handedness had a mode in *lis pendens* (73 right-handed participants, 3 left-handed). The sample for the analysis for Smartphone Usage Behavior and demographics was of 76 participants. Data of one participant was excluded for single measures due to technical problems during recording. This led to a final sample of 75 participants for the analyses including the neutral control condition and for self-related product quality.

2.1.3. Materials

In each experimental condition, one of the four test objects was used: the rubber hand, a hand prosthesis of about 27 cm length (Figure 1a), a wooden block of $1.4 \times 8.5 \times 2.5$ cm (Figure 1b), a smartphone of $1.5 \times 7.1 \times 0.8$ cm, switched off with black display (experimental condition smartphone neutral, Figure 1c), or the same smartphone showing a static image of the application WhatsApp (experimental condition smartphone plus activated self-relevance, Figure 1d). The used smartphone was a Huawei P20 (Huawei Technologies Co., Ltd., Shenzhen, China), however, it was only shown in front view and no brand name was visible. The fictitious, prototypical overview of chats was created for the study using WhatsApp as it is the most widely used instant messenger service in Germany [2,27]. It showed eight chats, each characterized by a profile picture, the name of the chat partner or name of the chat, the last message sent to or received by this person including the time of the outgoing or incoming message. To make the chat prototype as realistic as possible, the selection of the names of the chat partners were oriented on the most common names in the participants' age range in Germany [33]. The chat with "Mum" and the group chat "Family" were added to increase self-reliance through a family relationship. The chat messages were typical everyday conversations (e.g., "How are you?", "Cinema tomorrow?").

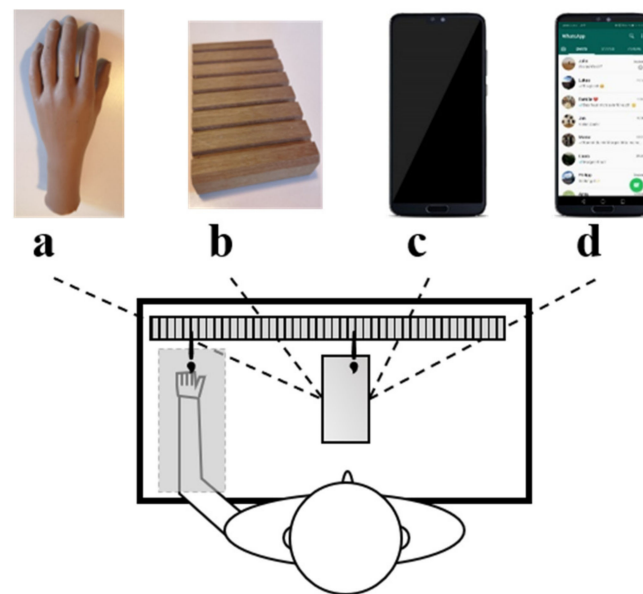


Figure 1. Set-up and test objects: (a) rubber hand, (b) neutral control object wooden block, (c) smartphone neutral and (d) smartphone plus activated self-relevance.

For the tactile stimulation of both a participant's hand and the test objects, two equal flat brushes were used. The brushes had a wooden handle and a width of 2 cm. The ruler for measuring the proprioceptive drift was a wooden stick of 143 cm in length.

2.1.4. Research Flow

The laboratory experiment consisted of three blocks presented in randomized order. Figure 2 depicts the entire research procedure. After being informed about the experiment, the first block of the experiment started. Participants placed their left hand [34] on the table in a small box to ensure that they could not see their own hand and their right hand under the table on their right thigh. A test object (rubber hand, wooden block or smartphone neutral or smartphone plus activated self-relevance) was placed on the table in the center of the subject's field of vision (see Figure 1). A cape covered the participants' upper body as well as the bottom line of each object [35]. Participants were asked to initially look at the test object for 30 s. This duration was based on the maximum time needed to read the WhatsApp chat overview in the experimental condition smartphone plus activated self-relevance. To boost self-relevance in the one smartphone condition, it was also verbally instructed ("Please imagine this is your smartphone. It's about half-past 12. You've just opened the app WhatsApp. Please have a look at everything and read it through"). For the pre-measurement (T1) of the implicit BOI-measurement, the ruler was put on the table, and participants were asked at what position of the ruler they localize their middle finger using steps of 0.5 cm (for example, position 10.0, 10.5, 11.0). For each block, the ruler's starting point was varied so participants did not have a fixed reference point. Next, participants' left hand and the test object were stroked with two brushes synchronously for one minute [21]. Right after the stimulation and without the participants moving their hands, post-measurement (T2) and explicit measurement with the BOI-questionnaire were conducted to finish the block. After the blocks 1 and 2 participants had to leave the lab for a five-minute break to avoid spillover effects [21]. After the final block, participants filled out the demographical questionnaire and the questionnaire of smartphone usage behavior. Afterward, they were debriefed and dismissed.

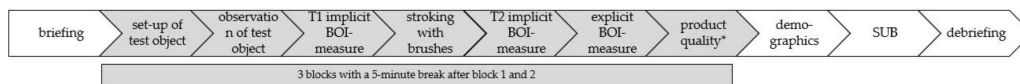


Figure 2. Research flow of the laboratory experiment. SUB = smartphone usage behavior. * Product quality was assessed in smartphone conditions only.

2.2. Measurements

2.2.1. Explicit Measurement of BOI

The questionnaire consisted of nine items (see Table 1) measuring four sub-constructs, namely, standard body ownership illusion [18], Body Part [36], Self-localization composed of the movement of the own hand towards the test object and movement of the object towards the own hand, body transformation [21], and attachment [8]. It was recorded on a visual analogue scale (9.7 cm) ranging from “completely disagree” to “completely agree”. The internal consistency was measured using the test score reliability coefficient Cronbach’s alpha. The internal consistency of the questionnaire was good to excellent ($\alpha_{M(\text{rubber hand, neutral control object, smartphone})} = 0.91$; $\alpha_{\text{rubber hand}} = 0.88$; $\alpha_{\text{neutral control object}} = 0.86$; $\alpha_{\text{smartphone}} = 0.86$) [37]. The questionnaire is reliable.

Table 1. Explicit measurement of BOI, sub-constructs and sample questionnaire of the conditions with smartphone.

Sub-Construct	Item
Standard BOI-items	Q1: It seemed as if I were feeling the touch of the paintbrush in the location where I saw the [smartphone] touched. Q2: It seemed as though the touch I felt was caused by the paintbrush touching the [smartphone].
Body Part	Q3: I felt as if the [smartphone] was my hand.
Self-localization	Q4: It seemed like the rubber hand was part of my body. Q5: It felt as if my hand was drifting towards the [smartphone].
Body transformation	Q7: It appeared as if the [smartphone] was drifting towards my hand.
Attachment	Q6: It felt as if my hand was turning into the [smartphone]. Q8: I felt emotionally connected to the [smartphone]. Q9: The [smartphone] is very dear to me.

2.2.2. Implicit Measure of BOI

The presence of an ownership illusion has been reported to correlate with a change of perceived finger location towards the rubber hand (i.e., proprioceptive drift) [18,38,39] and it is therefore commonly used as an implicit measure of illusionary body ownership. Usually, participants’ left hand is used as it represents the non-dominant hand in the majority of people. Research has for example shown that the proprioceptive drift is significantly enhanced when the visual-tactile stroking procedure is conducted on the non-dominant hand in comparison to the dominant hand [34]. Typically, it is argued that the dominant hand has greater representational stability at the level of primary sensorimotor representation in the brain and therefore shows a higher resistance to biases by the illusion induction [34,40].

To estimate the proprioceptive drift, we measured changes in the perceived position of the middle finger of participants’ hand that was used for the illusion. Participants sat at a table (see Figure 1). Before (T1) and after (T2) the stimulation, a ruler with veridical millimeters demarcations was put on the table, and participants were asked to report the number on the ruler which they felt best corresponding with the position of their real hidden finger. To calculate the proprioceptive drift measure [21,39], we then subtracted the perceived position of the participant’s middle finger assessed at the end of the stroking interval (T2) from the perceived position measured before the stroking phase (T1). A positive value indicates a displacement of a participant’s own hand towards the test object. A negative value indicates a displacement in the opposite direction.

2.2.3. Self-Related Product Quality

Self-related product quality was assessed with the hedonic scale of the AttrakDiff-Mini questionnaire [41], consisting of eight semantic differential items with a seven-point scale. While we were primarily interested in the perceived self-related, hedonic quality (e.g., cheap–valuable, lame–exciting), we also assessed the perceived pragmatic quality (e.g., confusing–clear, impractical–practical) as a measure of comparison. Thus, four items measured hedonic ($\alpha_{\text{hedonic}} = 0.67$) and four items pragmatic ($\alpha_{\text{pragmatic}} = 0.68$) product quality. Both scales correlated moderately, $r(73) = 0.42$. A median split was calculated to categorize the participants' perception into the categories *high hedonic* versus *low hedonic* (Mdn = 5.00, M = 4.93, SD = 0.96).

2.2.4. Smartphone Usage Behavior (SUB)

The questionnaire consisted of 17 items [6,8] and measured the participants' usage behavior of their private smartphone on four subscales: process usage (Q1–Q7, $\alpha = 0.77$, e.g., I use my smartphone “to relax”, “to stay up to date of the latest news”), social usage (Q8–Q12, $\alpha = 0.69$, I use my smartphone . . . “to interact with people”, “to maintain relationships”), memory (Q13–Q15, $\alpha = 0.80$, My smartphone . . . “symbolizes a bond with friends or family”, “is proof of something from my past”), and self-extension (Q16–Q17, $\alpha = 0.73$, “My smartphone reminds me of who I am”, “If I lose my smartphone, I would feel like I have lost a little bit of myself”). The Likert scale ranged from 1 (strongly disagree) to 7 (strongly agree). The internal consistency over all items was high ($\alpha = 0.81$).

2.2.5. Demographical Questionnaire

To describe the sample as well as to secure the participation criteria, the variables age, sex, knowledge of German, handedness, the presence of neurological or psychiatric illnesses and vision were recorded.

3. Results

3.1. Manipulation Check

From the questionnaire on the Smartphone Usage Behavior, we know that all participants do use their private smartphones (see Figure 3). The manipulation of self-relevance was operationalized using a prototypical WhatsApp chat overview in the condition smartphone plus activated self-relevance in comparison to the condition smartphone neutral where the smartphone was turned off. The success of the manipulation was calculated by comparing the degree of attachment to the smartphone in both conditions with the two items of the explicit measurement of BOI. The manipulation of self-relevance was successful because the experimental groups with smartphone differed significantly in their attachment to the smartphones (see Table 2b, line Attachment SM_N vs. SM_SR).

3.2. Descriptives: Smartphone Usage Behavior (SUB)

The overview of the participants' average smartphone usage behavior (Figure 3) shows mean values and standard deviations for the different subscales. While there were high agreement and low variance for the subscales process usage and social usage, indicating that the majority of participants use their private smartphone for entertainment, information seeking, and to pass the time (process usage) as well as to interact with their social network (social usage), there were lower mean values and a considerable variance for the subscales memory and self-extension. Thus, about 57.9% of participants seem to perceive their smartphone at least partly (percentage of participants who rated the items with the value 4 of 7 and higher) as a marker of their own past and memory and even fewer, 35.5% of the participants stated that their smartphone represents their own self at least partly.

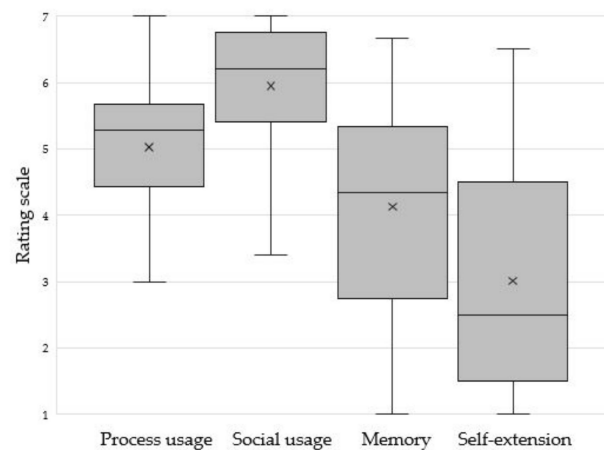


Figure 3. Standardized descriptive statistics of smartphone usage behavior (SUB). Box-plots depict the range of the inner 50% (box), the median (line dividing the box), minimum (bottom whisker), maximum (upper whisker) and the mean (X).

Table 2. a–c. Results of the evaluation of H2 comparing smartphone and neutral control object, H4b comparing smartphone neutral and smartphone plus activated self-relevance and H4a comparing smartphone plus activated self-relevance and neutral control object. *T*-tests comparing different experimental conditions for significant mean differences, one-tailed. SM = smartphone, SM_SR = smartphone plus activated self-relevance, SM_N = smartphone neutral, NEUT = neutral control object (wooden block). * Significant at $p < 0.05$, one-tailed. ** Significant at $p < 0.001$, one-tailed. *M* in cm, *SD* in cm. t = *t*-value, *df* = degrees of freedom, $|d|$ = effect size Cohen's *d*.

Scale	a Smartphone versus Neutral control OBJECT (H2). <i>T</i> -Test for Paired Samples. <i>N</i> = 75, <i>df</i> = 74					b Smartphone Plus Activated Self versus Smartphone Neutral (H4b). <i>T</i> -Test for Independent Samples. <i>N</i> = 38, <i>df</i> = 74					c Smartphone Plus Activated Self versus Neutral Control Object (H4a). <i>T</i> -Test for Paired Samples. <i>N</i> = 38, <i>df</i> = 37				
		<i>M</i>	<i>SD</i>	<i>t</i>	$ d $		<i>M</i>	<i>SD</i>	<i>t</i>	$ d $		<i>M</i>	<i>SD</i>	<i>t</i>	$ d $
Standard BOI-Items	SM	3.27	2.23	0.47		SM_N	3.12	1.90	−0.69		SM_SR	3.47	2.53	0.19	
	NEUT	3.16	2.23			SM_SR	3.47	2.53			NEUT	3.40	2.39		
Body Part	SM	1.81	2.07	1.76 *	0.20	SM_N	1.55	1.83	−1.17		SM_SR	2.10	2.25	2.21 *	0.36
	NEUT	1.41	1.86			SM_SR	2.10	2.25			NEUT	1.51	1.90		
Self-localization	SM	2.38	2.27	1.56		SM_N	2.01	1.77	−1.48		SM_SR	2.76	2.63	0.95	
	NEUT	2.07	2.01			SM_SR	2.76	2.63			NEUT	2.47	2.29		
Body transformation	SM	1.53	1.97	−0.05		SM_N	1.48	1.86	−0.31		SM_SR	1.62	2.08	−0.01	
	NEUT	1.54	2.00			SM_SR	1.62	2.08			NEUT	1.62	2.15		
Attachment	SM	2.76	2.60	4.24 **	0.49	SM_N	1.85	2.16	−3.22 *	0.70	SM_SR	3.65	2.69	4.56 **	0.74
	NEUT	1.52	1.96			SM_SR	3.65	2.69			NEUT	1.73	2.01		

3.3. Rubber Hand Illusion (H1)

H1 hypothesized that the rubber hand will evoke indicators of a body ownership illusion compared to the neutral control condition. In line with this assumption, the mean values in the condition rubber hand were always higher than the mean values of the neutral control condition, standard BOI-items, $t(74) = 10.04$, $p < 0.001$, Cohen's $|d| = 1.16$; Body Part, $t(74) = 10.42$, $p < 0.001$, Cohen's $|d| = 1.20$; Self-localization, $t(74) = 3.64$, $p < 0.001$, Cohen's $|d| = 0.42$; Body transformation, $t(74) = 6.05$, $p < 0.001$, Cohen's $|d| = 0.70$; Attachment, $t(74) = 7.22$, $p < 0.001$, Cohen's $|d| = 0.83$. The basic rubber hand illusion with medium to high effect sizes were found. Further results can be interpreted.

However, we did not find a behavioral indicator of the presence of an ownership illusion in terms of a finger displacement towards the test object. The rubber hand ($M = 0.03$, $SD = 1.34$) and neutral control condition ($M = -0.26$, $SD = 3.36$) did not differ significantly with respect to the proprioceptive drift measurement, $t(74) = 0.65$, $p > 0.05$. In conclusion,

the hypothesis that the rubber hand is incorporated but not the neutral control object is rejected for the implicit, however, maintains for the explicit measurement.

3.4. Attachment to and Self-Incorporation of a Smartphone (H2)

To investigate if a smartphone is generally incorporated in one's self, both conditions with smartphones were merged to overall scores for smartphones to test H2. Using a one-sided *t*-test for paired samples they were tested against the neutral control condition (see Table 2a). The test was significant for the feeling that the object was a part of the own body (see Table 2a, line Body Part SM vs. NEUT). Participants felt as if the smartphone belonged to their body, however, no effects were found for the standard BOI-items. Additionally, on a single-item level, participants felt their own hand moving towards the smartphone more ($Q5$, $M_{SM} = 2.76$, $SD_{SM} = 2.79$) than towards the neutral control object ($M_{NEUT} = 2.19$, $SD_{NEUT} = 2.26$), $t(74) = 2.30$, $p < 0.05$, $d = 0.27$). However, on the overall scale self-localization that was measured with two items no significant effect was found (see Table 2a, line Self-localization SM vs. NEUT). Additionally, participants felt more connected to the smartphone (see Table 2a, line Attachment SM vs. NEUT).

Regarding the implicit measurement proprioceptive drift, no significant difference was found between smartphone overall ($M = 0.07$, $SD = 1.23$) and neutral control condition ($M = -0.26$, $SD = 3.36$) with $t(74) = 0.74$, $p > 0.05$. Therefore, H2 is maintained for the explicit measurement, however, rejected for the implicit measurement.

3.5. Subjective Perception and Evaluation of Product Quality (H3)

To examine the subjective perception and evaluation of product quality [24] as a possible factor influencing the incorporation of a smartphone into one's self (H3) the grouping variable *hedonic high* and *hedonic low* was used. The analysis of the product perception as hedonic was hypothesis-based, the analysis of the pragmatic exploratory. A one-sided *t*-test with independent samples was calculated to test if smartphones that were perceived as more hedonic were rather incorporated than smartphones that were perceived as less hedonic. The *t*-test showed significant differences for self-localization (see Table 3, line Self-localization Low vs. High) and for attachment (see Table 3, line Attachment Low vs. High).

Table 3. Results of the evaluation of H3 comparing smartphone perceived as hedonic high versus low. *T*-Test comparing smartphone perceived as hedonic high with smartphone perceived as hedonic low for significant mean differences, one-tailed. * Significant at $p < 0.05$, one-tailed. *M* in cm, *SD* in cm. t = *t*-value, df = degrees of freedom, $|d|$ = effect size Cohen's *d*.

Smartphone Hedonic High versus Smartphone Hedonic Low (H3).					
<i>T</i> -Test for Independent Samples.					
$N_{\text{hedonic high}} = 46$, $N_{\text{hedonic low}} = 30$, $df = 74$					
Scale		<i>M</i>	<i>SD</i>	<i>t</i>	$ d $
Standard BOI-Items	Low	2.89	2.29	−1.28	
	High	3.56	2.17		
Body Part	Low	1.49	2.06	−1.15	
	High	2.04	2.05		
Self-localization	Low	1.74	2.11	−2.06 *	0.47
	High	2.81	2.27		
Body transformation	Low	1.28	1.93	−0.98	
	High	1.73	1.98		
Attachment	Low	1.57	2.29	−3.41 *	0.75
	High	3.51	2.50		

Regarding the implicit measurement, no differences were found comparing hedonic high ($M = 0.12$, $SD = 1.02$) and low ($M = -0.17$, $SD = 1.50$) with $t(74) = -0.47$, $p > 0.05$. For the explicit measurement, H3 is maintained, however, rejected for the implicit measurement.

3.6. Self-Relevance (H4)

H4b hypothesized that the smartphone plus activated self-relevance is more likely incorporated than the smartphone neutral. The *t*-test comparing the means of both conditions was only significant for attachment towards the test object (see Table 2b, line Attachment SM_N vs. SM_SR) (Due to lack of equality of variances an additional Mann–Whitney-U test was calculated for several items or scales, Movement of the hand ($U = 622.50, p = 0.301$), self-localization ($U = 635.50, p = 0.369$), and attachment ($U = 443.00, p = 0.004$). It showed the same results as the *t*-test for independent samples.). Participants felt more emotionally attached to the smartphone plus activated self-relevance than to the smartphone neutral.

Additionally, H4a and H4c were tested comparing each condition with smartphone individually with the neutral control object. Significant mean differences were found comparing the smartphone plus activated self-relevance to the neutral control object (H4a, see Table 2c) for the feeling that the object was a part of the own body (see Table 2c, line Body Part SM_SR vs. NEUT) and for attachment (see Table 2c, line Attachment SM_SR vs. NEUT). Participants rather perceived the smartphone as a body part than the neutral control object. No significant effect was found for self-localization in general (see Table 2c, line Self-localization SM_SR vs. NEUT). However, on a single-item level, a significant effect was found for the movement of the own hand towards the object. Participants rather perceived their own hand to move towards the smartphone ($M_{SM_SR} = 3.16, SD_{SM_SR} = 3.04$) than towards the neutral control object ($M_{NEUT} = 2.48, SD_{NEUT} = 2.83$), $t(37) = 1.72, p < 0.05, d = 0.28$. However, no effects were found comparing the *smartphone neutral* to the *neutral control object* (H4c), all $t_s > -0.06$, all $p > 0.05$.

Regarding the implicit measurement of the self-incorporation, the means did not differ significantly between smartphone plus activated self-relevance ($M = 0.13, SD = 1.09$) and neutral control object ($M = -0.26, SD = 3.36$) (H4a) with $t(37) = 0.56, p > 0.05$, smartphone plus activated self-relevance ($M = 0.13, SD = 1.09$) and smartphone neutral ($M = 0.00, SD = 1.36$) (H4b) with $t(74) = -0.47, p > 0.05$, and between smartphone neutral ($M = 0.00, SD = 1.36$) and neutral control object ($M = -0.26, SD = 3.36$) (H4c) with $t(36) = 0.55, p > 0.05$.

3.7. Interaction of Self-Relevance and Subjective Perception and Evaluation of Product Quality (H5)

H5 assumed an interaction of self-relevance and hedonic product perception. No interactions were found, all $F < 1.80$, all $p > 0.05$.

4. Discussion

Building on the findings of Liepelt et al. [21] and Belk [7,9] this study investigated the attachment to and self-incorporation of a smartphone using the established rubber hand illusion paradigm. Subjective perception and evaluation of the smartphone's product quality and self-relevance of the smartphone were manipulated and assessed as further variables (see Table 4 for an overview of all hypotheses and significant results). In a lab experiment, implicit and explicit measurements of the body ownership illusion were combined and linked to the participants' smartphone usage behavior.

Table 4. Key research questions and findings. The table gives an overview of all experimental conditions aligned to the research questions and hypothesis they answer as well as a list of the significant results for the explicit measurements of BOI.

Research Question and Experimental Conditions	Hypothesis	Significant Results for Explicit Measurement of BOI
Basic rubber hand illusion: Rubber hand–neutral control object	H1 The rubber hand will evoke indicators of a body ownership illusion compared to the neutral control condition.	The explicit measurement of BOI supports the hypothesis for standard BOI-items, body part, self-localization, body transformation and attachment.
Self-incorporation of smartphones: smartphones–neutral control object	H2 Overall smartphones (smartphone plus activated self-relevance and smartphone neutral) will evoke indicators of a body ownership illusion and a higher level of attachment than the neutral control condition.	The explicit measurement of BOI supports the hypothesis for body part and attachment.

Table 4. Cont.

Research Question and Experimental Conditions	Hypothesis	Significant Results for Explicit Measurement of BOI
Product quality high hedonic–low hedonic	H3 The perception of a smartphone as of high hedonic product quality (in contrast to low hedonic perception) will evoke indicators of a body ownership illusion and a higher level of attachment.	The explicit measurement of BOI supports the hypothesis for self-localization and attachment.
Self-relevance: H4a: Smartphone plus activated self-relevance–neutral control object H4b: Smartphone plus activated self-relevance–smartphone neutral H4c: Smartphone neutral–neutral control object	H4 Smartphone plus activated self-relevance will have a higher level of attachment and evoke more indicators of a body ownership illusion than the neutral control object (H4a) and more than smartphone neutral (H4b), whereby Smartphone neutral will evoke more indicators of a body ownership illusion than the neutral control object (H4c).	The explicit measurement of BOI supports H4a for attachment and H4b for body part and attachment.
Interaction of self-relevance and hedonic product quality	H5 Smartphone plus activated self-relevance and high hedonic product perception will evoke more indicators of a body ownership illusion and a higher level of attachment than the condition smartphone neutral and low hedonic product perception.	-

For the explicit measurement the rubber hand evoked an experience of body ownership including a change in the subjective self-localization, body transformation, and a closer attachment to the test object but not the neutral control object. The basic rubber hand illusion was replicated [42,43]. However, we did not find a significant positive proprioceptive drift of participants' hand towards the fake hand. Several previous studies have already reported a lack of correlation between both measurements as well as inconsistent findings for questionnaire-based assessments of the rubber-hand illusion and perceived finger position displacements [44–46]. In the present study context, this measurement might not have been sensitive enough to detect any changes in body perception. Future studies are needed that assess the validity of the proprioceptive drift measure as a proxy of ownership experiences.

4.1. Attachment to and Self-Incorporation of a Smartphone

We found support for the hypothesis that smartphones are generally incorporated in one's self and that people feel emotionally attached to a smartphone. Regarding self-incorporation, we found effects for the construct Body Part, however, no effects for the standard BOI-items. As regards content, the constructs standard BOI-items and Body Part mean the same. However, participants might have rationally refused to say that 'the smartphone was [their] hand' (Q3). The item that measured Body Part might have been easier to go along with. This could explain the slightly contrary findings.

Reflected by the finding that participants felt their own hand moving towards the smartphone and in line with previous work [47], we found behavioral support that participants incorporated a smartphone into the mental representation of their (bodily) self and felt the need to interact with the device. Research in general psychology suggests that a body ownership illusion is caused by a multisensory integration that is linked to an internal plausible anatomical model of one's own body including structural information about body parts [42]. The present study in contrast suggests that a fit with a reference model of the body is not necessary to induce an illusory incorporation of objects and adds that apart from an internal anatomical representation, we might also have an internal representation of everyday habits including objects that are frequently used or even a digital self as stated in Belk [7]. Research on the self-incorporation of or self-extension by tools [36,48] showed that a repeated use of a certain tool can lead to neuronal changes in the receptive fields of bimodal neurons, a type of neurons responding to visual and somatosensory stimuli on and near the hand [49–51]. As a result, these neurons no longer respond to stimuli near the hand, but also to the extended space surrounding the tool. We speculate that technological objects are incorporated in a person's internal representation of themselves like a tool. However, the incorporation of a smartphone is perhaps even more

powerful as smartphones are not only used for pragmatic purposes but are comprised of highly self-relevant features which are directly fed into self-identity.

4.2. Subjective Perception and Evaluation of Product Quality and ITS Influence on Self-Incorporation and Attachment

The subjective perception and evaluation of product quality according to the model hedonic and pragmatic product perception [24] was examined as a possible factor influencing the incorporation of a smartphone into one's self. The subjective perception of hedonic product quality influenced whether participants felt their hand and the test object moving towards each other. Additionally, participants that perceived the smartphone as more hedonic felt more emotionally attached to the smartphone or vice versa. Past research has already shown that hedonic product quality is related to product attachment and the self in general [25,26,52]. Our findings now empirically support the relationship between product quality and a person's self. Interesting in this context is the exploratory data analysis for the perception of pragmatic product quality because here no effects were found. This suggests that only products with perceived self-related qualities are incorporated into a mental representation of oneself.

4.3. Self-Relevance and Its Influence on Self-Incorporation and Attachment

In line with our assumption, participants felt more emotionally attached to the smartphone plus activated self-relevance than to the smartphone neutral. This finding can be interpreted on several levels:

First of all, our results suggest that increased emotional attachment to a smartphone is driven by activating the device's feature of social communication. Studies on nomophobia already showed that the separation of users from their smartphone can cause discomfort and stress because of the potential loss of social contacts [8,23,32,53] and studies on smartphones as a pacifier emphasize a smartphone's function as an attachment object that provides comfort [28–30]. Additionally, Harkin and Kuss [53] using a qualitative research approach found that smartphones are conceptualized as a part of or an extension of a person's body. Second, past research on product attachment has shown that an increase of attachment can be caused by time and financial investments in the product [11], personalization [11,54], a product's presence in daily life as well as self-related hedonic qualities [26]. The present study identified the use of a product for social communication as a further accelerator of attachment.

Third, Belk [7] argued that smartphones partially represent our autobiographical self [20]. In this study, the presentation of profile pictures and past text messages in WhatsApp might have acted as a reminder of the past. This presentation resulted in an increase of the attachment towards the phone. Additionally, participants' self-reports on their smartphone usage behavior are a further indication of smartphones representing a reminder of companions and events as well as a connection to friends and family. Thus, smartphones appear to be the open door to the own social network and thereby may even become constitutive of a person's self-identity.

The further analysis of the smartphone plus activated self-relevance versus the neutral control object revealed effects for the feeling that the object was a part of the own body, for attachment and on a single-item level even for the movement of the own hand towards the object. However, no effects were found comparing the smartphone neutral to the neutral control object. There seems to be an additional effect on the self-incorporation of smartphones. If participants were aware of the importance of a smartphone for social communication, they were more likely to incorporate it.

4.4. Interaction of Self-Relevance and Subjective Perception and Evaluation of Product Quality

There was no interaction of *self-relevance* and *hedonic product perception*. This indicates that both self-relevance and subjective product quality independently impact a body ownership illusion.

4.5. Practical Implications

This study stresses the importance of modern technologies in our life. Not only are modern technologies an integral part of living, they can also be perceived as a part of the self and emotionally important to people. For marketers, this is of high interest as emotionally important and self-relevant products might increase product and brand loyalty [55,56]. If this were to be found, technology designers should identify certain designs that increase self-incorporation of technologies, e.g., hedonic qualities or anthropomorphism. For example, it was shown that products with an anthropomorphic design decreased willingness of product replacement for cars [57], however, increased trust in driving agents [58], and a sense of connectedness to the object [59]. Smartphones are already used in many areas of application [60]. For HCI and User Experience Research our finding of smartphones as an appealing object that people rely on and feel attracted to interact with is of general interest as it may indicate that smartphones are a good medium to support users in behavior change or to establish desirable new, healthier routines (e.g., doing more sports, changing diet).

However, in contrast to potential positive effects on a person's self-regulation skills, our findings can also be associated with problematic smartphone usage or smartphone use disorder [61–63]. Several studies reported that people feel the urge of constantly checking the smartphone for notifications [6,64]. A study showed that participants unlock their phone more than 47 times a day [65] and check their smartphone every 18 min [66], a habit that appears to happen even without conscious thinking [47]. Problematic or addictive smartphone use can negatively influence productivity in the workplace and at home [67,68], sleep quality [69] and the emotional connection of individuals having a conversation [70].

4.6. Limitations and Future Research

The present study is subject to several limitations which need to be addressed by future research:

The sample was limited to an age range of 19 to 30 years in the university environment. The digitization of German society shows both a generational effect and an effect on the educational level of individuals [27]: Older people, as well as people with a lower level of education, show a lower degree of digitization. Therefore, it is likely that the effects found in the experiment do not apply to the total population. In addition, about 83% of the participants were female. Therefore, future studies are warranted assessing the effects in a more representative sample.

With respect to subjective perception and evaluation of product quality, we found an effect on the self-incorporation of a smartphone. However, as a quasi-experimental factor, we do not know whether perceived product quality characteristics are the cause or moderator of the observed effects.

Additionally, our data showed that the attachment towards the smartphone increased if self-relevance was activated. However, we do not know if the attachment is directed to the object itself or merely to the content stored on the phone. The effects for hedonic product perception might indicate that the phone itself with its design and haptic causes attachment to it. The intensive usage of smartphones for social and productive reasons indicates, however, that people are attached to the content the phone represents. Therefore, further research should investigate the source of attachment to technologies to clarify the importance of product design for product attachment. Furthermore, in our experiment the sensory user input coming from the smartphone was limited to visual information only. Further studies should consider investigating the role of multimodal interaction with smartphones as a potential cause for attachment and self-incorporation [71]. In addition, further studies may want to investigate if the self-incorporation of a smartphone also applies to other technologies such as smartwatches or fitness trackers that are worn more tightly on one's body. In this regard, the impact of one's individual user experience interacting with a device could also be interesting as it is likely that products with more positive user experience are more likely to be incorporated.

5. Conclusions

The self-incorporation of a smartphone and the attachment to it were experimentally investigated in the present research. Using the established rubber hand illusion, we showed that participants subjectively experienced the smartphone as a part of themselves, felt the need to interact with the device and felt emotionally attached to it. These effects were more prominent when hedonic characteristics were evaluated as high and when its usage for social communication was highlighted during the experimental condition. For interactive products, this consideration of a smartphone as an incorporated part of the self underlines the central role of smartphones as an important companion in everyday life. It is a self-relevant object due to its importance for social connection. Smartphones have the potential of enriching people's lives. However, they might also have a negative impact on well-being if users feel discomfort and stress without their smartphones because of the potential loss of social contacts.

From a marketing perspective, self-relevance and emotional importance might have a positive impact on product and brand loyalty because people are less likely to replace objects they feel emotionally connected to. Therefore, design attributes (e.g., hedonic or anthropomorphic) should be identified that increase product attachment and self-incorporation.

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