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Stores are Liable for Their Robots!? An Empirical Study on Liability in HRI with an Anthropomorphic Frontline Service Robot

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***Abstract*— Everyday life scenarios where non-expert users (e.g., customers) are confronted with frontline service robots will become more and more likely. In particular, misunderstandings and incidents may occur during these interactions because of wrong expectations of the robot's capabilities. Current applicable laws are based on technological assumptions from prior decades unsuitable to modern robotics and AI. The new AI Act as a part of the solution to this is still in development. In addition to the pure legal view, a technological viewpoint may be beneficial for establishing a fitting, trustful, and, thus, acceptable technology liability law. This work contributes to this by empirically evaluating the service robot non-expert user's liability expectations, the use of robots, and well-being. The results in a DIY store environment significantly show that the store deploying the robot should be liable if an incident happens. Further, we examined that even a minor simulated incident affected the participants' emotions and moods. Consequently, this influences their perception of liability while not mitigating their acceptance of frontline service robots.**

Fig. 1: Example interaction between a customer and an anthropomorphic service robot in a DIY store.

I. Introduction

Scenarios where non-expert users (e.g., customers) are confronted with frontline service robots will become more and more likely, in particular, if the technological improvements, including artificial intelligence (AI), further proceeds. For short-term interactions, as with frontline service robots, the customers' expectations of such systems can differ widely. Confusing interactions and even incidents can occur if these expectations are not well calibrated to the robot's technological capabilities or behavior.

If an incident during the interaction between a service robot and a customer occurs, the question of liability needs to be answered. This question is particularly relevant in the service sector (e.g., in a store), where humans may be forced to interact with a humanoid service robot to get the required service. Regarding human-human interaction, the question of liability and the associated expectations are learned in the course of life and are pretty clear. However, the question of liability is not clarified when robots are used. Since the currently applicable liability regulation during a human-robot interaction (HRI) is based on assumptions about technology that may not fit the state-of-the-art robots, the new AI Act is in preparation. During this process, the incorporation of the human and technological viewpoint, in addition to the pure legal view, is beneficial for the tailored usability of the developed laws. Further, the distinction between the particular application scenarios and applicable laws is important to not limit or hinder technological progress.

This work contributes to the challenge of establishing a fitting, trustful, and, thus, acceptable technology liability law among users and third parties affected by the use of service robots, by

- empirically evaluating the service robot non-expert user's expectations on responsibility and liability conducting an HRI study,
- and providing a user-centric assessment about using service robots, underlining the regulation focus revealed by the previous point.

Complementary to the self-assessment questionnaire, we have retrieved the study participant's affective state to gather a deeper insight into the emotional effect of failures and the validity of our study design.

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II. Related Work

While it is difficult for legal research to comprehensively grasp the technical foundations of new technologies, it is unusual to consider or shape the legal situation or expected regulations when developing these technologies. Even if legislation involves teams with technical expertise, this process may still lack a deep technical background. Therefore, an interdisciplinary approach seems to make sense to create insights into the other disciplines and close knowledge gaps.

Since the underlying European Union (EU) directive goes back to the 1980ies, current liability laws were not written for robots or even with robots and the underlying technologies in mind. Even if general laws are the rule, it is expected that standards and laws will have to be adapted in the case of revolutionary new technologies (see [1]).

Therefore, a central legal problem of AI is the black-box aspect and the resulting opacity. This opacity makes it difficult or impossible to attribute damages to a specific action, such as a line of code [1] (see [2], with a focus on medical applications). Besides the black box recorder, Websters dictionary[1] defines a black box as ”a usually complicated electronic device whose internal mechanism is usually hidden from or mysterious to the user” or broader ”anything that has mysterious or unknown internal functions or mechanisms”. These functions are problematic, as it is tough to prove causality between action and damages, resulting in the above-mentioned opacity.

In case of an accident, the opacity has to be counteracted by a complicated analysis of the chain of events that led to the damaging event. As this is often either impossible or, compared to the suffered damage, not economically justifiable, proof of causality cannot be provided in these cases. Here the concept of explainable artificial intelligence (XAI) comes into play. XAI should aim to be able to answer positive questions that can determine if a specific condition leads to a specific result. Depending on the technology used, the circumstances leading to the damage event can be analyzed in varying degrees of detail [1].

From the robotics point of view, the explanation of why the robot performs a certain action is central in HRI with autonomous systems and often called transparency [3], not only in the case of incidents. For this, the IEEE Standard 7001-2021 [4] has been proposed to establish a measurable and testable level of transparency [5]. Transparency is a means to calibrate human expectations with the robot's capabilities. Thus, the probability of misunderstandings and failures during the interaction should be reduced. Further, the transparency needs are different for different users [6]. Thus, the 7001 Standard also regards the users called “Incident Investigators”. For those, a transparent robot should provide an “Event Data Recorder” to investigate the causes of incidents and, thus, clarify liability. Nevertheless, it is currently unclear if such a recorder would fulfill the requirements for clarification of liability from the law's point of view. Still, the transparency requirements for incident investigators or even the recorders for robotic systems (e.g., [7]) underline the importance of an interdisciplinary view on this topic.

If liability for autonomous robotic systems is to be clarified, product liability regulations have to be investigated since the robot could, in general, be classified as a product in the sense of the regulation. One major problem is whether software as a fundamental part can be classified as a product in the sense of the regulation (see [8]). Products in the sense of the regulation are all “movables” and “electricity” (see article 2 of the EU directive). Since software is neither a “movable” nor “electricity”, it is not considered a product. Since a robot is a “movable” it is considered a product in the eye of the regulation. Through the robot, its embedded software is covered by the regulation. Nevertheless, the classification of the software itself is relevant, as it must also be considered as a sub-product. Fortunately, the EU has addressed the problem within the framework of the planned AI package of measures and, according to current drafts, will allow AI and software to be covered by the term ”product” in the future. This problem and other issues are also discussed in detail in legal commentaries like Product liability and product safety law (for example [9]).

The European Commission has published two especially relevant drafts regarding robots and AI: the proposal for a regulation of AI and the proposal for a new product liability directive. During this development phase publications focus on evaluating the drafts [10], [11]. Primarily because of the rather broad definition of AI in the EU regulation draft, there is a fear of over-regulation (see [12]), which would be counterproductive for the advancements of AI technologies. One idea to avoid over-regulation is to use voluntary safety commitments like best practices, codes of conduct, and professional guidelines (see [13]; also Articles 40, 42 EU AI Act draft). The question is whether such voluntary measures are enough to ensure the safe use of AI or how these could be intertwined in a reasonable way with mandatory measures.

Regarding the AI Act's difficulties, it is worth examining the General Data Protection Regulation (GDPR), where similar problems occurred. The GDPR was enacted in 2016 and regulates the processing of personal data in general. Thus, the existing approaches and solutions in the field of technology and AI were forced to adapt established solutions, which produced large overheads and hindered advancements. For example, inherent privacy-compliant algorithms [14] and architectures [15], as well as mechanisms to deal with data minimization or anonymization [16] were developed.

If technology development does not consider the later into effect coming AI Act beforehand, a similarly laborious adaption with the drawbacks mentioned above is likely to occur again when technology is faced with the final regulation. With this paper, we get ahead of this adaptation by focusing on the liability design of robots. In doing so, we consider the users' legal understanding and well-being by evaluating both via an empirical study. Furthermore, we examine non-expert users' perceptions of liability and acceptance regarding frontline service robots in a *liable* and a non-liable (*neutral*) condition.

[1] https://www.merriam-webster.com/dictionary/blackbox

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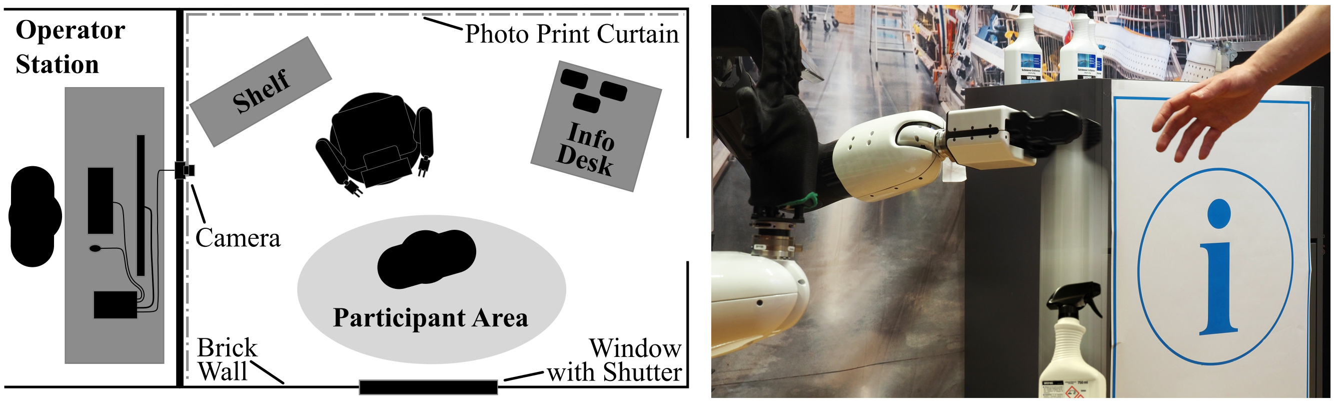

(a) Experimental setup

(b) Failing handover of mold remover.

Fig. 2: Experimental setup with a DIY store customer, including a) the Wizard of Oz method and b) the applied condition.

III. Experiment

In the course of an interdisciplinary project regarding responsible HRI, we designed an empirical study depicting a sales dialog between a customer and a consultant based on the results of [17]. The study scenario was designed to investigate all research questions of the involved disciplines, with individual adjustments for each discipline, creating corresponding study conditions. In the study scenario, the anthropomorphic service robot was deployed as a DIY store employee, providing advice about products or handing them over to the customers. A *neutral* condition was designed to act as a baseline. In this work, the focus lies on liability. Compared to *neutral*, only the product handover was changed, by creating an incident in the corresponding condition, as specified in Section III-A. Fig. 2a shows the experimental setting in a laboratory environment. The experimental area contained a photo print curtain with a DIY store setting, a stocked shelf, an information desk, and the service robot.

A. Liability Expectation

During the experiment, the question of who is liable for caused damages should be raised with the customer. To trigger this question, a situation comparable to an accident had to be induced. The DIY store environment is especially suited as the products bury a higher risk for damage. Moreover, the cause of the outcome should not be clearly attributable to any of the parties involved. Since a mistake by the robot without any involvement of the customer was therefore unsuitable, a product handover was quickly identified as a fitting scenario. In particular, because a well-defined and repeatable accident can be created without bringing the participants into an actually dangerous situation. As product, a mold remover bottle was chosen.

It proved difficult to carry out the handover in a way that it did not go wrong in an obviously planned manner. If the robot opens the hand too early, it is clearly the robot's fault; if it opens it too late, there is a chance that the participant will be able to grasp the product correctly. By conducting a pre-test, the "sweet spot" for releasing the product after finishing the handover arm motion was found. In addition to a short pause after reaching out the arm for handover to initiate the customer to react, the robot's announcement, "Okay, I will hand over the bottle to you and open my hand." shifted the "blame" further onto the participant. The bottle was placed on the robot's base, which ensured a reliable grab. It was filled with bells producing a loud noise during the failing handover to amplify the emotional trigger. As intended, the *neutral* condition consisted of a successful handover, while it failed in the *liability* condition in all cases.

B. Scenario Instructions

The role of the participants and the details of their interaction task were described using a vignette [18]. Here, it was described that they should buy a drill according to the given features and introduced application. They were also asked to create a user account to get a discount and buy a mold remover. In the *liability* condition, the focus lay on the failing mold remover handover. During the HRI, the participants had a short "shopping list", summarizing the contents of the vignette. They were instructed to strictly follow the vignette ensuring the comparability among the participants and the applicability of the used Wizard of Oz method [19]. According to this method, the robot's behavior, including utterances and motions, is pre-programmed and controlled by a hidden operator. Generally, the participants were supposed to ask for the needed information. In case the participant forgot about vignette content, the robot asked if it could help in another way or give more information (e.g., "Is there anything else on your shopping list that I can help you with?"). In the considered conditions the robot behaved in a friendly, neutral tone. It answered the questions briefly and comprehensively without providing additional information or using gestures. For example, when asked about mold remover, the robot replied: "To remove mold, we have only this product in the range." but did not reveal the price. The participant did not have to walk around during the interaction, reducing the interference with physiological data caused by movement.

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C. Procedure

The participants were welcomed in the lab's entrance area. They were informed about the overall purpose of the experiment, the procedure, the potential experimental benefits, and the privacy policy. After the participants agreed to attend the experiment, they were asked to complete the pre-questionnaire, provide demographic information (e.g., age, education, etc.), and their current mood was assessed.

Afterward, the robot was shortly shown to reduce the first emotional impression [20]. Then, the experiment vignette was handed out. After verifying that they understood the interaction tasks, the participants were led to the robot with the instruction to wait (alone in the experiment area) until the robot started the interaction. After interacting with the robot, the participants were asked to complete the post-questionnaire.

D. Service Robot

As a service robot, the platform Tiago++ from PAL Robotics was used. Its anthropomorphic appearance originates from its two arms (consisting of seven rotary joints each), the liftable torso, and its head (with two degrees of freedom). The robot is equipped with, amongst others, an RGB-D camera in the head, two microphones, a speaker, and a touch screen. Tiago++ weights 72 kg, has an adjustable height of 110 cm to 145 cm, a base footprint of 54 cm, a reach of 87 cm and maximum arm joint speeds of 102 deg/s to 132 deg/s.

E. Data Acquisition

Liability. The liability was evaluated by self-developed scales (see Tab. I), as there were none, to the best of our knowledge, assessing our research goals. The most important scale for determining the involved parties' perceived grade of responsibility regards the opinion about the liability among the three involved parties, i.e., robot, DIY store, and customer. In order to be able to evaluate the consistency of the answers, one has to rate the responsibility only between two parties at once. In a second group of questions, the participants had to state how much they agreed (totally disagree to totally agree) with the liability of a specific party. Further questions were asked about the perceived responsibility of specific parties, the consequence of robot usage for responsibility, and whether robots should be used in the displayed scenario. The question about the use in the store was repeated with the assumption that the store is liable for occurring damages in any case.

With regard to the questionnaires, it was problematic to describe the legal problem without conveying a certain answer as the correct one to the participants. Thus, it should be determined who is responsible under liability law according to the participants. It would have been difficult to convey certain liability law concepts and legal principles in terms of scope and would likely have distorted the opinion.

TABLE I: Overview questionnaire liability

	In any case, who would be more likely to be responsible if damage occurs in the interaction with the robot?		
	DIY Store	○ ○ ○ ○ ○ ○ ○	Robot
	DIY Store	○ ○ ○ ○ ○ ○ ○	Customer
	Customer	○ ○ ○ ○ ○ ○ ○	Robot
	Who should be liable for potential damages arising from interactions with the robot?		
		Totally Disagree … Totally Agree	
a	DIY Store	○ ○ ○ ○ ○	
b	Customer	○ ○ ○ ○ ○	
c	Robot	○ ○ ○ ○ ○	
	To what extent do you agree with the following statements: (Totally Disagree ○ ○ ○ ○ ○ Totally Agree)		
a	For damages that occur during the interaction with the robot, the market deploying the robot should be responsible.		
a	The deploying markets are responsible for damages occurred during the interaction with robots.		
*b**	When using a robot, customers should not be liable for any damage caused, even in the case of minor errors.		
c	Robots are responsible for damage caused in interaction with them.		
c	For damages that occur during the interaction with the robot, the robot should be responsible.		
d	Service robots should be used in DIY stores.		
d	Service robots should be used in the scenario chosen. for the experiment.		
e	Markets deploying service robots should be more liable for damages occurring during interaction with these robots than those deploying human employees.		
*e**	The use of robots should not affect the market's responsibility for damages.		
	Assume that the DIY store will have to pay for any damage that occurs in the interaction with the robot in any case. (Totally Disagree ○ ○ ○ ○ ○ Totally Agree)		
f	Service robots should be used in DIY stores.		
f	Service robots should be used in the scenario chosen for the experiment.		

Note: Items of scale a) "DIY Store Liable", b) "Customer Liable", c) "Robot Liable", d) "Use Robots", e) "Adjust Store Liability", and f) "Use Robot Store Liable". Inverted items marked with *.

Human Affect. The participants' affect was assessed through pre- and post-questionnaires, evaluating specific emotional triggers or mood scenes, and via physiological sensor data. In the questionnaire "emotion" and "mood" were defined according to Scherer's [21] and Levenson's [22] emotional models. Here, emotions are short-term reactions driven by stimuli and subjective evaluation. Conversely, the mood was described as a diffuse affective state with low intensity over a more extended period, where the affective trigger could not be specified. On a five-point Likert scale, participants evaluated their moods and emotions using the Self-Assessment Manikins (SAM) developed by Bradley and Lang [23]. The SAM involved ranking mood and emotions on the valence and arousal scales. The scale ranged from one, unpleasant/low arousal (calm), to five, pleasant/high arousal (excited). Further, the participants wore the Empatica E4 wristband [24] to gather Galvanic Skin Response (GSR) related to the human arousal state [25]. Emotional triggers can be found in the GSR signal as a peak [25].

IV. Evaluation

A. Participants

146 persons took part in the experiment. They were in advance assigned to specific conditions. 98 were assigned

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to conditions that viewed different aspects of HRI, that are not the content of this paper. 44 were assigned to either the *neutral* ($N = 22$) or the *liability* ($N = 22$) condition. The participants were reached by email among the Technical University of Darmstadt members, with the call also open to anyone outside the university. In the *neutral* condition 10 participants were female, and 12 were male, with an average age of 31.32 years (SD: 10.22). The *liability* condition involved 7 female, and 15 male persons, with an average age of 25.18 years (SD: 7.72). Except for one participant in the *liability* condition all participants had at least completed the baccalaureate. A majority had a bachelor's or master's degree, with even one having a doctor's grade, in the *liability* condition.

B. Liability in a HRI

To analyze the scales of the self-assessment results, a linear regression analysis was conducted, which resulting regression parameters, Adjusted R^2, and F Statistic are shown in Table II and III. Since homoscedasticity could only approximately be observed in the data, robust standard errors with the HC2 correction [26] are reported in brackets.

In Table II, we examine the impact of our conditions (i.e., *neutral* and *liability*) on users' understanding of who should be responsible for incidents in an HRI. Thereby, no significant change could be observed in the responsibility assignment "customer - store" or "robot - customer". However, a significant increase in the responsibility of the robot can be examined in the liability condition compared to the neutral one. In particular, the mean value of the scale changes from 2.356 to $2.356 + 1.078 = 3.434$, which lies approx. in the center of the scale value range. Overall, when the customer's responsibility is compared to the store's or the robot's, the scale value stays on the customer's opponent's side. In case of an incident, the assignment of responsibility is balanced between the store and the robot, with a tendency to store.

However, when looking at the liability scales of the involved parties (see Table I scales a) to c)), the store clearly should be liable for damages during an HRI (see Table III "Constant (Store)" regression parameter). Compared to the store, customers and robots were seen significantly less liable, with regression parameter values -2.352 and -2.470, respectively. Among the neutral and liability condition, no significant difference for the scales a) to c) could be observed.

Regarding the use of robots in the considered DIY store environment, the results comparing scales d) and f) are listed in the left part of Table III. Here, the participants saw no difference whether the liability was clearly assigned to the DIY store. Furthermore, it is highly emphasized that all participants agree to use the robot.

The last scale considered if deploying service robots in stores should result in an adjustment of the store's liability (see Table I scale e) and right most column in Table II). Here, the result did not significantly change among the two conditions and tend not to change the store's liability.

Overall, in principle, the store is seen as the most liable. In the event of damage during interaction with the robot, however, equal responsibility is assigned between the robot and the store. Independent of the scenario, the usage of robots finds approval in a retail setting.

TABLE II: Impact of the liability condition on the responsibility for damages

	Robot (7) ↔ Store (1)	*Customer (7) ↔ Store (1)*	*Robot (7) ↔ Customer (1)*	*Adjust Store Liability*
Liability Condition	1.078 **	0.619	-0.365	0.324
	(0.384)	(0.404)	(0.549)	(0.331)
Constant (Neutral)	2.356 ***	1.905 •	5.065 ***	2.116 **
	(0.425)	(0.900)	(0.919)	(0.645)
Adjusted R^2	0.199	0.017	-0.029	-0.018
F Statistic (df=2; 41)	6.346 **	1.377	0.399	0.624

Note: $N = 44$; •p<0.1; *p<0.05; **p<0.01; ***p<0.001
Dependent variable in italic with scale extrema values in brackets.
Models controlled for age

TABLE III: Impact of the customers understanding on the parties liability and the application of a robot.

	Liability		*Use Robot*
Robot (Ref.: Store)	-2.470***	Store Liable	0.080
	(0.179)		(0.203)
Customer (Ref.: Store)	-2.352 ***	Constant (General)	4.716
	(0.185)		(0.355)
Constant (Store)	4.817		
	(0.274)		
Adjusted R^2	0.611		0.029
F Statistic (df=3; 128)	69.63 ***	(df=2; 85)	2.314

Note: $N = 44$; •p<0.1; *p<0.05; **p<0.01; ***p<0.001
Dependent variable in italic. Models controlled for age

C. Human Affect in a liability scenario

In order to understand and interpret the results from section IV-B, the change of the affective human state relative to the previous interaction scene or trigger is evaluated. Since the *neutral* and *liability* conditions only differ during the handover of the mold remover bottle, we focus on these scenes. Fig. 3 and 4 show the differences in mood and emotion between the single scenes and emotional triggers over all participants, respectively. The shown markers represent the mean values of the participants in each scene or for each trigger, with significant changes in valence and arousal noted in parentheses at the respective line. On the left-hand side, we can find the *neutral* condition in red, and on the right-hand side, the *liability* condition in blue.

Regarding mood (see Fig. 3), we can find in the neutral condition a strong significant increase in valence (more pleasant) and a significant change in arousal (lower arousal state) between the *Account* and the mold remover interaction (*Mold*). Contrary to that, the increase for the valence scale in liability is less intensely (nevertheless significant), and the arousal increases (not significant). These changes show

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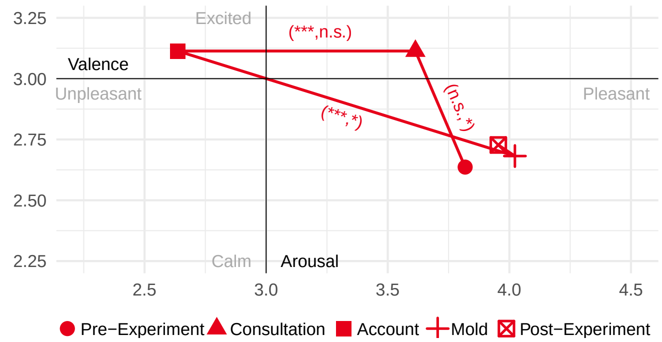
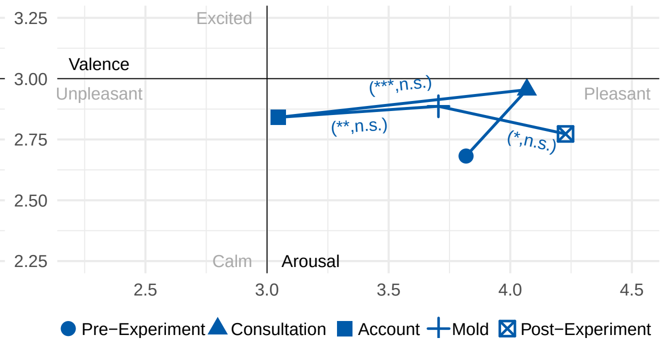
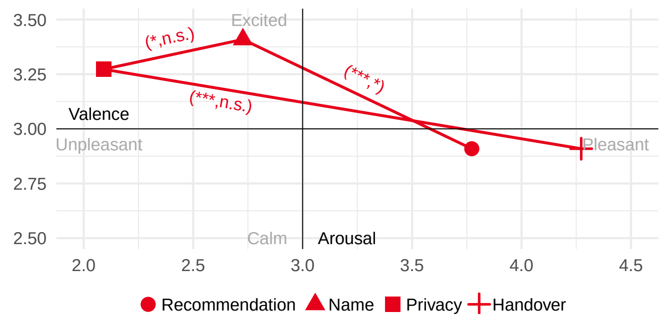


(a) Mood in neutral condition

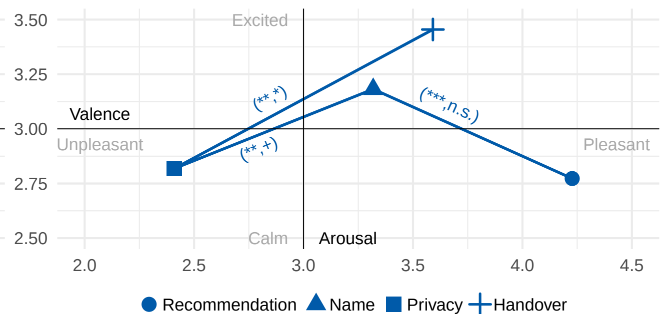


(b) Mood in liability condition

Fig. 3: Differences for the mood in the neutral and liability condition for both scales (valence, arousal), with the markers representing the different interaction scenes during the experiment.



(a) Emotion in neutral condition



(b) Emotion in liability condition

Fig. 4: Differences for the emotions in the neutral and liability condition for both scales (valence, arousal), with the markers representing the different emotional triggers during interaction.

that physically interacting with the robot was more pleasant for our participants than being confronted with data privacy issues. However, a failed interaction reduces the pleasantness. Interestingly the failing interaction has a minor influence on the *Post-Experiment* affect, since the valence in the *liability* condition significantly recovers to a comparable value as in the *neutral* condition.

Comparable results can be observed when looking at the trigger events in the emotional states Fig. 4. At the *Handover* trigger, as for the mood values, the valence value in both conditions significantly increases but not to the same extent and with a significant increase in arousal in the *liability* condition.

We apply the difference-in-difference technique to investigate whether changes in human affect can be explained by the effect constructed by the failing compared to the successful mold remover handover (reference condition). The effect δ comparing the changes in mood and emotional outcomes over the interaction time is listed in Table IV. It shows that only the changes caused by the manipulated handover significantly differ among the conditions. Regarding mood, the differences in valence change between *Account* $\rightarrow$ *Mold* and *Mold* $\rightarrow$ *Post-Experiment* are significant, giving evidence that the failing interaction has a negative effect on the participant's valence (unpleasant) during the interaction. Nevertheless, physical interaction is more enjoyed than disclosing personal information and getting confronted with privacy issues (*Account*). Regarding the emotions, the significant change in valence and arousal between the triggers *Privacy* $\rightarrow$ *Handover* shows that the failing interaction arouses the participants more and again that the increase in valence (pleasant) is restrained.

TABLE IV: Impact of liability condition on human affect

Mood - Scene Change	$\delta_{valence}$	$\delta_{arousal}$
Pre-Experiment $\rightarrow$ Consultation	-0.4545	0.2045
Consultation $\rightarrow$ Account	0.0455	0.1136
Account $\rightarrow$ Mold	0.7273^{*}	-0.4773^{+}
Mold $\rightarrow$ Post-Experiment	-0.5909^{*}	0.1591
Emotion - Trigger Change		
Recommendation $\rightarrow$ Name	-0.1364	0.0909
Name $\rightarrow$ Privacy	0.2727	0.2273
Privacy $\rightarrow$ Handover	1.0^{*}	-1.0^{*}

In Fig. 5, we see the averaged GSR signals with a confidence interval of 95% for both conditions across all participants during the handover. All GSR signals were axis-shifted to start at $0\mu S$ for comparison. Before the handover started (see Fig. 5, $\overline{t_{L0}}$ and $\overline{t_{N0}}$ for the mean handover starting time in *liability* and *neutral* respectively), the robot moved to grab the mold remover bottle. During this period, the mean GSR signals of both conditions are similar. While in the neutral condition, the handover was successfully

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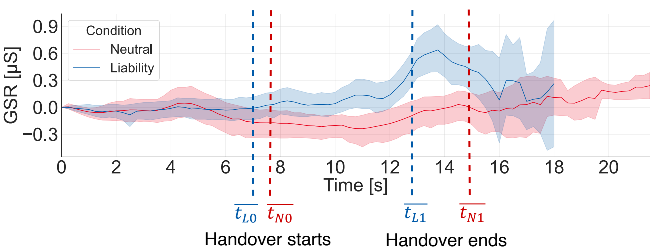

Fig. 5: Mean Galvanic Skin Response (GSR) signals over all participants during the *Mold* scene.

completed ($\overline{t_{N1}}$) in the liability condition, the bottle fell before "Handover ends" ($\overline{t_{L1}}$) was reached. This emotional trigger of the failed handover increases the GSR signal for the participants in *liability*, which can be interpreted as an increase in their arousal (excitement) [25]. This finding supports our observation in Fig. 4b, which displays the participants increased arousal state they reported via the SAM questionnaire.

V. Discussion and Limitations

A. Discussion

Since it was not likely that the participants, in their role as the customer, would see too much blame in their own behavior, and it is difficult to see actual responsibility with the robot, we assumed that the participants perceived the store as the most responsible party. The questionnaire results confirmed this assumption and showed, thereby, that the store is the party that should be responsible. The significantly higher responsibility of the robot compared to the store in the *liability* condition is likely attributed to the failing handover. These participants experienced an incident through the robot, which can also be found in their measured emotion (see Section IV-C). Thus, their evaluation and decision-making regarding responsibility are biased, as emotions can influence those [27]. In comparison, the participants in the *neutral* condition only imagined this incident. Since the robot is probably just perceived as an executing entity, the store might be the only considered party besides the customers themselves. Nevertheless, it should be transparent to which extent the robot was involved in the incident and whether it was intentional for the interaction. This implies that a technical mechanism (e.g., a logging system) is advisable to clarify the liability between the store and the robot.

From a legal perspective, a central argument in favor of clear liability standards is that clear regulations create trust in new technologies [10]. In the view of most "customers" the store is liable. Therefore, one can assume that it is sufficient for the customers to be comprehensibly informed that there is no unreasonable liability risk for them. Thus, from the customers' point of view, it is sufficient to prove the liability between all other parties and themselves. Further, misunderstandings during the HRI should be avoided by a high level of implemented robot behavior transparency.

The results show a generally positive attitude regarding the application of service robots in our scenario (see Table III) that was not significantly influenced by the condition. This can be explained through the assumption that it is only important for the customers that they are not liable. Therefore, a shift of liability from the store to the robot could be deemed irrelevant to the customers. Thus, as long as the customers are not liable, they support the utilization and application of service robots (see Section IV). Consequently, the applicability of robots lies in the implementation of the AI Act, which can hinder and drawback technological innovation (see Section II). The results show that deploying robots instead of employing human service personal should not affect the store's liability. This result contrasts the unclear liability of and for robots and the generally not concurrent liability laws for humans and robots. Thus, it seems advisable that the new regulations, compared to the liability for human employees, do not entail any disadvantages for stores using robots. This means that the economic advantages of using robots may also be accompanied by a corresponding risk, but this risk must not be so great that it discourages the use.

B. Limitations

Participants. Caused by our advertisement (email to the Technical University of Darmstadt's employees and students) and the small number of participants per manipulation, an imbalance in sociodemographic characteristics, technical affinity, and experience with robots can be observed. Thus, we controlled our statistical results by considering the participant's age to receive generalizable results, as age correlated to the other demographic data.

Questionnaires. The questionnaires regarding liability (see Tab. I) were self-developed. The considered parties (e.g., robot, customer, DIY Store) were generalized to simplify the questionnaire because a detailed explanation of the concepts of manufacturer liability holds the danger of overwhelming or manipulating the participants. For example, the "party" robot does not distinguish between the provider of certain parts (e.g., software), the manufacturer, the seller, or the robot itself. However, this generalizes our results, as we cannot distinguish between particular parties covered by these terms. In future work, a short explanation or clarification could be helpful to interpret the results in a more detailed manner. Many people struggle to correctly rate or name their affective state [28], causing a bias. Thus, GSR sensor data was added, reflecting the participant's affective state.

VI. Conclusion

This work addressed the challenge of establishing a fitting, trustful, and acceptable technology liability regulation for frontline service robots. For this, an empirical study was conducted to evaluate the frontline service robot's non-expert user's expectations of responsibility and liability. The results in our DIY retail store environment suggest that the store deploying the robot should be liable if an incident happens. This result implies that from the customers' perspective, liability regulation should focus on the store. Further, we

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examined that even a minor simulated incident affected the participants' emotions and moods, which was measurable through the self-assessment questionnaire and GSR data. Consequently, even small incidents influence the customers' affect and, thus, their perception of liability, well-being, and decision-making, which makes a clear regulation of liability to create trust in new technologies even more important. The results further suggest that the customers support the utilization and application of service robots as long as they are not liable. Hence, the implementation of liability regulations could hinder and drawback technological innovations when not also considering the user's legal perception. At least, it is indicated that the deployment of robots instead of human service employees should not affect the store's liability. Thus, it seems advisable that the new regulations encompass similar liability consequences as for human employees so that it does not entail larger (economic) disadvantages.

From a technical point of view, these results suggest that the deployed robot should provide a high level of transparency to avoid incidents or misunderstandings during the interaction. This also includes providing a logging system to clarify liability, thus, protecting all involved parties equally regarding attributions of blame. Nevertheless, compliance with the data protection regulations is mandatory [10].

Regarding the AI Act, in developing the technologies concerned, attention should be paid as early as possible to the preconditions that are already foreseeable (e.g., transparency and robustness). In this way, costly adjustments can be avoided at a later stage.

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