How do Lonely, Young Adults Perceive Interactive Technologies With Varying Human-Likeness? An Experimental Lab Study

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Abstract

For young adults in particular, it is proposed that interactive technologies can help alleviate loneliness. However, while state loneliness was found to lead to a more positive evaluation of interactive technologies, general loneliness was found to have the opposite effect. Since interactive technologies vary regarding their human-likeness in appearance and behavior, it needs to be investigated how this affects the perception of young adults while considering potential effects of their loneliness. In an experimental lab study with a 2x2 between-subjects design, 101 participants aged 18-35 years interacted either with a social robot or a voice assistant which either displayed a rather human-like or machine-like communication style. General and state loneliness were assessed alongside evaluations of the interactive technology. Overall, the participants appeared to be more comfortable the more their interaction partner looked and talked in a human-like manner. The self-reported state loneliness was very low and appeared to have no influence on evaluations. General loneliness hints towards a trend towards a more negative evaluation of the interactive technology's social attractiveness - a finding that should be further investigated in future studies.

Keywords

human-machine interaction, human-likeness, social robots, voice assistants, loneliness, young adults,

1. Introduction

The intense social isolation and distancing measures that we experienced during the COVID-19 pandemic are anticipated to have negative consequences in terms of increased loneliness [1]. Loneliness is defined as the perceived gap between desired and actual social relationships and associated with mental health issues such as depression and physical health problems [2]. Young adults are particularly susceptible to loneliness, a vulnerability exacerbated by the pandemic, which emphasizes the need to address this issue urgently [3, 1] . Considering that young adults are often tech-savvy and engaged, interactive technologies that offer features akin to a human interaction partner may be used to alleviate acute loneliness and further train social skills to diminish general loneliness. For instance, previous studies explored the potential of using a social robot to aid young adults facing loneliness as a companion or a social skills coach [4, 5, 6] . However, there is evidence suggesting that particularly individuals suffering from severe loneliness perceive social technologies and their effects differently – mostly more negatively (e.g., social robots [5], video call technologies [7], social media [8]). This could be because they do not experience the same level of social need satisfaction by using these technologies as others do [9]. Even worse, using these technologies and not receiving the need satisfaction they are seeking, may even amplify their feelings of loneliness as their social need dissatisfaction becomes more salient. The perception of interactive technologies by lonely young adults is a multifaceted issue that requires a nuanced understanding of how these technologies can do both, alleviate and exacerbate feelings of loneliness. The current study therefore employs an experimental study design to deepen our understanding of what role different types of loneliness (state and general) play in how young adults perceive interactive technologies that vary regarding their human-likeness.

1.1. Perception of Interactive Technologies and Loneliness

Numerous studies show that interactive technologies such as robots, virtual agents, voice assistants, and chatbots trigger social reactions in people as soon as they fulfill a few conditions (interactivity, natural language, fulfilling a social role; [10, 11, 12, 13]). Since interactive technologies are able to take over social roles and are frequently perceived and treated as social interaction partners, they are often proposed to be used to satisfy social needs – particularly for individuals suffering from loneliness [4]. When experiencing a dissatisfying social need state (e.g., "I feel lonely"), individuals are motivated to take action to resolve it (e.g., "I will talk to a friend"; [14]). However, if this action is not able to satisfy the need, the individual is still experiencing the need dissatisfaction and the motivation to take action to resolve it [9]. For instance, young adults often turn to social media platforms as a means of seeking connection and alleviating feelings of isolation. Paradoxically, intensive social media use was found to amplify their sense of loneliness [15, 16]. This two-sided nature of the relationship between technology and loneliness underlines the complexity of its impact on young adults. The question arises what factors determine whether interactive technologies can satisfy social needs of lonely young adults. With this aim in mind, it needs to be further investigated how lonely young adults perceive interactive technologies in general and how this is affected by the appearance and behavior of the technologies. There is extensive research on how artificial entities' appearance and behavior are generally perceived by their human interaction partners (e.g., [17, 18, 19, 20, 21] . In this study, however, the influences of current and general loneliness in young adults are specifically taken into account.

1.1.1. State Loneliness

In situations where social needs are not satisfied and human interaction partners are not available, people may turn to interactive technologies as an alternative strategy. The results of various studies suggest that social robots (e.g., Aibo,

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Paro, Vector) are quite effective in reducing current feelings of loneliness [22]. Also voice assistants can be perceived as companions that may improve social connectedness and alleviate loneliness [23]. Previous research suggest that when feelings of loneliness are activated, individuals tend to anthropomorphize interactive technologies more strongly [24, 25] . For instance, they reported to feel a stronger social presence than other people while interacting with social robots [26]. This could be the case because socially dissatisfied individuals are more sensitive to social cues [27]. Another explanation is that Anthropomorphism helps to fulfill social needs by offering a humanlike interaction with non-human entity [28]. State loneliness further seems to result in a more positive evaluation of a technological interaction partner, for instance regarding its warmth, friendliness, and sociability [25]. We therefore hypothesize:
H1: Individual's state loneliness positively affects an interactive technology's a) perceived sociability, b) perceived competence, and c) overall evaluation. It is assumed that higher human-likeness of interactive technologies leads to more positive effects in social settings. For instance, a robot's more human-like appearance led to a stronger perception of mind [8]. Human-likeness in appearance also increases social conversation chances: participants were observed to speak and respond more to a social robot than a voice assistant. They further reported to feel more interpersonal warmth, to enjoy the conversation more, and to feel less lonely with the social robot than the voice assistant [29]. More human-like behavior – in terms of speaking styles – were also found to result in more positive evaluations of the technological interaction partners, for instance regarding warmth and sociability [30] . Therefore, we hypothesize:
H2: More human-likeness of an interactive technology's a) appearance (social robot vs. voice assistant) and b) behavior (human-like vs. machine-like communication style) leads to less state loneliness.

1.2. General Loneliness

As outlined before, previous research reports a link between state loneliness and anthropomorphizing tendencies. In contrast to state loneliness which describes a temporary, short-term experience of feeling alone that can be relieved once the situational factors causing it are resolved, general or chronic loneliness is defined as a prolonged and persistent state of feeling alone, even when surrounded by others [31]. People with longer lasting loneliness, however, were found to attribute less human traits to an interactive technology (i.e., humble, broadminded, polite), which may discourage them from developing anthropomorphic inferences (e.g., social response, warmth, competence) [32, 33]. In a different study, a robot that was proposed to alleviate loneliness by functioning as companion or as social skill coach was evaluated as less socially attractive the higher the raters' self-reported general loneliness [5]. There have been similar observations by researchers in the context of computer-mediated communication: During the pandemic, people reported to feel even more unsatisfied in terms of social needs after interacting with others using video call technologies [7]. Also social media is frequently found to have more negative effects the more lonely the users report to be [16]. Apparently, longer-lasting general loneliness leads to more negative reactions towards social technologies. Thus, a currently lonely person may be inclined to anthropomorphize interactive technologies and experience a positive impact from interacting with them, but only if their level of loneliness is not on a generally high level. Therefore, we assume that people who are more strongly affected by general loneliness react differently to the interactive technology's human-likeness, resulting in a more negative evaluation compared to people that are less affected by general loneliness:
H3: General loneliness has a negative effect on an interactive technology's a) perceived sociability, b) perceived competence, and c) overall evaluation.
H4: The positive effect of an interactive technology's human-likeness (in behavior and appearance) on their a) perceived sociability, b) perceived competence, and c) overall evaluation is diminished by general loneliness.

2. Method

An experimental lab study with a 2x2 between-subjects design was conducted. The study was approved by the local ethics committee. Supplementary study material (data set, questionnaires, script) can be found online: https://osf.io/nzs5v/.

2.1. Sample

A power analysis (conducted with the software G*Power; .80 power, an effects size of $f^2 = 0.15$, and .05 alpha error probability) recommended a minimum of 55 respondents. In total 105 participated in the study. Two datasets were excluded due to incompletion, one by request of the participant, and one due to a suspicious answering pattern. Of the remaining 101 participants, 37 identified as male and 64 as female. Participants had to be at least 18 years old and no older than 35 years. On average, participants were M = 23.12 (SD = 3.63) years old. With 88.1 %, most participants were students. Accordingly, 70.3 % of participants stated to have a university entrance qualification and 23.8 % to have a university degree. Participants' general enthusiasm for technology was rather high (M = 3.55, SD = 0.56). Of the 50 people in the social robot condition, only ten had personally interacted with a social robot before, 14 had observed someone else interact, and 27 had seen a report about social robots. Of the 51 in the voice assistant condition, 35 had personally interacted with a voice assistant before, 42 had observed someone else interact, and 26 had seen a report about voice assistants.

2.2. Procedure

Following informed consent and reviewing the study materials, participants answered questions about their sociodemographic background and technical affinity on a laptop. The experimenter then introduced either the voice assistant or the social robot and explained the interactive task (Figure 1). A cover story was used claiming that the purpose of the study was to test an interactive technology for everyday personal use and to improve their speech and communication skills. The experimenter pretended to start the interaction program by saying "start interaction program" and left the experiment room, allegedly so that the participants would not feel observed during the interaction. From an adjacent room, the experimenter was able to control the voice assistant's or robot's outputs by using a webcam that was installed in the lab to see and hear the participant

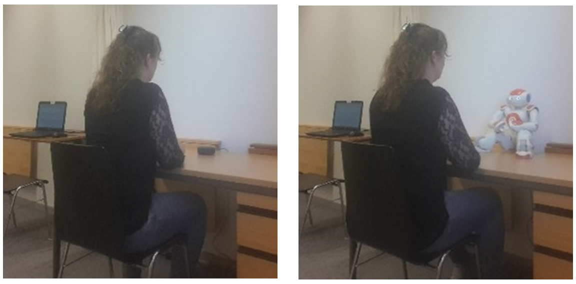

Figure 1: Study Setup With Voice Assistant Alexa (left) or Social Robot Nao (right).

and letting the voice assistant or robot react accordingly (Wizard of Oz design; see [34]). The webcam was justified by explaining that in case of errors the developers could track what went wrong. During the interaction, the voice assistant or robot displayed a rather human-like (expression of emotions and intentions such as "this makes me happy", using terms from humans' everyday life such as "I work...") or machine-like (e.g., more functional, command-based language and phrases attributing to the technical processing such as "your response has been saved and processed") communication style. First, the voice assistant or robot asked the participant to provide background information about themselves, including their name, a brief description of their profession, age, leisure activities, the reason why they are on campus today and anything else they would like to disclose. Next, the robot or voice assistant asked about wishes for the future. Last, the participant was asked about happy, unpleasant, and finally sad experiences. To facilitate self-disclosure via reciprocity [35], the voice assistant or robot always disclosed the desired information about itself first. Three different answers were prepared, depending on whether the test subject answered the question, did not want to answer the question, or could not think of an experience. At the beginning and the end of the interaction, the participant was asked about their current mood. After the interaction, participants were sent back to the laptop for the second part of the questionnaire. They were asked to state their current sense of loneliness, evaluate the interaction and their interaction partner, and answer manipulation checks as well as questions about their person. Finally, participants were debriefed and compensated (either course credits or 5 €). The interaction lasted about 10 minutes and the entire experiment about 45 minutes.

2.3. Measurements

2.3.1. Personal Background

Participants reported their sociodemographic information (age, gender, education, occupation), their previous experiences with robots or voice assistants (frequency of personal or observed contact, reception of reports; 0 = "never"; 1 = "very rarely" to 5 = "very often" [19]), and their technical affinity (TA-EG; [36]; 19 items; e.g., "I enjoy trying an electronic device."; 1 = "does not apply at all" to 5 = "applies completely"; α = 0.76).

2.3.2. Loneliness

Participants' state loneliness was measured with the short scale for measuring loneliness by Hughes et al. ([37]; 3 items; e.g., "I feel left out." with the pre-face "The following questions relate to your feelings of loneliness at the present moment."; 1 = "not at all" to 5 = "completely";α = 0.70; M = 1.66, SD = 0.70). General loneliness was assessed via the short version of the Social Loneliness Scale ([38]; 5 items; e.g., "I do not have any friends who understand me, but I wish I did."; 1 = "strongly disagree" to 7 = "strongly agree"; α= 0.75; M = 2.71, SD = 0.78). 14 data sets had missing values for the social loneliness scale and were excluded from the analyses that involved this measure.

Table 1
Regression Analysis Results With State Loneliness as Predictor

Criterion	b	SE B	β	p	R^2	$F_{(1,99)}$
Sociability	0.14	0.10	.15	.138	.02	2.24
Competence	-0.09	0.09	-.11	.283	.01	1.17
Overall eval.	0.01	0.11	.01	.951	.00	0.00

2.3.3. Interactive Technology Evaluation

The interactive technology's perceived sociability and competence were assessed via adjective pairs that were rated on a 5-point semantical differential ([39, 40] ; sociability: 6 items; e.g., "friendly – hostile";α =0.77; M = 3.33, SD = 0.66; competence: 6 items; e.g., "professional – amateur"; α=0.70; M = 3.26, SD = 0.58). For the overall evaluation, four items from Burgoon and Walther [41] were adapted (e.g., "I was enjoying the interaction with the voice assistant Alexa/the social robot Nao.";α = 0.77; M = 3.20, SD = 0.79).

2.3.4. Manipulation Checks

Participants were asked to rate the external appearance and the communication style of the voice assistant or robot (1 = "more machine-like" to 6 = "more human-like). Two MANOVAS show that the experimental manipulations significantly predicted participants' perceptions regarding the appearance, $F(1, 99) = 33.74, p < .001, \eta_p^2 = .25$, but not regarding the communication style, $F(1, 99) = 0.09, p = .771, \eta_p^2 = .00$.

3. Results

Statistical analyses were conducted with IBM SPSS Statistics 29 and the PROCESS macro v4.3, significance was determined using the standard $p < .05$ criterium.

3.1. State Loneliness (H1-H2)

To investigate H1 (state loneliness positively affects an interactive technology's a) perceived sociability, b) perceived competence, and c) overall evaluation), three linear regression analyses were conducted. State loneliness was always the predictor, the criterion was either the interactive technology's perceived sociability, its perceived competence, or its overall evaluation. The results, presented in Table 1, show that state loneliness had no significant effect on any of the interactive technology's evaluation measures. Consequently, the hypothesis H1 needs to be rejected. For H2 (more human-likeness of an interactive technology's a) appearance and b) behavior leads to less state loneliness), an ANOVA was conducted with type of

Table 2
Regression Analyses With General Loneliness as Predictor

Criterion	b	SE B	β	p	R^2	$F_{(1,85)}$
Sociability	-0.17	0.09	-.21	.057	.04	3.71
Competence	-0.09	0.08	-.12	.261	.02	1.28
Overall eval.	-0.17	0.11	-.16	.128	.03	2.36

Table 3
Moderation Analyses With General Loneliness as Moderator and Type of Technology as Predictor

Criterion	R^2	F(3, 83)	p	ΔR^2	$F_{(1,83)}$	p
Sociability	.07	2.61	.057	.01	0.69	.408
Competence	.03	0.54	.656	.01	0.27	.607
Overall eval.	.06	1.80	.154	.01	0.21	.645

technology (social robot vs. voice assistant) and communication style (human-like vs. machine-like) as factors and the participant's state loneliness as criterion. There was no significant effect found, neither for type of technology, $F(1,97) = 0.18, p = .672, \eta_p^2 = .00$, nor for communication style, $F(1,97) = 0.18, p = .670, \eta_p^2 = .00$. Therefore, the assumptions of H2 are not supported.

3.2. General Loneliness (H3-H4)

To investigate H3 (general loneliness has a negative effect on an interactive technology's a) perceived sociability, b) perceived competence, and c) overall evaluation), three regression analyses were calculated. As can be seen from the results presented in Table 2, no significant effect of general loneliness could be found. It is noteworthy that there is a marginally significant effect on sociability: Higher general loneliness appears to lead to a more negative evaluation of the interactive technology's sociability. Hypothesis H3 is not supported. To test H4 (the positive effect of an interactive technology's human-likeness on their a) perceived sociability, b) perceived competence, and c) overall evaluation is diminished by general loneliness), six moderation analyses with general loneliness as moderator variable were calculated using the PROCESS macro by Hayes [42]. Bootstrapping with 5000 samples and heteroscedasticity consistent standard errors (HC3) were employed. The first three incorporated type of technology as predictor, with either the interactive technology's perceived sociability, its perceived competence, or its overall evaluation as criterions. The analyses did not show that general loneliness moderates the effect between the type of technology and its evaluation significantly (see Table 3 for statistic values). The other three moderation analyses contained the technology's communication style as predictor and the same variables as criterions as the previous three moderation analyses. As the results presented in Table 4 show, general loneliness also does not appear to moderate the effect between the technology's communication style and its evaluation significantly. Consequently, H4 needs to be rejected. Following recommendations by Hayes [42], the interaction term was disregarded to have a look at the main effects instead. Therefore, a MANCOVA was calculated with type of technology and communication style as factors, general loneliness as covariate, and perceived sociability, perceived competence, as well as overall evaluation as criterions. Using Pillai's trace, there was a significant main effect of type of technology, V = 0.00, F(3, 80) = 2.73, p = .049, η_p^2 = .09, as well as communication style, V = 0.15, F(3, 80) = 4.51, p = .006, η_p^2 = .15, when controlling for general loneliness. For type of technology, separate univariate ANOVAs on the outcome variables reveal a marginally significant effect on perceived sociability, F(1, 82) = 3.26, p = .074,η_p^2 = .04, and overall evaluation, F(1, 82) = 3.26, p = .074, η_p^2 = .04, but no significant effect on perceived competence, F(1, 82) = 0.27, p = .608, η_p^2 = .00. For communication style, the separate univariate ANOVAs reveal a significant effect on perceived sociability, F(1, 82) = 12.17, p < .001,η_p^2 = .13, and a marginally significant effect on overall evaluation, F(1, 82) = 3.76, p = .056,η_p^2 = .04, but again no significant effect on perceived competence, F(1, 82) = 0.22, p = .641,η_p^2 = .00. Summing up, the additional analyses regarding the main effects suggest that the more human-like a technology appears and behaves, the more sociable and generally positive it is evaluated (see Table 5).

Table 4
Moderation Analyses With General Loneliness as Moderator and Communication Style as Predictor

Criterion	R^2	F(3, 83)	p	ΔR^2	$F_{(1,83)}$	p
Sociability	.15	5.49	.002	.00	0.10	.759
Competence	.03	0.76	.519	.02	1.13	.290
Overall eval.	.07	1.82	.149	.00	0.30	.583

4. Discussion

The aim of the current study was to deepen our understanding of the roles that state and general loneliness play in how young adults perceive interactive technologies that vary regarding their human-likeness. For this purpose, an experimental lab study with a 2 (robot vs. voice assistant) x 2 (human-like vs. machine-like communication style) between-subjects design was conducted.

4.1. State Loneliness

Against our assumptions, the results suggest that state loneliness has no effect on the interactive technology's perceived sociability, competence, or overall evaluation. However, it needs to be noted that the state loneliness was generally very low indicating a floor effect. Previous studies that found an effect of state loneliness on the perception of interactive technologies employed a setting where state loneliness was intentionally primed [25]. Since we were also interested in whether the differences in human-likeness of an interactive technology's appearance and behavior influences state loneliness, we chose to not influence their state loneliness via a priming task. However, we also did not find any significant effect of the interactive technology's appearance (social robot vs. voice assistant) or behavior (human-like vs. machine-like communication style) on participants' state loneliness. Since state loneliness was low across all groups, we assume that the interaction with the technology itself had a positive effect regarding the currently experienced loneliness. Although previous research found differences in perception in respect to an interactive technology's human-likeness, our results are very much in line with fundamental media psychological research findings. According to the media equation theory, minimal social cues elicit social reactions [13]. If a technology is interactive, uses natural

Table 5
Descriptive Statistics of the Interactive Technology's Perceived Sociability (S), Perceived Competence (C), and Overall Evaluation (OE)

	Voice Assistant		Social Robot		Machine-like		Human-like	
	M	SD	M	SD	M	SD	M	SD
S	3.20	0.64	3.47	0.65	3.11	0.62	3.58	0.61
C	3.27	0.56	3.24	0.61	3.21	0.62	3.30	0.54
OE	3.03	0.72	3.37	0.82	3.05	0.80	3.38	0.75

language, and fulfills a social role, this is sufficient for humans to react to them socially. All three criteria were met in our study by both interactive technologies and in both communication style conditions. Therefore, the interaction in all conditions might have been sufficient to bring all participants' state loneliness to a low level (cf. [5]). However, considering the detrimental long-term effects of chronic loneliness [1, 2], the examination of general loneliness as influencing factor for the perception of interactive technologies is particularly critical.

4.2. General Loneliness

Against our assumptions, the results show no significant effect of general loneliness on the evaluation of an interactive technology. Furthermore, general loneliness was also not found to diminish the positive effect of an interactive technology's human-likeness on how it is evaluated. As the additional analyses reveal, the more human-likeness there is in an interactive technology's appearance and behavior, the more socially attractive and generally positive it is rated. With this results we are in line with previous research that shows that increasing certain aspects of an interactive technology in terms of human-likeness leads to positive effects in how they are perceived (e.g., [8, 30, 29]). However, there was a marginally significant effect with regard to sociability: the higher people's general loneliness, the less socially attractive they rate the interactive technology. Although this finding needs to be interpreted with caution, it is in line with previous research that people with unsatisfied social needs evaluate social technologies (to interact with or through) more negatively [5, 7, 32, 33, 16]. In future research, this phenomenon and the mechanisms behind it need to be further investigated also by focusing specifically on young adults suffering from severe general loneliness.

4.3. Limitations and Future Research

Due to the cross-sectional nature of the study no conclusions regarding causal relationships can be derived. Moreover, all results are based on self-report which can affect the accuracy and reliability of the data. Particularly loneliness is highly stigmatized [43] and might therefore be reported in a biased way. One of the current study's strengths is that it employs a real interaction. Future studies should extend this with several interactions over a longer period and by considering other interactive technologies such as virtual agents or chat bots as well. Since state loneliness was rather low in this study, we recommend to employ techniques to experimentally manipulate state loneliness if the effect of it is of central interest (see [25] for loneliness priming). In our study, we were also interested in investigating the effect of the interactive technologies on individuals' state loneliness. To get a clearer picture of the influence of general loneliness, future studies should consider recruiting two groups – one with high and one with low levels of general loneliness.

5. Conclusion

If a gap between desired and actual social interactions persists over a longer period, profound consequences on physical and mental health are likely [1, 2] . To address the pervasive issue that is largely affecting young adults, it is crucial to understand the nuances of loneliness, for instance concerning the perception of potential technology-based interventions. The findings from our study particularly shed light on the question how loneliness (state and general) influences the perception of human-likeness in interactive technologies that are proposed to alleviate loneliness. Self-reported state loneliness had little effect on the evaluation of an interactive technology. However, state loneliness was generally low in this study, likely because interacting with any kind of interactive technology that fulfills a few social check boxes elicits social reactions in humans. Overall, participants appeared to feel more at ease with an interactive technology the more it appeared and communicated in a human-like manner. Since the results further suggest that general loneliness is linked to a less positive view of an interactive technology's social appeal, the underlying mechanisms causing this effect should be investigated in the future by including young adults who are severely affected by general loneliness and its consequences.

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A. Online Resources

Supplementary material (data set, questionnaires, script) can be accessed via https://osf.io/nzs5v/.