

Germ-Free Robotic Friends: Loneliness during the COVID-19 Pandemic Enhanced the Willingness to Self-Disclose towards Robots – Supplementary Material

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1. Supplementary Material

This supplement contains additional analyses for the data presented in the main article. Specifically, we present distributions of participants within the three conditions (exclusion, inclusion, and control) regarding age, gender, and variables considered as covariates such as positive and negative affect [48], quality of imagination of the conversation, estimated conversation capabilities, robot experiences, technology commitment [49], current loneliness during the start of the COVID-19 pandemic [62], pre-pandemic loneliness [62], and social anxiety [50]. We also report the distribution across conditions regarding the situational loneliness, i.e., the change from pre-pandemic to current loneliness. We refrain from computing the exploratory multivariate analysis of covariance as suggested in the preregistration in order to avoid repeated analyses with the same dependent variables.

In addition to possible covariates we also computed a multivariate analysis of variance with inclusionary status as independent variable and further exploratory variables as dependent variables which are perceived competence of the robot [56-58], the intimacy of proposed conversation topics for a conversation with the robot assessed by two independent raters, the number of proposed conversation topics with the robot, positive anticipation of a conversation with the robot, preferred length of the conversation indicated in minutes and preferred subjective length of the conversation assessed on a 7-point Likert scale. Moreover, we conducted a multivariate analysis of variance with the inclusionary status as independent variable and the three self-disclosure subscales [54] which vary in valence and intimacy as dependent variables.

1.1 Age distribution in the three conditions

We looked at the age distribution in the three conditions (exclusion vs. inclusion vs. control). The distribution of raw responses is given in Table S1. An univariate analysis of variance (ANOVA) revealed no significant differences regarding age in the three conditions, $F(2, 134) = 0.52$, $p = .594$, $\eta_p^2 = .01$.

Table S1. Age in the three conditions.

Condition	N	M	SD
Exclusion	43	30.77	13.79
Inclusion	46	28.46	10.88
Control	48	28.48	11.95

Note. In the inclusion condition one participant did not indicate age.

1.2 Gender distribution in the three conditions

We looked at the gender distribution in the three conditions (exclusion vs. inclusion vs. control). The distribution of raw responses is given in Table S2. A chi-squared test

revealed no significant differences regarding gender in the three conditions, $X^2(4) = 2.07$, $p = .723$.

Table S2. Gender in the three conditions in absolute values.

Condition	N	male	female	Other gender
Exclusion	43	13	30	0
Inclusion	47	13	33	1
Control	48	18	30	0

1.3 Exploratory variables considered as covariates.

We assessed if positive affect, negative affect, current loneliness, pre-pandemic loneliness, situational loneliness, social anxiety, technology commitment, quality of the imagination of a conversation with the robot and a robot's expected technical incapability to have a conversation differ between the conditions. First, we describe the variables which are not already described in the main article. All items are assessed on 7-point Likert scales with an exception of the loneliness measures which uses a 4-point Likert scale. Cronbach's α is indicated for all measures. Descriptive statistics of the exploratory variables are depicted in Table S3.

Positive and Negative Affect. Positive affect ($\alpha = .82$) and negative affect ($\alpha = .83$) were assessed with five items, respectively [48]. Participants were asked to indicate how they felt during the recall task, regarding positive affect, e.g., "active", and negative affect, e.g., "upset" on a scale from 1 not at all to 7 very much.

Technology commitment. Technology commitment ($\alpha = .81$) was assessed with 12 items, e.g., "I like to use the newest technological devices" [49] on a scale from 1 totally disagree to 7 totally agree.

Social anxiety. Trait social anxiety ($\alpha = .82$) was assessed with six items, e.g., "I get embarrassed very easily" [50] on a scale from 1 totally disagree to 7 totally agree.

Imagination quality. The imagination quality of a conversation with the robot NAO ($\alpha = .88$) was assessed with four self-generated items, e.g., "I could clearly imagine the conversation with the robot NAO" on a scale from 1 totally disagree to 7 totally agree.

Conversation incapability. The expected technical conversation incapability of the robot ($\alpha = .75$) was assessed with three self-generated items, e.g., "I think that it is technically not possible for the robot NAO to have a fluent dialogue with me" on a scale from 1 totally disagree to 7 totally agree.

Table S3. Descriptive statistics of the exploratory variables considered as covariates within the three conditions.

Condition	Exclusion	Inclusion	Control
Variable	M (SD)	M (SD)	M (SD)
Positive affect	3.54 (1.11)	4.42 (1.11)	4.55 (1.16)
Negative affect	3.44 (1.16)	1.37 (0.58)	1.98 (1.08)
Current loneliness	2.59 (0.73)	2.57 (0.74)	2.45 (0.76)
Pre-pandemic loneliness	2.12 (0.67)	2.18 (0.79)	2.15 (0.67)
Situational loneliness	0.47 (0.67)	0.40 (0.88)	0.30 (0.75)
Technology commitment	4.97 (0.93)	4.97 (0.89)	4.90 (0.98)
Social anxiety	3.79 (1.31)	3.59 (1.16)	3.47 (1.29)
Imagination quality	3.73 (1.20)	3.77 (1.37)	4.04 (1.29)
Conversation incapability	3.49 (1.50)	3.10 (1.61)	3.01 (1.33)

To test if positive affect, negative affect, current loneliness, pre-pandemic loneliness, changes in loneliness, social anxiety, technology commitment, quality of the imagination of a conversation with the robot and expected technical incapability to have a conversation differ between the conditions, we conducted a MANOVA with these variables as dependent variables and the conditions (exclusion, inclusion, and control) as independent variable. Overall, the inclusionary status (Wilk's $\Lambda = .469$, $F(16, 256) = 7.37$, $p < .001$, $\eta_p^2 = .32$) had an effect on the named dependent variables. Following univariate analyses revealed that only positive affect, $F(2, 135) = 10.54$, $p < .001$, $\eta_p^2 = .14$, and negative affect, $F(2, 135) = 53.14$, $p < .001$, $\eta_p^2 = .44$, differed between the conditions, while all other exploratory variables did not differ significantly, $p > .260$. We computed post-hoc tests for positive and negative affect. Tukey post-hoc tests are reported, when the assumption of homogeneity of variances was met, as determined by Levene's test of homogeneity of variance ($p > .05$). If variances were not homogeneous, Games-Howell post-hoc test was used. Multiple comparisons revealed that positive affect was higher in the inclusion condition ($M = 4.42$, $SD = 1.11$) than in the exclusion condition ($M = 3.54$, $SD = 1.11$, $p = .001$). Furthermore, positive affect was higher in the control condition ($M = 4.55$, $SD = 1.16$) than in the exclusion condition ($M = 3.54$, $SD = 1.11$, $p < .001$). Positive affect was not significantly different in the inclusion condition ($M = 4.42$, $SD = 1.11$) vs. the control condition ($M = 4.55$, $SD = 1.16$, $p = .834$). Multiple comparisons revealed that negative affect was lower in the inclusion condition ($M = 1.37$, $SD = 0.58$) than in the exclusion condition ($M = 3.44$, $SD = 1.16$, $p < .001$). Furthermore, negative affect was lower in the control condition ($M = 1.98$, $SD = 1.08$) than in the exclusion condition ($M = 3.44$, $SD = 1.16$, $p < .001$). Negative affect was significantly lower in the inclusion condition ($M = 1.37$, $SD = 0.58$) vs. the control condition ($M = 1.98$, $SD = 1.08$, $p = .003$).

To check if positive and negative affect as covariates change the main results, we conducted a multivariate analysis of covariance (MANCOVA). This analysis revealed that neither positive affect (Wilk's $\Lambda = .975$, $F(5, 129) = 0.67$, $p = .644$, $\eta_p^2 = .03$) nor negative affect (Wilk's $\Lambda = .960$, $F(5, 129) = 1.07$, $p = .382$, $\eta_p^2 = .04$) had an impact on the main dependent variables (self-disclosure, preferred conversation intimacy, perceived warmth, perceived experience, perceived agency). Furthermore, through including positive and negative affect as covariates, the effect of the conditions on the main dependent variables (self-disclosure, preferred conversation intimacy, perceived warmth, perceived experience, perceived agency) remained non-significant (Wilk's $\Lambda = .937$, $F(10, 258) = 0.85$, $p = .577$, $\eta_p^2 = .03$).

1.4 Additional dependent variables.

MANOVA additional dependent variables. To test if the inclusionary status (exclusion vs. inclusion vs. control) as independent variable affected the perceived competence, the topic intimacy of proposed conversation topics with the robot, the number of named conversation topics, the positive anticipation of a conversation with the robot, preferred conversation length indicated in minutes, and subjective conversation length, we conducted a MANOVA. Descriptive statistics of the additional dependent variables, also reported in the correlational analysis of the associated main article, are depicted in Table S4. There was no overall effect of the inclusionary status on the additional dependent variables, Wilk's $\Lambda = .900$, $F(12, 260) = 1.17$, $p = .308$, $\eta_p^2 = .05$.

Table S4. Descriptive statistics of the additional dependent variables within the three conditions.

Condition	Exclusion	Inclusion	Control
Variable	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
Competence	3.75 (0.91)	3.75 (0.91)	3.43 (1.07)
Topic intimacy	3.07 (1.82)	3.16 (1.69)	2.79 (1.64)
Number of named conversation topics	2.19 (1.10)	1.79 (1.28)	2.04 (1.25)

Anticipation	3.91 (1.54)	3.72 (1.64)	3.69 (1.34)
Objective length of conversation (minutes)	36.51 (38.84)	23.55 (19.36)	32.35 (34.57)
Subjective length of conversation	4.23 (1.43)	3.66 (1.48)	3.81 (1.30)

1.5 Self-disclosure subscales.

To test if the inclusionary status (exclusion vs. inclusion vs. control) affected the willingness to self-disclose on subscale-level, we conducted a MANOVA with the inclusionary status as independent variable and the willingness to self-disclose 1) positive topics low in intimacy, 2) positive topics high in intimacy, and 3) negative topics high in intimacy towards the robot as dependent variables. Descriptive statistics of the self-disclosure subscales are depicted in Table S5. There was no overall effect of the inclusionary status on the self-disclosure subscales, Wilk's $\Lambda = .995$, $F(6, 266) = 0.11$, $p = .995$, $\eta_p^2 = .00$.

Table S5. Descriptive statistics of the self-disclosure subscales within the three conditions.

Condition	Exclusion	Inclusion	Control
Variable	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
Positive self-disclosure low in intimacy	5.49 (1.33)	5.43 (1.43)	5.51 (1.20)
Positive self-disclosure high in intimacy	4.30 (1.58)	4.18 (1.76)	4.28 (1.61)
Negative self-disclosure high in intimacy	3.67 (1.60)	3.65 (1.73)	3.63 (1.69)

Discussion. We could show through the analyses that most variables which might could have an influence on the main dependent variables of the related main article did not differ between the conditions. However, positive affect was lower in the exclusion condition than in both other conditions. It seems that the effect of the social exclusion manipulation did not only affect specific affective states related to social exclusion but did also reduce overall positive affective states. Furthermore, negative affect was the higher in the exclusion condition than in both other conditions, while negative affect was lower in the inclusion condition compared to the control condition. These results are in line with prior research showing an association of social exclusion and higher negative affect combined with reduced positive affect [51]. However, including positive and negative affect as covariates into a MANCOVA with the inclusionary status as independent variable and self-disclosure, preferred conversation intimacy, perceived warmth, perceived experience and perceived agency did not yield divergent results from the MANOVA reported in the associated main article. The inclusionary status had also no effect on the perceived competence, the topic intimacy of proposed conversation topics with the robot, the number of proposed conversation topics to discuss with the robot, the positive anticipation of a conversation with the robot, preferred conversation length indicated in minutes, and subjective conversation length with the robot. Furthermore, the inclusionary status had no impact on the subscales of the self-disclosure scale. Thus, we found no evidence that exclusion vs. inclusion vs. control leads to any attempt to connect with a social robot. In addition, the robot was not perceived as more favourable, e.g., in terms of competence, in the exclusion condition compared to inclusion vs. control condition. These additional results also support the assumption that social exclusion did not result in connection seeking behaviour towards robots. We conclude that a more differentiated view of an unfulfilled need to belong is needed to understand its relationship with connection behaviour

towards robots. Furthermore, the methodological issues discussed in the main article need to be addressed in future research.

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