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**UNIVERSITÉ
DE LORRAINE**

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Connaissances)

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Par
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Sentiment de solitude, agents et robots sociaux : acceptabilité et confiance

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Abstract

Today, about one person in ten suffers from loneliness, a feeling that has multiple consequences on physical and mental health. Social robots are a potential solution to alleviate loneliness and help resocialization, but there are barriers related to acceptance and trust. This thesis explores the concepts of acceptance, acceptability and adoption in order to better understand how it would be possible to bring people suffering from loneliness to use companion robots. The literature shows that if acceptability and acceptance are multifactorial, trust appears more and more in the models as an important factor. Like acceptance, trust is a complex and dynamic phenomenon. Models of trust in human-robot interaction show that trust is based on the competence of the robot but also on its ability to behave in a socially appropriate way. Another type of trust based on the possibility to share information is also put forward (it includes perceived intimacy, perceived security and privacy as well as self-disclosure). All these elements would contribute to a better acceptability and acceptance of companion robots, taking into account elements of human-robot interaction, which is a particular type of interaction (such as anthropomorphism, embodiment or social presence).

This thesis is articulated by four studies exploring how individuals might better accept robots. A first hierarchical top-down thematic study of user feedback (N= 85,629) highlighted the importance of cost, conversational capabilities and limitations, technical issues, and companionship for the acceptance of a companion chatbot. In a second part, it shows that the evolution of a chatbot into an avatar amplifies users' expectations. A second study with 70 participants underlined that voices (human in particular) are important for acceptance and anthropomorphic perception of individuals, more than appearance. A third study with 139 users of 5 different robots and agents (Cozmo and Vector, Replika, Google Home and Amazon Echo speakers, and Roomba vacuum cleaners) was able to link a type of trust based on perceptions of privacy, confidentiality, security, and self-disclosure, called informational trust. This study also highlighted the link between acceptance and perceived privacy, anthropomorphism and trust. A fourth study opens the work on a universal design perspective by measuring the acceptance of a robot with neurotypical and autistic children, and their parents (N = 18), before and after. The work of this thesis concludes with a discussion of the contributions, limitations and perspectives that could be explored to complement this research.

Résumé

Aujourd'hui, environ une personne sur dix souffre de solitude, un sentiment qui a de multiples conséquences sur la santé physique et mentale. Les robots sociaux sont une solution potentielle qui permettrait de pallier à la solitude et aider à la resocialisation, mais des freins liés à l'acceptance et à la confiance existent. La présente thèse explore dans un premier lieu les concepts d'acceptance, d'acceptabilité et d'adoption pour mieux comprendre comment il serait possible d'amener des personnes souffrant de solitude à utiliser des robots compagnons. La littérature montre que si l'acceptabilité et l'acceptance sont multifactorielles, la confiance apparaît de plus en plus dans les modèles comme un facteur important. Tout comme l'acceptance, la confiance est un phénomène complexe et dynamique. Les modèles de la confiance en interaction homme-robot montrent que cette dernière est basée sur la compétence du robot mais aussi sa capacité à se comporter de manière socialement appropriée. Un autre type de confiance basée sur la possibilité de partager des informations est aussi mis en avant (elle comprend l'intimité perçue, la sécurité et la confidentialité perçues ainsi que la divulgation de soi ou *self-disclosure*). Tous ces éléments contribueraient à une meilleure acceptabilité et acceptance des robots compagnons, en prenant en compte des éléments de l'interaction homme-robot qui est un type d'interaction particulière (comme l'anthropomorphisme, l'*embodiment* ou la présence sociale).

Cette thèse est articulée par quatre études qui explorent comment les individus pourraient mieux accepter les robots. Une première étude thématique descendante hiérarchique de commentaires utilisateurs (N= 85 629) a mis en avant l'importance du coût, des capacités et des limitations conversationnelles, des problèmes techniques et sa capacité de compagnonnage pour l'acceptance d'un chatbot compagnon. Dans une deuxième partie, celle-ci montre que l'évolution d'un chatbot en avatar amplifie les attentes des utilisateurs. Une seconde étude auprès de 70 participants a souligné que les voix (humaines en particulier) sont importantes pour l'acceptance et la perception anthropomorphique des individus, plus que l'apparence. Une troisième étude auprès de 139 utilisateurs de 5 robots et agents différents (Cozmo et Vector, Replika, les enceintes Google Home et Amazon Echo, et les aspirateurs Roomba) a pu mettre en lien un type de confiance basé sur la perception de l'intimité, de la confidentialité, de la sécurité et de la divulgation de soi, appelée confiance informationnelle. Cette étude a aussi mis en avant le lien entre acceptance et intimité perçue, anthropomorphisme et confiance. Une quatrième étude ouvre les travaux sur une perspective de design universel avec des travaux mesurant l'acceptance d'un robot auprès d'enfants

neurotypiques et avec autisme, et leurs parents (N = 18), avant et après une interaction avec un robot Pepper. Les travaux de cette thèse se concluent sur une discussion des apports, des limites et des perspectives qu'il serait pertinent d'explorer pour compléter ces recherches.

Table of contents

Acknowledgements	3
Abstract	4
Résumé	5
Table of contents	7
Figures Index.....	10
Tables Index.....	12
Preface.....	14
Introduction.....	15
Context.....	18
1. Prevalence of loneliness around the world	19
2. Who is lonely? Loneliness factors	20
3. The concept of loneliness	22
4. Measuring loneliness	24
5. Consequences of loneliness	25
6. Today's solutions to loneliness	28
7. Robots, agents: What are they?	29
State of the art	32
1. Acceptability in human-machine interaction (HCI)	33
1.1. Elements of definition	33
1.2. Measurements	35
1.3. Models in HCI.....	36
1.3.1. Theory of Reasoned Action (Ajzen & Fishbein, 1975).....	36
1.3.2. Theory of Planned Behavior (Ajzen, 1991)	37
1.3.3. Nielsens' model (1994)	38
1.3.4. The TAM (Technology Acceptance Model) (David et al., 1989)	40
1.3.5. The UTAUT (Venkatesh et al., 2003)	44
1.3.6. The public acceptance of technologies (Gupta et al., 2011; Rogers, 1995)	45
1.4. Models related to HRI	49
1.4.1. Phased framework for long-term user acceptance (de Graaf et al., 2018)	49
1.4.2. The Almere Model (Heerink et al., 2010)	51
1.4.3. Link with User Experience.....	53
1.4.4. Link with Trust.....	55
2. Trust in human-machine and human-robot interaction.....	56
2.1. Elements of definition.....	56
2.2. Trust measurements	58
2.3. Trust models	61
2.3.1. Integrative model of Organizational Trust (Mayer et al., 1995).....	61
2.3.2. Lee & See (2004)	62
2.3.3. Hoff & Bashir (2015)	64
2.3.4. Three-factor model of Trust in Automation (Schaefer et al., 2016) and the three-factor model of human-robot trust (Hancock et al., 2011)	65

2.3.5. A multi-dimensional conception and measure of human-robot trust (Malle & Ullman, 2021)	67
2.3.6. The expanded trust model (Hoffman et al., 2006)	68
2.4. Other components of trust	70
2.4.1. Perceived Security	71
2.4.2. Perceived Privacy	72
2.4.3. Self-disclosure	74
2.4.4. Intimacy	75
3. The human-robot interaction	78
3.1. An interface	78
3.1.1. Human-robot interaction regarding the Media richness theory	78
3.1.2. Human-robot interaction regarding affordance and the CASA paradigm	79
3.2. Anthropomorphism	80
3.2.1. Scales used to measure perceived anthropomorphism	83
3.2.2. The Uncanny Valley theory (Mori, 1970)	84
3.3. Embodiment: agents and robots	85
3.4. Social presence	90
Research process	92
Empirical contribution	98
Study 1	99
1. Objective	99
2. Method	100
2.1. Study overview	100
2.2. Tools and process	100
2.2.1. The studied agent: The Replika chatbot	100
2.2.2. Data retrieval and cleaning	101
2.2.3. Data analysis	101
3. Results	104
3.1. Results overall	104
3.2. Results before the avatar update	106
3.3. Results after the avatar update	109
3.4. Comparison before and after the avatar update	112
4. Discussion	113
4.1. Discussion about overall results	113
4.2. Discussion about the updates' impact	117
4.3. Limitations, conclusion, and perspectives	119
Study 2	122
1. Objective	122
2. Method	123
2.1. Study overview	123
2.2. Participants	125
2.3. Measure scales	125
2.4. Procedure	127
3. Results	128
3.1. Mean differences in the scores	128

3.1.1. By group in the scores	128
3.1.2. By group: Loneliness	129
3.1.3. Conditions and loneliness groups combined	130
3.2. Correlations between factors	132
4. Discussion.....	133
 Study 3	139
1. Objective	139
2. Method	140
2.1. Study overview	140
2.2. Participants.....	145
2.3. Measure scales	145
2.4. Procedure and ethics.....	146
3. Results.....	146
3.1. Participants.....	147
3.2. Effect of the robot types on the scales	148
3.3. Mean differences in the scores	148
3.4. Relationships and correlations between measure scales	149
4. Discussion	151
4.1. Participants.....	151
4.2. Results for robots and agents	151
4.3. The different factors.....	154
 Study 4	157
1. Objective.....	157
2. Method.....	159
2.1. Study overview	159
2.2. Participants.....	160
2.3. Measure scales	160
2.4. Procedure and ethics.....	161
3. Results.....	162
3.1. Summary results	162
3.2. Effect of the interaction with Pepper	162
3.3. Group differences.....	164
4. Discussion	166
 General Discussion	170
1. Synthesis and contributions	171
2. Other contributions	172
3. Ethics relevant to this work	174
4. Limits.....	176
5. Conclusion	179
 References	180
 Appendices	208

Figures Index

Figure 1. Representation of the Theory of Planned Behavior	38
Figure 2. Representation of Nielsens' model	38
Figure 3. Technology Acceptance Model from Davis, Bagozzi & Warshaw	40
Figure 4. Representation of the 3 rd edition of the Technology Acceptance Model (TAM 3) combined with previous versions.....	42
Figure 5. The UTAUT model.....	45
Figure 6. Representation of innovation adopters through time	48
Figure 7. Components of the Integrative model of Organizational Trust	61
Figure 8. The dynamic process of trust	63
Figure 9. Factors related to trust from the work of Hoff & Bashir.....	65
Figure 10. Revised three-factor model of trust in automation.....	66
Figure 11. General model of trust, adapted from Hoffman et al., (2006).....	69
Figure 12. Representation of the Uncanny Valley phenomenon (from Mori et al., 2012).....	84
Figure 13. The Cleverbot chatbot.....	86
Figure 14. The avatar of the chatbot Kuki.....	87
Figure 15. The Amazon Echo.....	87
Figure 16. The Pepper robot	87
Figure 17. Types of agents that users are able to interact with, depending on embodiments and other characteristics	88
Figure 18. The chatbots' first icon and appearance	101
Figure 19. The chatbots' avatar	101
Figure 20. Summary figure of the used method and process	103
Figure 21. Dendogram for the results overall, produced with the Rainette package	105
Figure 22. Dendogram for the results before the avatar update, produced with the Rainette package	108
Figure 23. Dendogram for the results after the avatar update, produced with the Rainette package	110
Figure 24. Representation of the clusters' size changes (by %)	112
Figure 25. Screen capture of the course in video B1 (avatar + human voice).....	124

Figure 26. Acceptance scores in lonely (red) and not lonely (blue) participants in the different conditions (A1, A2, B1 and B2).....	131
Figure 27. Anthropomorphism scores in lonely (red) and not lonely (blue) participants in the different conditions (A1, A2, B1 and B2).....	131
Figure 28. Disturbance scores in lonely (red) and not lonely (blue) participants in the different conditions (A1, A2, B1 and B2).....	132
Figure 29. Roomba© vacuum (model J7).....	141
Figure 30. Amazon Echo© (2nd generation).....	141
Figure 31. A Google Home© assistant.....	141
Figure 32. The Replika chatbot application with its default avatar (2022)	142
Figure 33. The Cozmo© (left) and the Vector© robot (right).....	142
Figure 34. Representation of the participants' countries of residence	147
Figure 35. Graphic representation of the mean scores to the scales for each robot	150
Figure 36. Picture type score from the PST, before (1) and after (2) the session for all children groups.	163
Figure 37. Picture type score from the PST, before (1) and after (2) the session for children with ASD.	163
Figure 38. Attrakdiff dimensions scores before (1) and after (2) the session.	165
Figure 39. Robot acceptance scores from the Almere questionnaire, before (1) and after (2) the session.....	165

Table Index

Table 1. Summary of key risk factors associated with loneliness by age group in the UK in 2006	20
Table 2. Summary of the acceptance reactions in the study of de Graaf et al., (2017)	30
Table 3. Summary of the definitions of acceptability found in the literature	34
Table 4. Definitions of the constructs in the TAM 3	43
Table 5. Determinants influencing public acceptance of technologies.....	46
Table 6. The 13 constructs of the Almere model	51
Table 7. Items within each subscale in the MDMT	68
Table 8. Examples of interaction patterns leading to the development of psychological intimacy	76
Table 9. Summary of the research for the four studies.....	93
Table 10. Description of the clusters resulting from the dendrogram and the reviews for all the results	106
Table 11. Description of the clusters resulting from the dendrogram and the reviews before the update	109
Table 12. Description of the clusters resulting from the dendrogram and the reviews after the update	111
Table 13. Clusters before and after the avatar update	112
Table 14. Gender distribution by age.....	125
Table 15. Mean score and standard deviation for each measured scale in the different conditions .	128
Table 16. MANova decomposition results in the different groups (Kruskal-Wallis)	129
Table 17. Mean score and standard deviation for each measured scale in the different conditions .	129
Table 18. MANova decomposition results in lonely/non-lonely groups (Kruskal-Wallis)	129
Table 19. Mean score and standard deviation for each measured scale in the different conditions, depending on lonely (Lon.) vs. non-lonely (N.Lon) participants	130
Table 20. Summary of the answers to the question “Would you like to have this “teacher” in future courses?”	132
Table 21. Correlations between the studied factors	133
Table 22. Comparison of the communication types (or also the interpretation of communication the user does) and the different purposes of the studied robots and agents.....	143
Table 23. Number of permissions and trackers in each application required for the use of each robot	144

Table 24. Age and gender representation per group	147
Table 25. Means of the scores obtained from the different scales followed by mAnova decomposition results	149
Table 26. Pearsons' correlation values between the different factors studied.....	149
Table 27. Summary table of the different questionnaire scores with means (and standard deviations)	162
Table 28. Comparison of the scores for the PST in children with TD and children with ASD.....	164

Preface

This thesis begins with a preface to better understand its evolution. The theme of this thesis has evolved since its beginnings. In October 2018, the title was "acceptability of assistive technologies for the elderly in loss of autonomy". However, this topic has encountered some limitations. First of all, with the arrival of COVID-19, access to an elderly population (especially those with loss of autonomy) was likely to be severely limited which would have threatened the progress of the thesis. During the exploration of the literature, it became apparent that the theme of loneliness and social isolation (among others), often studied in the elderly population, also actually affects the entire population, which made it relevant to focus on a general population. The theme has also been refined towards robots as a potential assistive technology but taking more into account its social aspect. The theme of trust was also added because it represents an important, heavy concept linked to acceptability. Thus, little by little, the theme was refined and changed permanently at the beginning of 2020.

Introduction

This PhD thesis takes place in the middle of the first half of the 21st century. While technologies and the “tech” community are advancing at a rapid pace, human and social issues are always present. Written during the COVID-19 pandemic, this thesis attempts to bring loneliness to the forefront as it affects and can affect each one of us while having deleterious effects and an impressive comorbidity.

The use of companion robots to alleviate loneliness via companionship or by encouraging individuals to contact other people for example, is considered in this thesis since this is sometimes the reason why some robots or agents are designed (e.g., Fribo, Paro or Replika). But the acceptance of these robots by humans is not acquired yet, and this issue, along with utility and usability, is relevant to ergonomics and psychology.

Thus, this thesis explores the concepts of acceptance, acceptability and adoption in order to better understand how it would be possible to get people suffering from loneliness to use companion robots. The literature shows that if acceptability and acceptance are multifactorial, trust appears more and more in the models as an important factor. Like acceptance, trust is a complex and dynamic phenomenon. Models of trust in human-robot interaction show that trust is based on the competence of the robot but also on its ability to behave in a socially appropriate way. This thesis also highlights another type of trust based on the possibility to share information (it includes perceived intimacy, perceived security and confidentiality, and self-disclosure).

All these elements would contribute to a better acceptability and acceptance of companion robots, taking into account elements of human-robot interaction, which are particular. Thus, the goal of this thesis is to attempt to understand how to make individuals accept companion robots more, especially for lonely people. In attempting to answer this question, this thesis is organized into several parts:

Part 1: Context and State of the art

This document first presents loneliness in an extensive way because it is part of the context, but it also needs to be understood properly, with its impacts or without being cofounded with social isolation. It states also how robots and agents could represent a solution to this issue and how there are still barriers to the acceptance and acceptability of agents and robots.

The State of the Art describes acceptance, acceptability, the associated models, and concepts. In this way, this part brings out the theme of trust as an important factor of acceptance. Components and models of trust are also presented while adding the notion of informational trust. Elements of the human-robot interaction are finally addressed in a third section as they influence the perception of robots and therefore, their acceptance. If relevant, methods used to evaluate the different concepts are presented.

This whole part aims at emphasizing the whole complexity of our problem.

Part 2: Research Process

This part details gives an overview of the thesis' research. After the state of the art, this short part proposes an overview of the proposed studies with the different methods used to answer the research questions. These research questions try to address the limitations of the state of the art. To answer these questions a sequence of studies is proposed to address the limitations of the current literature.

Part 3: Empirical contribution

This section presents the empirical contribution of this thesis which consists in 4 different studies. Each of the studies includes a brief introduction, an explanation of the method, results, and a discussion.

Study 1: User feedback of a companion agent and mediation of anthropomorphic embodiment

This study first consists of an analysis of user reviews that aims to identify the concrete acceptance factors of a companion agent. In a second part, this study proposes to study the impact of the embodiment of the companion agent on these acceptance factors.

This study led to one publication:

Zehnder, E., Dinet, J., & Charpillat, F. (2021, July). Social virtual agents and loneliness: Impact of virtual agent anthropomorphism on users' feedback. In *International Conference on Applied Human Factors and Ergonomics*, (pp. 285-292). Springer, Cham.

Study 2: Effect of anthropomorphism and loneliness on acceptance

The study 2 remotely observes how students evaluate and accept a teaching agent through 4 learning conditions, where the anthropomorphism of an agent is modulated.

The study also explores how social isolation and loneliness can have an impact on the evaluation of the results in the four different conditions.

Study 3: Anthropomorphism' mediation of acceptance and informational trust

This study proposes to explore links between informational trust, acceptance, and perceived anthropomorphism in 5 different companion and personal robots. This study takes into account the more or less invasive character of each of these robots taking into account the personal data and the level of solitude of each participant.

This study led to two publications:

Zehnder, E., Dinet, J., & Charpillet, F. (2022, August). Perception of physical and virtual agents: exploration of factors influencing the acceptance of intrusive domestic agents. In *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)* (pp. 1050-1057). IEEE.

Zehnder, E., Dinet, J., Charpillet, F. (2021, October). Anthropomorphism, privacy and security concerns: preliminary work. In *ERGO'IA 2021*.

Study 4: Towards a universal acceptance: assistant robots' acceptance for children with autism and their parents

The fourth and last study measures the acceptance and anthropomorphism before and after an interaction with a robot for children with and without autistic spectrum disorder and their parents. The goal is to use our thematic focus on a public with disabilities through the perspective of universal design.

This study led to one publication:

Zehnder, E., Jouaiti, M., Charpillet, F. (2022). Evaluating Robot Acceptance in Children with ASD and their Parents. In *14th International Conference on Social Robotics*. (accepted)

Part 4: Discussion

This last chapter is a discussion of the research work. First, a synthesis of the studies is proposed. The contribution of the thesis is then discussed. Limitations and perspectives are presented, and a conclusion ends the document.

This PhD was also funded by the Lorraine Université d'Excellence fellowship and is the fruit of a pluridisciplinary collaboration between robotics (CNRS, Inria, Loria, Team Larsen) and psychology (2LPN, Université de Lorraine).

Context

The worldwide phenomenon of loneliness

«Imagine there is a condition that makes a person prickly, depressed, and self-centered, and is associated with a 26% increase in the odds of premature mortality. Imagine too that around 1 in 3 people in America is affected by this condition, and 1 in 12 is affected severely. The condition is typically reversible, but common-sense solutions are not helpful.

Income, education, gender, and ethnicity are not protective, and the condition is contagious. Moreover, the condition reflects the most fundamental feature of social species—the relationships between an individual and con specific.

There is such a condition—loneliness.» Cacioppo & Cacioppo (2018)

1. The prevalence of loneliness around the world

Loneliness has gained a great interest during the recent years because its prevalence in industrialized and individualistic countries is increasing (Snell, 2017) while representing a mortality factor for the elder population. In 2018 in the UK, loneliness even became the target of a national plan aiming to prevent it in the population.

A few recent and public surveys can give us a first insight into the general prevalence of loneliness. In 2019, a survey by Cigna (an American insurance company) conducted on 20,000 adults using the UCLA loneliness scale reveals that 61% of them feel lonely (a percentage that has increased by 7% since 2018). In 2018, a study of 3005 total individuals from the Kaiser Family Foundation, in partnership with The Economist, found that more than one-fifth of adults in the U.S. (22%) and U.K. (23%) and one in ten adults (9%) in Japan say they often or always feel lonely, feel a lack of companionship, and feel excluded or isolated from others (DiJulio et al., 2018). If loneliness is often seen and as a problem that primarily affects older people, most lonely participants of this study are under 50 years old. In France in 2018, a study conducted on 1010 French people by the BVA Institute for the Astrée association (2018), showed that 66% of those under 35 regularly experience a feeling of loneliness, for 44% of the rest of the population.

Specifically, prevalence rates of loneliness in industrialized countries range from approximately 25% to 50% of people who feel lonely at least some of the time, and 5% to 10% of people who often or always feel lonely (Jylhä, 2004; Savikko et al., 2005; Victor & Bowling, 2012; Victor & Yang, 2012; Yang & Victor, 201).

In 2009 and among older adults over 65 in the United States, based on a single item of the Health and Retirement Study (HRS) was 19.3% (Theeke, 2009), while responses to the HRS three-item loneliness scale (Hughes et al., 2004) indicated that 29% of adults 75 years or older reported feeling lonely at least some of the time (Perissinotto et al., 2012). Another survey with USA respondents using responses from the same three-item loneliness scale found a higher prevalence rate where 27% reported moderate levels of loneliness and 28% reported severe levels of loneliness (Musich et al., 2015). Finally, Cacioppo and Cacioppo report in 2018 that loneliness (frequently or all the time) affects about 5 to 10% of industrialized countries.

2. Who is lonely? Loneliness factors

In order to define risk groups and propose intervention strategies, academic studies have been conducted reporting the prevalence of loneliness depending on socio-demographic factors such as gender, age, and culture.

In 2012, Victor and Yang report key factors associated with loneliness (Table 1) showing that these may vary by age group. Gender, marital status, education level, subjective evaluation of social activities, and the ability to confide in others carry a significant association with the sense of loneliness experienced by individuals from age 30 to over 60.

Risk Factor	Young adults (15 to 29 years old)	Adults (30 to 59 years old)	Seniors (60 and more)
Gender		X	X
Marital Status		X	X
Education		X	X
Subjective assessment of health level	X	X	
Self-reported limitations in daily activities	X	X	
Self-reported depression	X	X	X
Frequency of social contact	X	X	
Evaluation of social activities		X	X
Opportunity to confide/be intimate		X	X

X = statistically significant relationship with severe feelings of loneliness

Table 1. Summary of key risk factors associated with loneliness by age group in the UK in 2006 (Victor & Yang, 2012)

Another recent work on the frequency of loneliness around the world (Barreto et al., 2021) with more than 46 000 participants showed that the younger population was the one reporting more loneliness compared to the middle-aged and the older one. Other studies outlined that loneliness is relevant to all ages (Qualter et al., 2013, 2015).

Men also reported more loneliness than women and people in individualistic countries were also lonelier than those in collectivist countries (Barreto et al., 2021). The study of Beutel et al., (2017) conducted on 15,010 individuals found that 10.5% of the participants reported

some degree of loneliness. Loneliness was more frequent among women, single participants, without children and living alone. Socioeconomic status had a negative correlation with loneliness. Gender differences in loneliness can depend on the age group (Lasgaard et al., 2016). As with other mental health-related issues, males can be less likely to report loneliness when asked directly (that is, using the term 'lonely'; Borys & Perlman.,1985; von Soest et al. 2020). Living alone seems to be a significant determinant of loneliness for both men and women.

However, there is less work in the literature regarding cognitive and psychological factors. As early as 1998, Anderssons' literature review suggests that if the strongest predictors of loneliness are subjective (e.g., being shy). Some individual traits such as low self-esteem, shyness, introversion, self-consciousness, resilience, or optimism have been pointed out (Perlman and Peplau, 1981).

Russell (1996) found that loneliness is associated with measures of the adequacy of the individual's interpersonal relationships (especially social support). Loneliness is also significantly related to trait dimensions as Neuroticism and Introversion-Extroversion. The authors also found dimensions of adjustment or well-being, including depression, life satisfaction, and job-related burnout to be correlated with loneliness. Among the elderly, it was correlated to perceived health status and the number of chronic illnesses.

Recently, constructs such as wisdom for the elders and the sense of mastery for all ages have been negatively associated with loneliness (Ben-Zur, 2018; Morlett Paredes et al., 2021). Other authors (Macia et al., 2021) pointed out that, meaning in life (the capacity of a person to attach value and significance to his or her life, (Steger, 2012), is a major predictive factor for loneliness, compared to socio-demographic factors and lifestyles, which were very little predictive of loneliness. While many socioeconomic, cognitive, and health-related variables are linked to loneliness, the perceptual and subjective aspect of loneliness shows that this important phenomenon is not inevitable and that it can be countered.

During the previous years, loneliness has been the focus of a number of studies to date, reporting on its frequency and related factors. It is a feeling that can concern up to around 50% of the population according to the studies conducted, which is important enough to be considered. Different factors can lead to loneliness, but they may vary depending on the studies, which leads us to believe that everyone can eventually be affected by it.

3. The concept of loneliness

The term loneliness can sometimes be confused with social isolation. Loneliness is defined as a gap between desired and achieved levels of social connectedness (Perlman & Peplau, 1981). In its primary definitions, loneliness is described as *“a state characterized by feelings of distress, depression, dehumanization, and detachment that a person experiences when faced with a gaping void in his or her life due to an unfulfilled social and/or emotional life”* (Murphy, 2006, p. 22). Peplau and Perlman (1981, p.31) define loneliness as *“the unpleasant experience that occurs when a person’s network of social relations is deficient in some important way, either quantitatively or qualitatively”*. The authors add that loneliness is *“the psychological state that results from discrepancies between the desire for relationships and the actual composition of those relationships”*. Young (1982) defines loneliness as *“the perceived absence of satisfying social relationships, accompanied by symptoms of psychological distress that are related to the perceived absence”* (p. 380) while Serrat (1978) defines loneliness *“as a perceived discrepancy between the types of interpersonal relationships that individuals perceive themselves to have and the type of relationships they would like to have”* (p. 274). It is closely related to the perception of unmet intimate and social needs (Perlman, 1982).

Thus, we could be in a crowd and still experience this feeling of being « alone ». As loneliness is strongly subjective, it explains why social situations (marital status, number of connections) in different people or cultures can lead, or not, to different experiences of loneliness (Perlman, 1982; Rokach et al., 2001; Klinenberg, 2016 ; Snell, 2017).

Austin (1989) finally described loneliness as an alienation of the self that is sometimes seen as global, generalized, disagreeable, uncomfortable, and more terrible than anxiety.

Loneliness remains different from aloneness which regards individuals who choose to be alone to improve creativity, concentration, or other skills (Luanaigh & Lawlor, 2008). To understand loneliness even more, it is necessary to contrast it with two important related concepts: social isolation and connectedness.

- **Links with social isolation**

Loneliness is a subjective emotional state of the individual, whereas social isolation is an objective state of deprivation of social contact and content (Bennett, 1980). For Gardiner et al. (2018), it is an objective absence of contacts and interactions between a person and a social network. One of the most used scales to measure social isolation is the Lubben Social Network Scale (Lubben et al., 2006) in which, for example, it is asked questions related to frequency, size, the closeness of contacts of the respondent’s social network. Some questions are related to the perceived level of support the respondent gets from friends and family, but

it remains something quantitative (e.g., “How many relatives/friends do you feel at ease with that you can talk about private matters?”). Social isolation is then an objectively measurable state composed of a lack of meaningful and sustained communications or minimal contacts with family or the wider community.

There are, however, links between loneliness and social isolation. Hoeffler (1987) for example found that the mere perception of social isolation was more predictive of feelings of loneliness than actual isolation. Their impact is also related. Studies that have included both social isolation and loneliness have linked these factors independently to poorer health behaviors and biological risk factors (Pressman et al., 2005 ; Shankar et al., 2011).

On the other hand, socially isolated people often feel lonely (Yildirim & Kocabiyik, 2010) but social isolation and loneliness are often not significantly correlated (Coyle & Dugan, 2012; Perissinotto & Covinsky, 2014). Some people can indeed have minimal social contact and be content with it; others may have frequent social contact but still suffer from loneliness.

- **Links with connectedness**

On a graduated scale, social connectedness could be considered as the opposite phenomenon to loneliness. Lee and Robbins (1998) described connectedness as “the subjective awareness of being in close relation with the social world” (p. 338). Van Bel et al., (2009) defined social connectedness as a short-term experience of relatedness and belonging, depending on quantitative and qualitative social judgements, and relationship salience. Riedl et al. (2013), indicate that social awareness (an understanding of the activities of others, defining one’s own activities (Dourish and Bellotti, 1992)) and social presence (“degree of salience of the other person in a mediated communication and the consequent salience of their interpersonal interactions” (Short et al., 1976, p. 65)), have a direct effect on social connectedness, while ones’ networks’ size has a moderating effect.

Like loneliness, connectedness is rather a subjective phenomenon. It happens when an individual feels like a part of the world and other people while being able to influence it, to take part in it.

An interesting thing is that connectedness has been shown to be one of the major underlying motivating principles behind social behavior (Smith and Mackie, 2000). So, ones’ lack of connectedness could make it more difficult to engage in social behaviors. As already cited in the work of Satıcı et al. (2016), literature on social connectedness shows that contrary

to loneliness, connectedness has some benefits. Feeling connected provokes a higher perceived intimacy, general sense of sharing and group attraction. It increases self-esteem, self-efficacy, subjective well-being, self-reported mental health, and is negatively correlated with anxiety, adjustment difficulties, depression and suicidal ideation.

4. Measuring loneliness

A way of better understanding a concept is to know how it is commonly evaluated.

In 1978, Russell, Peplau and Ferguson elaborated the UCLA Loneliness scale. This is the most known and used scale to measure loneliness. The version 3 is composed of 20 items interrogating individuals about different ways of feeling (e.g. "How often do you feel close to people?"), with a frequency scale (never = 1, rarely = 2, sometimes = 3, always = 4). This questionnaire is mostly based on the perceived social support and the satisfaction of social needs. In a factor analysis, McWhirter (1990) found that loneliness related to "intimate others", "social others" and the "affiliative environments" to be the three main dimensions of the revised-UCLA Loneliness scale. Overall, this version was tested on college students, nurses, elders, and teachers for a total of 1416 participants with Cronbachs' alphas ranging from .89 to .94. Thus, it is a rather reliable scale across different types of populations.

Valtorta et al., (2016) a classification of the scales used for measuring loneliness, but also social isolation and social relationships. For the authors, two main dimension define scales evaluating loneliness. The first dimension revolves around structure and function. The structural aspect of the scales refers to general social networks, the frequency, diversity, density and the reciprocity of a persons' social network. Functional aspect of the scales refers to the qualitative and behavioural characteristics of interactions and exchanges between people (nature of relationships, beneficial functions, receiving and providing social support). This includes emotional help (expressions of love and caring), tangible help (transport), information exchange or companionship.

The second dimension revolves around the level of subjectivity asked from respondents, from the involvement in relationships (e.g. "how many relatives do you see or hear from at least once a month" in the Lubben Social Network Scale), which is considered as objective, to more subjective scales revolving around feelings towards social relationships (e.g. "how often do you feel left out?" in the UCLA Loneliness scale). In between, a lot of scales revolve around the perceived availability of social relationship (e.g. « Do you have someone

who is supportive of your opinions and actions? » in the social isolation scale used in the Japan Public Health Center-based Prospective Study II) or the perceived adequacy of social relationships, which rather refers to the satisfaction with the quality or quantity of their interactions with other people (e.g. « How satisfied are you with the kinds of relationships you have with your family and friends? » In the 11-item Duke Social Support Index).

Thus, loneliness can appear as complex since it is close to concepts like social isolation and social support. But as seen earlier, the latest is correlated with loneliness. Some social support questionnaires include dimensions of structure and function (such as the Duke Social support index), while others, such as the widely used UCLA loneliness scale, are functional and highly subjective. It would be possible to consider that the concept of loneliness encompasses certain levels of subjectivity while excluding the number and frequency of social relationships, the structural aspect that is specific to social isolation.

5. Consequences of loneliness

More than an uncomfortable feeling, the literature has shown that loneliness has deleterious consequences on mental, physical, and physiological health. Human beings have the fundamental need to belong and feel connected (Smith & Mackie, 2000). According to Cacioppo and Cacioppo's evolutionary theory of loneliness (ETL) (Cacioppo and Cacioppo, 2018), the uncomfortable aspect of loneliness is based on the fact that from an evolutionary point of view, because we have evolved as social beings where altruism and support has generally proven to be beneficial for survival in general. Therefore, loneliness acts as a biological warning encouraging humans to repair or replace their social environments.

The first paper to report on the consequences of loneliness dates back to 1937 and was written by Parfitt, who noted that "cardiovascular degeneration and high blood pressure are the commonest physical findings" (Parfitt, 1937, p. 321) in lonely people. Since then, a growing body of literature has highlighted the consequences of loneliness, especially when it is experienced on the long-term and frequently, on a day-to-day basis. In the Evolutionary Theory of Loneliness paper, Cacioppo and Cacioppo (2018) highlight precisely how loneliness could be linked to increased mortality, mentioning that it leads to:

- A decreased sleep quality
- A heightened activation of the HPA axis (a component of the neuroendocrine system regulating physiological functions such as metabolism, digestion, immunity,

energy storage and use and the physiological preparation for responses to a perceived harmful event, attack, or threat to survival)

- An elevated activity in the sympathetic adrenomedullary system (involved in the fight-or-flight response to stressors)
- Altered transcriptome dynamics (not the gene structure but rather the gene functioning)
- A decreased viral immunity
- An increased inflammatory state
- An increased prepotent responding (usual responses to a stimulus are more dominant than novel ones)
- An increased depressive symptomatology

More broadly, a growing literature focuses on the impact of this insidious feeling on:

- Physical health (Holt-Lunstad & Smith, 2016; Holt-Lunstad, Smith, et al., 2015; Luo, et al., 2012),
- Mental health (Cacioppo et al., 2015)
- Brain health (Karelina et al., 2009; Weil et al., 2008; Wilson et al., 2007) even when social isolation, individual social support, age, gender, ethnicity, income, and marital status are controlled in the studies.

Finally, loneliness has been linked to increased chances of premature death by about 26% (Holt-Lunstad et al., 2015; Tabue Tegu et al., 2016).

These health consequences have, by extension, an economic cost which has only been little studied. In UK, loneliness has been estimated to cost 2.5 billion per year to UK employers alone (Jeffrey et al., 2017). Most studies on loneliness focus on the elder population and are done in the UK, making it difficult to evaluate the worldwide impacts (Mihalopoulos et al., 2020).

On a behavioral level, loneliness has some interesting effects which makes it even more difficult to counter. While it may encourage an individual to seek social contact and reconnection, loneliness has been related to an increased egocentrism and hypervigilance for social threats. The evidence was brought by studies using fmri, electrical neuroimaging, eye-tracking and behavioral studies (see Cacioppo and Cacioppo, 2018).

These results from the work of Cacioppo et al., (2015) revealed that the brain differentiated negative social stimuli from negative nonsocial stimuli more quickly in the

solitary brain (280 ms) than in the non-solitary brain (490 ms). This difference was not observed for positive stimuli. Another literature review by Spithoven, Bijttebier and Goossens (2017) shows that loneliness is associated with a negative cognitive bias in all phases of information processing. Specifically, individuals with loneliness appear to have increased attention for threatening social stimuli, have negative and hostile intention attributions, expect rejection, evaluate themselves and others negatively, endorse less approach-oriented and more avoidance-oriented goals, and have low self-efficacy. For Cacioppo and Cacioppo (2018), perceived social isolation indicates that the likelihood of mutual aid or altruism is low, and the likelihood and cost of betrayal is high for the person perceiving themselves as isolated.

Therefore, loneliness also creates a conflicting motivation to avoid others, which increases an individuals' tendency for self-preservation. When there is a low probability (or high uncertainty) that social interactions will result in mutual benefit or altruism, fitness promotes an emphasis on selfishness and, in limited cases, spite.

Loneliness thus activates conflicting motivations:

- one to connect and reach out to others to repair or replace missing links for mutual benefit in the service of long-term self-preservation, but also
- the other one to be vigilant and avoid potential social threats in the service of short-term self-preservation.

Therefore, loneliness not only increases the motivation to care for and approach others, but also automatically triggers the motivation to preserve oneself in the short term with:

- an increased vigilance and avoidance of social threats,
- an increase in responses that reflect concern for one's own interests and well-being, and
- Interrelated behavioral, neural, hormonal, cellular adjustments promoting short-term survival.

The literature has highlighted the many deleterious consequences of feeling lonely. It has important effects on mental and physical health, as well as on life expectancy, especially if experienced over the long term. Moreover, it is a state from which it can be difficult to emerge because loneliness changes our perception of interactions, making them more threatening.

6. Today's solutions to loneliness

Efficient interventions to mitigate loneliness have been summarized in the work of Cacioppo et al. (2015). That kind of **one-on-one interventions** (e.g., befriending; or mentoring, group therapy (e.g., groups of lonely people), and wider community interventions (e.g., community events reaching out to a lonely persons). More specifically, the various interventions consist of:

- **Providing social support** to lonely individuals. But according to the authors, this support has to be reciprocal, mutual to be efficient.
- **Increasing opportunities for social interaction.** However, a large number of contacts does not mean high quality relationships. Even if lonely individuals want to connect, the hypervigilance for social threats induced by loneliness can lead them to be more negative with or withdraw from others.
- Teach lonely people to **master or increase their social skills**. This can be effective for people lacking social skills, but an experimental research by Cacioppo et al. (2006) shows that most adults have at least minimal social skills, but these adults are more likely to call upon these social skills when they feel low rather than high in loneliness.

In recent years, these ways of reducing loneliness have been implemented in technological and robotic tools. One of their advantages is that they are usually available to a user at any time.

Some robots (Aibo (Banks et al., 2007), Paro (Robinson et al., 2013), Vector (Tsiourti et al., 2020; Odekerken et al., 2020)) have proven to be effective to reduce loneliness by providing companionship or emulating more human-human interactions while Chatbots such as Replika on the other hand have shown to provide social support (Ta et al., 2020).

While robots are useful to alleviate loneliness, some virtual agents have also proven effective such as Replika, a chatbot whose appearance made it evolve into a digital agent over the years. Chatbots in general attract users partly because they can provide social, textual interaction (Brandtzaeg et Følstad, 2017).

7. Robots, agents: What are they?

The definition of robots its boundaries can be difficult to define. To date, there is no “official” classification of the many sorts of robots, although one can see names such as “social robots”, “assistance robots”, “humanoid robots”, “service robots”, etc. These informal categorizations are usually based on the principal use and function of the robot (personal assistance, entertainment, service) or its appearance (animal, humanoid, robotic arm...) (De Graaf, 2015; Heerink et al., 2010).

In general, robots constitute *“a particular family of systems, combining mechanics, electronics and computer science (“mechatronics”), which aim to replace human beings for repetitive, tedious, dangerous or even impossible tasks”* (Lonchamp, 2017, p. 8). The etymology of the word “robot” comes from the proto-Slav *robot*, which means “work, task, chore”, suggesting their role is to replace humans in doing tedious chores. In the case of loneliness though, we can expect to have robot assistants or social robots. Naneva et al., (2020) define social robots as: *“a physically embodied artificial agent (i.e., something that has a physical structure that mimics the behaviour, appearance, or movement of a living being—usually a human, but could also be an animal or plant) that:*

(a) has features that enable humans to perceive the agent as a social entity (e.g., eyes);

(b) is capable of interacting with humans via a social interface; and

I can communicate verbal and/or non-verbal information to humans. In short, a social robot is an embodied system that can be perceived as a social entity and is capable of communicating with the user.” (p. 1179). This definition interestingly extends the definition to the human perception of what can eventually be seen as a social entity.

In general, the use of robots by the public is on the rise. According to the International Federation of Robotics, published in “Executive Summary World Robotics 2018 Service Robots” worldwide sales of robots for domestic tasks were estimated at nearly 6.1 million service robots (vacuuming, lawn mowing, window cleaning, etc.) in 2018 and it has been growing ever since. However, during the recent years, a lot of questions have been raised when it comes to the acceptance or acceptability of social robots or social agents in different contexts (healthcare, education, household...). The literature review of Naneva et al., (2020) shows that in recent studies, while people have rather positive general attitudes (in 55% of the studies), 42% of the studies showed that people didn’t accept social robots. People feel rather neutral when it comes to anxiety towards robots and 43% of the studies showed that people don’t

trust social robots. Of course, a lot of factors influenced the studies such as the design of the robot, the culture of the participants, the domain of application of the robot or the type of exposure to robots (no human-robot interaction, direct human-robot interaction, or indirect human-robot interaction), but it still shows that some work needs to be done around the subject of acceptability for social robots.

The study by de Graaf et al., van Dijk (2017) is another example and proposes an original approach that highlights different reasons for abandoning a social robot (Karotz) used over the long term (7 months) by 102 individuals at home in the Netherlands. The authors were able to make a distinction between Resisters (gave up using the robot on the first data collection), Opponents (gave up using the robot after two weeks or one month) and Discontinuers (stopped using the robot after 2 or 6 months).

Reasons of non-use	Resisters (16 participants)	Rejecters (51 participants)	Discontinuers (75 participants)
Disenchantment		37%	11%
End of novelty		2%	11%
Lack of motivation		10%	5%
Needs not satisfied		10%	27%
Reliance on others		2%	2%
Replaced by another tool		10%	27%
Restrictions and problems		29%	16%
No reason given	38%		
Language	38%		
Privacy concerns	12%		
Other reasons	12%		

Tab. 2. Summary of the acceptance reactions in the study of de Graaf et al., (2017)

The main reasons for rejecting the robot are disenchantment (gap between expectations and reality) also restrictions and usability problems. Reasons for discontinuation

are mostly related to the fact that the needs were not met, and that the robot could be replaced by other tools. The two main reasons given by resisters were language barriers (because in the study, the robot could not speak Dutch) and worries towards privacy.

Summary

This part explores how and why, loneliness is a problem that ergonomics and robotics need to address today.

During the previous years, loneliness has been the focus of several studies to date, reporting on its frequency and related factors. It is a subjective feeling concerning up to 50% of the population according to the studies conducted, which is important enough to be considered. Different factors can lead to loneliness, but they may vary depending on the studies, which leads us to believe that everyone can eventually be affected by it.

The literature has highlighted the many deleterious consequences of loneliness. It is also a state from which it can be difficult to emerge because it changes our perception of interactions, making them more threatening.

Social robots appear as a potential solution, but ergonomic issues such as acceptability and acceptance remain.

The concepts of acceptability and acceptance are therefore studied in the next section.

State of the art

1. Acceptability in human-machine interaction

Acceptability is a key concept in the field of ergonomics, in relation to utility and usability (Tricot et al., 2003). They each include requirements that, when met, explain the effective and satisfactory use of a tool. This section will consist of delimiting the different aspects of the notion of acceptability by first attempting to define it through the definitions issued in recent years in the literature, while going through the different models present in human-computer and human-robot interaction.

1.1. Elements of definition

Despite the large body of work on acceptability, few studies begin by clearly defining the meaning of this concept. As stated by Regan et al. (2002, p.10): "While everyone seems to know what acceptability is, and all agree that acceptability is important, there is no consistency across studies as to what "acceptability" is and how to measure it". The meta-analysis by Adell, Varhelyi and Nilsson (2018) summarizes the definitions of acceptability found in the literature into five categories:

- In the first case, the word "accept" is used as a basis for defining acceptance: *"acceptance is the degree to which a law, measure or device is accepted"* (Risser, Almqvist and Ericsson, 1999, p. 36), which is relatively limited.
- In the second case, Nielsens' model (1994) is used to define acceptability. According to his work, acceptability is based on the satisfaction of users' needs and requirements leads to the estimation of the usefulness of the system. Nielsen has been describing usefulness as *"the fundamental question of whether the system is good enough to satisfy all the needs and requirements of users and other potential stakeholders"* (1994, p.24). And if the system is useful, therefore it is acceptable.
- In the third case, acceptance is often related to the sum of all attitudes, which implies that emotional components are added to the more "rational" assessment of the usefulness of the system.
- In the fourth case, acceptability is related to the willingness to use a system. Chismar and Wiley-Patton (2003) state that acceptance is the intention to adopt. This may come from the theoretical knowledge of a technology and its use or on actual experience.

- The fifth category emphasises only on the actual use of the system. Dillon and Morris (1996, p. 5) define acceptance as *“the demonstrated willingness of a group of users to use information technology for the task it is intended to perform”*.

1	2	3	4	5
Using the word “accept”	Satisfying needs and requirements	Sum of attitudes	Willingness to use	Actual use

Tab.3. Summary of the definitions of acceptability found in the literature (Adell, Nilsson et Várhelyi, 2018)

This first analysis tends to show how broad definitions of acceptability can be in the literature while being confused with other terms. In their work, Nadal, Doherty, and Sas (2019) in turn point out that the concepts of acceptability, acceptance, and adoption are often used interchangeably: *« many studies stating that they measure a system’s acceptability (i.e., participants’ perception before use) in reality measure longer term usage, and so acceptance or adoption may be more appropriate terms »* (p.4). These terms are sometimes related to different moments during acceptance or adoption as a process.

In 1995, Rogers indeed proposes the concept of technology adoption as a process starting from the discovery of a new technology, an innovation and leading to its actual adoption. Renaud et al. (2008) rather see adoption as a process that begins with the decision to adopt (select, purchase, or commit to use) and then ends with persistent use. For other authors (Terrade et al., 2009), acceptance can refer to the user’s first interaction with a system in a controlled environment. If the interaction occurs, therefore the system is accepted.

The idea of acceptability as a process joins the statement of Bobillier-Chaumon and Dubois (2009), for whom the whole technological adoption is the process that goes from representations of the technology to its acceptance. They also state that the adoption of a technology can *“disrupt and deregulate the system, forcing the individual either to reposition himself in this new configuration or to dismiss the threat by rejecting the new device”* (p. 362), placing technology adoption into a system with different actors and factors influencing its success or failure. For Shackel (2009), an acceptable system satisfies appropriately the requirements of its users for utility, usability, but also cost. The latter definition adds a certain subjectivity to acceptance criteria.

The use of the term acceptability in the literature is ambiguous and is sometimes confounded. Nevertheless, it seems to be part of a process starting with the knowledge of the existence of a technology and ending with the persistent use of this technology and even identification to it (de Graaf et al., 2018).

1.2. Measurements

Understanding types of measurements for acceptability, acceptance or adoption is a helpful way to understand what revolves around these concepts but also how it is treated in the literature.

Nadal, Doherty and Sas (2019) report in their work that technology acceptance (on the basis of 30 references) is mostly evaluated through customized surveys (42,9%), standardized surveys (31,4%), usage (11,4%) and qualitative feedback (8,6%). While customized surveys are widely used, the authors state that the problem with ad-hoc surveys is that there is no coherence across studies in the assessment of technology acceptability, acceptance, and adoption. There is a lack of standardized tools to assess these concepts that are often interchanged. The advantage of self-reported measures is that they can encompass many aspects and are a cost-effective mean of assessment. However, acceptability, acceptance or adoption are terms that are often interchanged and the tools that assess it are sometimes used loosely. Moreover, acceptance is a process that can evolve over time. Thus, obtaining a quantitative score at a given point in time is not necessarily the best way to assess a more global acceptance, which makes longitudinal studies more robust for this type of measurement.

Online reviews can also be considered as a measurement type of acceptance as they directly give a users' attitude about a product or technology after its use. Online reviews are retrospective and self-reporting (De Bruyn and Lilien, 2008), but also represent a rather "natural" situation where reviews are spontaneous and uncontrolled (Tang and Guo, 2015). They can also represent a high data volume.

Interviews could be considered for acceptance as they are a qualitative self-reported measure. As for online review, interviews provide information on elements of acceptance that are sometimes not mentioned in questionnaires. However, they do not always reflect real and lasting acceptance. This can be a difficult measure to use and implement.

Another measure type for acceptance is the observed behaviour, an « objective » measure, where the user is basically using the technology, especially on the long term. However, it can be difficult to translate actual acceptance or adoption from a behaviour. For example, a user could buy a product and use it on the short term but not on the long term. As for self-reported measures, observational measure could provide more evidence on the long term.

Acceptability, acceptance or adoption are thus mostly evaluated through self-reported measures, after an experiment where a technology is used (Nadal, Doherty and Sas, 2019). It can also be during the use or before (for acceptability, when the concept is properly understood).

1.3. Models in HCI

During the last 50 years, work attempting to predict action behavior has emerged, giving rise to increasingly precise models related to acceptance, and that of technologies in particular. This section explores the most notable theories and models that will help to understand the revolving concepts around acceptability and acceptance.

1.3.1. Theory of Reasoned Action (Ajzen & Fishbein, 1975)

The Theory of Reasoned Action was first introduced by Ajzen and Fishbein in 1975, and then in 1980 (Ajzen & Fishbein, 1980). According to this theory, an individual's attitude towards a situation is based on subjective norms and then forms the behavioral intention, which in turn influences the actual behavior. This theory is presented here since it was the starting point for models of technology acceptance (Davis et al, 1989). It explains an individual's decision making through norms, attitudes, and intentions and then predicts behavior. But some more recent research (Norberg, Horne & Horne, 2007) shows that behavioral intention doesn't always lead to the actual and expected behavior.

Attitude here is defined as attitude towards a behavior, "the individual's attitude toward performing a particular act in a given situation with respect to a given object..." (Ajzen & Fishbein, 1969, p. 402). This attitude is determined by an individuals' subjective expectation of a behavior creating an outcome, including the subjective value assigned to that outcome. Attitudes are shaped by a set of behavioral beliefs (Ajzen, 1985).

The subjective norm refers to an individuals' perception of a specific behavior, influenced by others' judgement. Normative beliefs refer to the perceived social pressure to perform a specific action by an individual, it will influence perceived attitude of other individuals toward the specific behavior.

The Theory of Reasoned Action has been used in theoretical and applied research related to technology and use prediction (Davis, Bagozzi & Warshaw, 1989; Liker & Sindi, 1997; Yousafzai, Foxall & Pallister, 2010; Aleassa, Pearson & McClurg, 2011) but also lead to more theories such as the theory of planned behavior as it had "*limitations in dealing with behaviors over which people have incomplete volitional control*" (p. 181).

1.3.2. Theory of Planned Behavior (Ajzen, 1991)

One of the fundamental claims of the previously described Theory of Reasoned Action is that the model is only fit to predict behavior that is entirely voluntary. Ajzen (1985, 1991) advanced the Theory of Planned Behavior to overcome this constraint. Perceived behavioral control would account for the person's impression of her personal abilities and monetary resources, according to it.

Perceived Behavioural Control is defined as the perception of the difficulty to enact a behavior. It takes into consideration both internal and external, actual or imaginary, challenges and resources. They are the individual's perceptions of the elements that may help or impede the execution of the behavior. Perceived Behavioural Control can emerge from both reasonable and "not-so-realistic" assessments. A high degree of Perceived behavioral control enhances the intention, boosting effort and perseverance and, as a result, influencing behavior via Behavioral Intention.

In this theory, behaviour is a function of the intention, which is the combined expression of attitude, subjective norms, and perceived behavioral control. The relative relevance of these three will differ depending on the contexts.

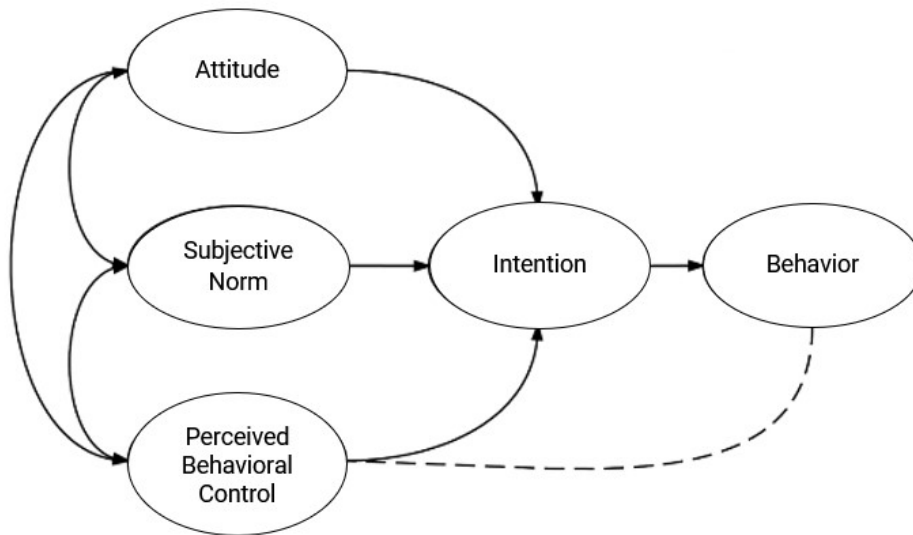


Fig. 1. Representation of the Theory of Planned Behavior

The Theory of Planned Behavior has also been used in theoretical and empirical research, including technology related ones. From the adoption of e-commerce (Grandón, Nasco & Mykytyn, 2011) to the acceptance of social robots (Tay, Jung & Park, 2014). Results generally support the model, with the different factors explaining between 35% and 81% of the behavioral intention.

1.3.3. Niensens' model (1994)

According to Nielsen (1994), acceptability has a practical and social dimension. In this model, a system is acceptable if it is usable and useful.

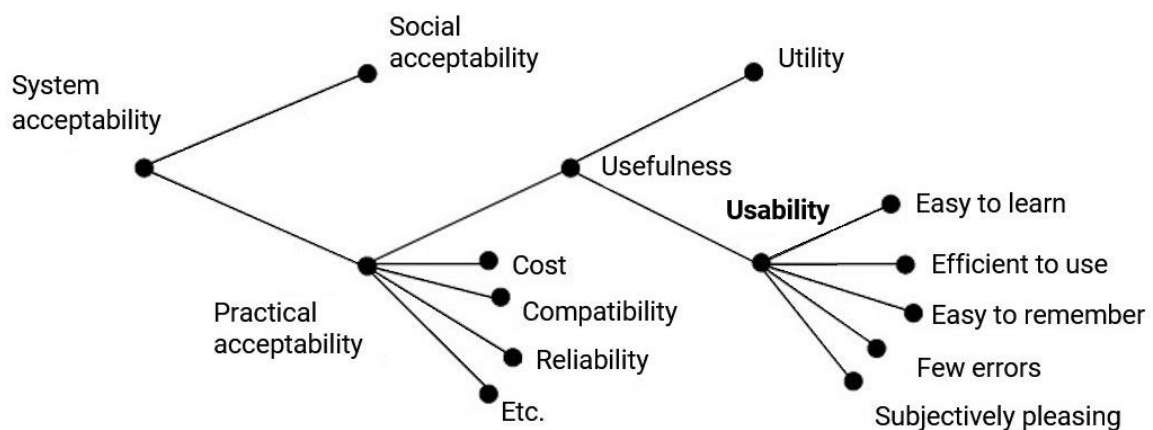


Fig. 2. Representation of Nielsen's model (1994)

Here, the acceptability of a system can be understood as the combination of its social acceptability and its practical acceptability.

Social acceptability refers to the degree to which the system obeys and/or satisfies society's requirements in terms of image, ethics, legality, etc. (Bastien et Tricot, 2008) ("how well is it to be seen owning a robot?"). Practical acceptability, on the other hand, depends on several factors such as cost ("wouldn't a robot be too expensive for the use I would have of it?"), reliability ("what if the robot broke down?"), theoretical usefulness or usability of the system.

Even if we can appreciate the introduction of a subjective evaluation dimension in this acceptability model, the notion of satisfaction raises conceptual problems. Some authors suggest separating the concepts of satisfaction and affect. Others (Westbrook & Oliver, 1991) show a distinction between the two constructs and suggest that satisfaction corresponds to a post-purchase evaluative judgement, based in particular on the affects felt during the use of the system and on the comparison of the level of performance and quality of the latter with the individuals' pre-purchase expectations.

More recently, Lindgaard and Dudek (2003) argue that satisfaction is a construct involving an affective component, another of perceived usability and a component of adequacy of the product with respect to the users' prior expectations. Moreover, Hassenzahls' comments (2004) allow us to refine the differentiation between affects and satisfaction: according to him, affects, as feelings, would constitute perceptions. Satisfaction, on the other hand, refers to a higher-level evaluative judgment, partly constructed on the basis of different types of perceptions (including affective perceptions). The notion of satisfaction, as it is classically defined through the usability approach, raises another problem: it reduces users' feelings to their appreciation of the instrumental qualities of the technology.

User satisfaction, which is one of the dimensions of usability (alongside effectiveness and efficiency), corresponds to the subjective dimension of usability (measured by a scale). In the ISO 9241-11 standard, satisfaction corresponds to the comfort felt during use. Brangier and Barcellina (2003) define satisfaction as "*an affective reaction that concerns the act of using a device and that can be associated with the pleasure that the user receives in exchange for his act*" (p. 50). Satisfaction would be linked to the fact that the user can comfortably, acceptably achieve his goals through the system. It should then be linked to the utility of the system and its qualities leading to user acceptance. Work on user experience, however, emphasizes that other aspects of technology can arouse affective reactions, such as the aesthetic of the

product or its symbolic value (Desmet & Hekkert, 2007; Mahlke, 2008; Hassenzahl, 2004). Some evaluations seem to show that an innovation that does not bring anything in terms of quantitative performance criteria can at the same time bring greater satisfaction to users (see, for example, the studies carried out by Olson and his colleagues on videoconferencing: Olson, Olson & Meader, 1995).

1.3.4. The TAM (Technology Acceptance Model) (David, Bagozzi and Warshaw, 1989)

The TAM is an application of Ajzen & Fishbein's Theory of Reasoned Action (TRA). The TRA itself has evolved into the Theory of Planned Behavior (TPB), and the influence of this variant can be found in several versions of the model. In this current model, acceptability is determined by the intention of use, the adoption of a technology. Two types of perceptions influence users'; attitudes and then intentions to use: the perceived usefulness of the product and its perceived ease of use.

Perceived usefulness is the degree to which a person believes that using a particular system would enhance their performance. Perceived ease of use is the degree to which using a technology will be effortless.

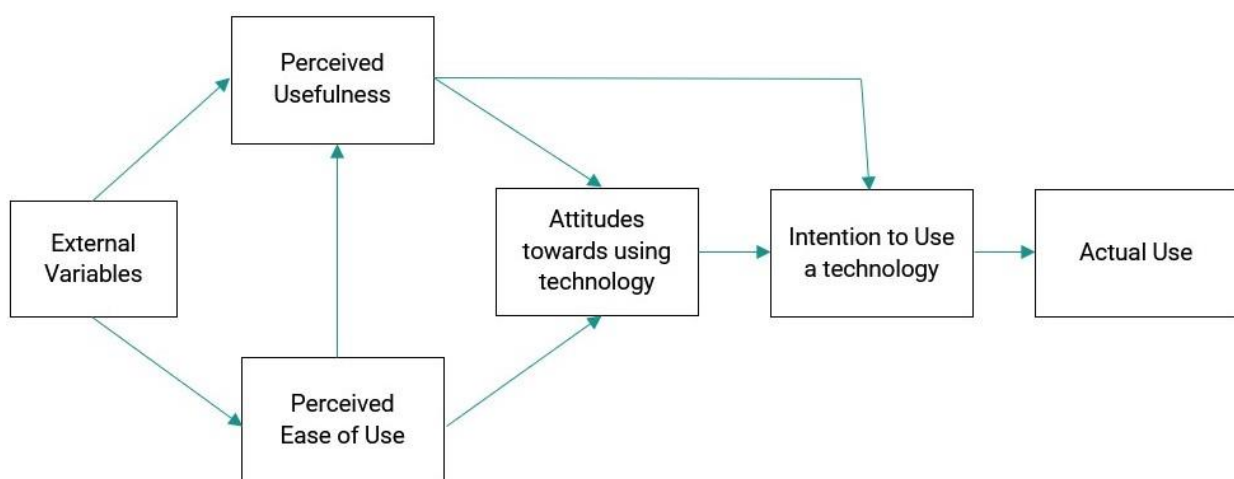


Fig. 3. Technology Acceptance Model from Davis, Bagozzi and Warshaw (1989)

This model has been reworked by authors to result in TAM 1 (Davis, 1989), parsimonious TAM (Davis, Bagozzi & Warshaw, 1989) TAM 2 (Venkatesh & Davis, 2000) and TAM 3 (Venkatesh & Bala, 2008). The technology acceptance model is considered the most influential and commonly applied theory for describing an individual's acceptance of

information systems (Lee, Kozar, & Larsen, 2003). According to Lee and his colleagues (2003), three elements are mostly responsible for this popularity. First, the model is specific to IT and designed to explain and predict acceptance of a wide range of systems among a diverse population of users in various organizational and cultural contexts and at different skill levels. Second, the TAM model has a well-documented and validated theoretical foundation and inventory of psychometric measurement scales, making it operationally attractive for use. Finally, the model has accumulated strong empirical support for its overall explanatory power and has become a major model of user acceptance of technology (Yousafzai, Foxall & Pallister, 2007).

Venkatesh and Davis suggested the TAM 2 in 2000. The TAM 2 adds explanations for the reasons users deem a certain system as beneficial over three moments in time: pre-implementation, one-month post-implementation and three-month post-implementation. This adds the notion of temporality in acceptance and exposes it as a process. Venkatesh and Bala (2008) combined TAM2 (Venkatesh & Davis, 2000) and added the model of the determinants of perceived ease of use (Venkatesh, 2000) to develop the TAM3. The authors developed the TAM3 using the four different types including the individual differences, system characteristics, social influence, and facilitating conditions which are factors of perceived usefulness and perceived ease of use.

Though, Bagozzi (2007) claims that the previous versions were too simplistic and were lacking important variables. The TAM has been deficient when it comes to social processes which consider individual differences regarding cognitive or motivational reasons to use technology. The TAM 3 has mainly been used in IT-related projects but its applicability in robotics has received less investigation (Tossavainen, 2020). A few researchers have emphasized that the TAM should be re-evaluated and tested if it's used in a new context such as robotics (Turner et al., 2010). Nonetheless, the TAM has factors relevant to attitudes toward technology, past experience with technologies, trust, and perceived usefulness which can be used in a robotics context (Venkatesh & Bala, 2008; Savela et al., 2018).

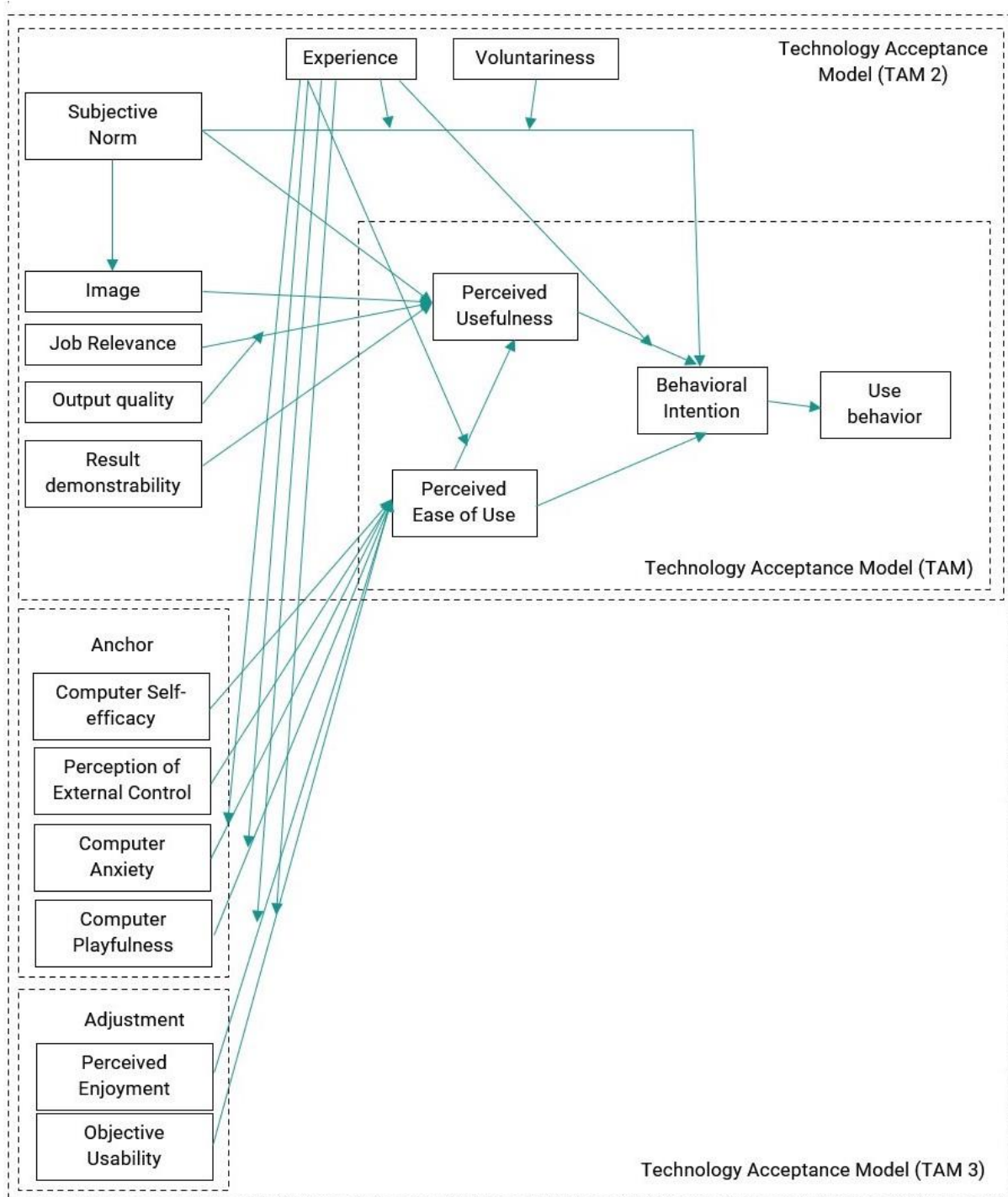


Fig. 4. Representation of the 3rd edition of the Technology Acceptance Model (TAM 3) combined with previous versions (Venkatesh & Bala, 2008)

Determinants		Definitions
Determinants of perceived usefulness	Perceived ease of use	The degree to which a person believes that using an IT will be free of effort
	Subjective Norm	The degree to which an individual perceives that people important to him, think he should (or not) use the system
	Image	The degree to which an individual perceives that use of an innovation will enhance his status in a social system
	Job Relevance	The degree to which an individual believes that the system is applicable to his or her job
	Output Quality	The degree to which an individual believes that the system performs his or her job tasks well
	Result Demonstrability	The degree to which an individual believes that the results of using a system are tangible, observable, and communicable
Determinants of perceived ease of use	Computer Self-Efficacy	The degree to which an individual believes that he or she can perform a specific task/job using the computer
	Perception of External Control	The degree to which an individual believes that organizational and technical resources exist to support the use of the system
	Computer Anxiety	The degree of "an individual's apprehension, or even fear, when she/he is faced with the possibility of using computers"
	Computer Playfulness	The degree of spontaneity through the systems' interactions
	Perceived Enjoyment	The extent to which "the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use"
	Objective Usability	A "comparison of systems based on the « actual » level of effort required to completing specific tasks"
Experience		The experience a user has with the system
Voluntariness		The individual voluntariness to use the system

Tab. 4. Definitions of the constructs in the TAM 3, partially from Venkatesh & Bala (2008)

1.3.5. The UTAUT (Unified Theory of Acceptance and Use of Technology) (Venkatesh et al., 2003)

One of the most widely used models of technology acceptance is the Unified Theory of Technology Acceptance and Use (UTAUT), developed by the same researchers who worked on the TAM modifications (Venkatesh et al., 2003). It is composed of four key constructs that will directly influence behavioral intention:

- Performance Expectancy: The capability of the technology to provide benefits and enhancing the performance to the user according to his or her expectations (Venkatesh et al., 2003, p. 447).
- Social influence: The expected influence on the user to start and continue using the technology, by others (Venkatesh et al., 2003, p. 451).
- Facilitating Conditions: The expected level of technical and organizational infrastructure supporting technology use (Venkatesh et al., 2003, p. 453).
- Effort Expectancy: User expectations about the technology's ease of use (Venkatesh et al., 2003, p. 450).

The UTAUT can explain up to 70 percent of usage intention by adding two additional variables (Social Influence and Facilitating Conditions) and four moderating factors (Gender, Age, Experience and Voluntariness of Use).

While developing the UTAUT model, the authors reviewed and consolidated concepts from eight theoretical models used in previous research to explain information systems use behavior (Theory of Reasoned Action, TAM, Motivational Model, Theory Planned Behavior, the Personal Computer Use Model, Diffusion of Theoretical Innovations and Social Cognitive Theory). This model is based on an empirical approach. UTAUT considers expected performance, expected effort, social influence, and facilitating conditions to be direct determinants of intention to use and actual use. Gender, age, experience, and voluntariness of use are posited to moderate the impact of these four key concepts on intention to use and actual use. Thus, the effects of the independent variables do not extend beyond the users' intention, and the only predictor of actual system use is behavioral intention.

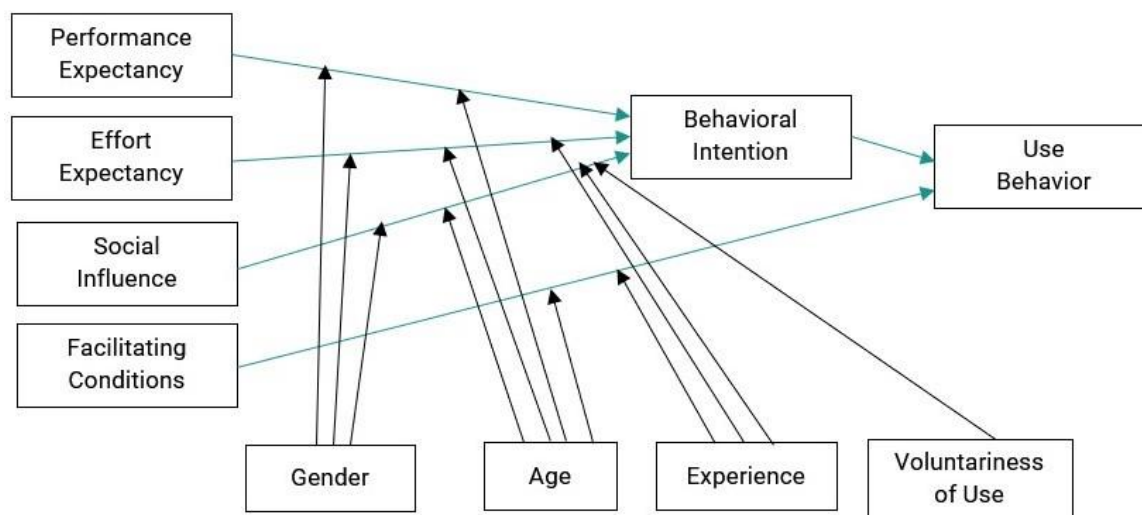


Fig. 5. The UTAUT model (Venkatesh et al., 2003)

One of its strengths is its holistic approach, which addresses a variety of psychological and social factors that influence technology acceptance, as well as the validity and consistency of data collection using this tool. While this model combines strongly correlated variables to produce high explained variance (Yoo et al., 2012), the UTAUT may lack parsimony since it requires numerous variables to obtain a significant degree of explained variance (Straub & Burton-Jones, 2007). The model does not explain underlying mechanisms of users' use intention and general views on it, but rather focuses on explaining users' motivations for continued and increased adoption of a particular technology (Peters, 2011).

The authors also transformed the original model to a second edition (Venkatesh, Thong & Xu, 2012), where the measures of social influence and facilitating conditions aren't very robust. While these concepts are rather complex, they are only measured with only using two items. Furthermore, by incorporating social influence and facilitating conditions into the first model, we end up with a model close to the theory of planned behavior model. The two concepts of social influence and facilitating conditions in UTAUT are similar to the concepts of subjective norm and perceived behavioral control in the Theory of Planned Behavior.

1.3.6. The public acceptance of technologies (Gupta, Fischer & Frewer, 2011; Rogers, 1995)

The work of Gupta, Fischer & Frewer (2011) isn't a main model in human-computer interaction, but it introduces the concept of "public acceptance". Wüstenhagen et al., (2007) will distinguish between public and community acceptance. Public acceptance refers to the

overall acceptance of individuals at the national level, as citizens, who are not likely to be directly affected by the implementation of a policy or technology, whereas community acceptance refers to the specific acceptance of local actors who are likely to mitigate the direct impacts of the implementation of the technology (in this case, in Wüstenhagens' work, an energy technology). While previous acceptances were more on an individual level, this community acceptance is more about the group. Gupta, Fischer, and Frewers' (2011) approach is interesting since it views technology as inextricably linked to the society into which it is introduced. While a technology may change the fate of a society, the fate of that technology is equally dependent on the society. Thus, a negative reaction from society may be caused by the new risks posed by the technology (Gunter and Harris, 1998). Therefore, the implementation of technologies is often influenced by controversies and public concerns (Horst, 2005). The rejection of innovations by the general public has had a negative impact on their commercialization in the past. Unexpected public incidents and tragedies have worked as a signal, causing anxiety and hesitation to accept particular technologies, resulting in consumer rejection of the technologies' products. And if a technology is rejected, it is no longer in an acceptability process.

Overall, this paper consists of a meta-analysis of papers on the acceptance of a variety of technologies that have been the subject of controversy (genetic modification, nuclear energy, pesticides, nanotechnologies, cell phones...). The authors identified 31 "determinants" of the acceptance of these technologies through 184 papers (considered as factors in other works). Of the 31 determinants, 6 determinants represented about 60% of all determinants mentioned in the sample (Tab. 5).

Major determinants	Number of citations
Perceived risk	86
Trust	63
Perceived advantages/benefits	51
Knowledge	50
Individual differences	44
Attitudes	42

Tab.5. Determinants influencing public acceptance of technologies

Thus, this work on public acceptance reminds us of the public and cultural influence on the acceptance of new technologies. Indeed, work has already been done comparing the perceptions and the acceptance of western society and Japan towards robots (Kaplan, 2004; Kitano, 2006; Bröhl et al., 2019) and supports the fact that cultural context has an impact on

human–robot interaction, since individuals interact more easily with a robot if it's part of a cultural norm. While a study (Nomura, Syrdal et Dautenhahn, 2015)) showed that British citizens felt more negative toward humanoid robots than did the Japanese when using the “Frankenstein Syndrome Questionnaire” (FSQ), another one (Bartneck, et al., 2007) found that Japanese participants are more concerned with the impact that robots might have on society than Westerners. A given explanation could be related to their higher exposure to robots, mostly through medias (Bartneck et al., 2007; Bartneck et al., 2005; Haring et al., 2014).

Although it cannot be changed or controlled, society and its cultural context must always be considered when introducing a technology into a society and its market for a better acceptance.

This recalls the work of Rogers who, in 1995, proposed the theory of diffusion of innovation which aims to explain the acceptance and adoption of innovations. His theory summarizes research from 508 studies and explains “the process by which an innovation is communicated through certain channels over time among the members of a social system” (Rogers, 1995, p. 5). It shows how members of a social system communicate about an innovation with different channels through time (diffusion). The theory describes how the adoption of innovation can take place after going through a few stages such as :

- Knowledge, when an individual is aware of the innovation and has an idea of its functionalities
- Persuasion, when an individual develops an attitude that is rather favorable or unfavorable towards the innovation
- Decision, when an individual engages in activities leading to a rejection of an adoption of the innovation
- Implementation, when an individual uses the innovation
- Confirmation, when an individual assesses the results of previous decisions made about the innovation.

The theory is represented with an adoption curve describing innovation adopters over time and its diffusion. Innovators, early adopters, early majority, late majority and laggards (Fig. X).

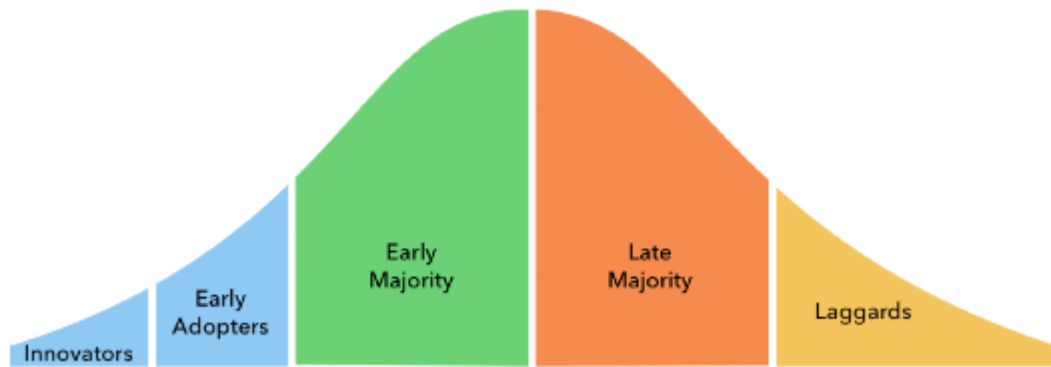


Fig. 6. Representation of innovation adopters through time

Innovators (2,5%) are enthusiastic about the innovation and technology and have a good knowledge of its functionalities and technical abilities. They are motivated by the innovation in itself and require the shortest adoption period.

Early adopters (13,5%) are opinion leaders and play a greater role in socially influencing the majority. They aren't cost sensitive and are motivated by the revolution of industry's' rules.

The Early Majority (34%) also serve as opinion leaders and interact often with peers. They are motivated by the innovation for its benefits but expect those to be reliable and effective. They expect results without having to provide too much training.

The Late Majority (34%) will respond to peer pressure and economic necessity. They are cost sensitive and influenced by laggards. They are usually motivated by the need to keep up with trends or competitors.

Laggards (16%) are isolated from opinion leaders and are skeptical with innovations. They may also show more technology anxiety and will only invest in an innovation if other alternatives are worse in results.

The interest of the theory is that it also points out how decision stages depend on the decisions of other members of a system. The social influence (under the forms of conformity, need for socialization, peer pressure, obedience, leadership, persuasion, sales, marketing) is rather important.

These two examples of models highlight the importance of societal context and social influence (social influence was also already point out in the UTAUT) in the acceptance and adoption process. It reinforces the idea that the process of acceptance and adoption are part of a dynamic system between individuals, technologies, environment, and society.

1.4. Models related to HRI

To best introduce robots and agents as innovations into society, some work has also been done during the recent years to understand the acceptability and acceptance of robots and agents as they are a specific type of technology. This section explores models and theories of robot acceptability and acceptance, but also factors that have helped to better understand acceptance in human-robot interaction.

1.4.1. Phased framework for long-term user acceptance (de Graaf, Ben Allouch & van Dijk, 2018)

The authors introduced a six-phase technology acceptance framework (see below). The novelty of this model is that it proposes to take into account the influence of media (identification phase) in the acceptability of a domestic social robot.

Expectation phase: Individuals learn about a new technology, create expectations about it, and decide whether or not to have it at homes. Individuals figure out what the technology's purpose(s) are and create a mental image of the way it can operate. Utility and enjoyment are deemed as very important at this phase.

Encounter phase: It happens during the initial encounter with the technology, which may involve a shop trial or seeing others use it. Utility is essential, with attitude toward usage having a considerable impact on intention to use the technology.

Adoption phase: the decision to buy a certain technology for the first time. It does not imply that the technology has been embraced and effectively incorporated into a user's' life, but rather that the individual was intrigued enough to purchase it. The expectations of each group differentiate early adopters from the early majority in this era. Early adopters may be content with large behavioral adjustments to adapt to the technology, although most may be more hesitant. At this point, a cycle is created between actual use and habit development, along with usefulness playing a role and attitude toward use influencing intention to use. A crucial factor is enjoyment.

Adaptation phase: it begins after the initial adoption. Users are still having feelings of excitement as well as frustration as they experience new features and encounter learnability flaws. Users familiarize themselves with the technology, identify any issues or concerns, and show the technology to others. As people stay curious about and aware of the presence of the

technology and try to appropriate it, they will determine reaffirmation of their initial adoption or rejection of further use. The adaptation phase consists of exploring the purpose of the technology in a natural environment (at home for example) and trying to adapt its use.

Integration phase: Users may feel a dependency on the technology, have created routines of use, and have integrated the technology in their everyday lives. During this phase, the technology has been changed or modified by the user, and the technology has become meaningful. Users no longer notice the presence of the technology in their homes as long as it does not have their primary attention. If the technology allows users to personalize it, the probability of long-term acceptance increases. However, the technology could be used differently from the way it was intended by designers. The integration phase consists in integrating the technology in daily use routines.

Identification phase: The technology exceeds its functional purpose and becomes a personal object as users get emotionally attached to it. The technology is accepted in users' everyday lives and differentiates users from other people. Technology use and adoption will be mean personal and social identification for users. Personal identification (e.g. personalization) and social identification (e.g. self-expression and developing a sense of community) increase over time. Users will seek reinforcement for the initial adoption and are sensitive to dissonances about the technology. Dissonance can be resolved by altering personal beliefs (attitude toward the technology) or a performed behavior (use of the technology). As familiarity develops, users will also become more willing to ignore a technology's limits. During this phase, users need supportive information preventing dissonance, and users are willing to influence others about the technology. The identification phase consists in finding supportive information approving the use of it.

This model is interesting because it proposes a relatively temporal and global view of acceptance. The authors indeed observed that users may go through the entire 6 phases process during robots' use but some phases can overlap or be iterated. The actual process isn't as linear as the proposed framework. The authors also measured user experience during each acceptance phase, reminding the work of Karapanos et al., (2009). We can indeed find inspirations from Rogers's work (1995) but also from UX models (Karapanos et al., 2009).

Though, this model was only tested with the Karotz robot and participants of the study didn't have to buy the robot to use it, making risk and cost factors may have been inexistent for some participants and are therefore, not included in this model while they are important.

1.4.2. The Almere Model (Heerink et al., 2010)

Almere's model (Heerink et al., 2010) is built on previous acceptability models such as UTAUT by adapting to robotic technology and virtual agents. Four studies were conducted to validate the model. Two were of them used the iCat robot, one with a video of a Robocare robot, and another one had a screen agent. In total, the model was tested on 188 elder participants. This model is based on 13 constructs (Table 6).

Anxiety	Evoking anxious or emotional reactions when it comes to using the system
Attitude towards technology	Positive or negative feelings about the appliance of the technology
Facilitating conditions	Factors in the environment that facilitate use of the system
Intention to Use	The intention to use the system over a long period of time
Perceived adaptiveness	The perceived ability of the system to adapt to the needs of the user
Perceived enjoyment	Feelings of joy/pleasure associated with the use of the system
Perceived ease of use	The degree to which one believes that using the system would be free of effort
Perceived sociability	The perceived ability of the system to perform social behavior
Perceived usefulness	the degree to which a person believes that the system would be assistive
Social influence	The persons perception that people who are important to him think he should (or not) use the system
Social presence	The experience of sensing a social entity when interacting with the system
Trust	The belief that the system performs with personal integrity and reliability
Use	The actual use of the system over a longer period of time

Tab. 6. The 13 constructs of the Almere model

It incorporates a few new constructs to take into account social aspects of the interactions with embodied agents or on-screen characters:

- **Perceived enjoyment:** Here, perceived enjoyment with a computer system influences individuals in their behavioral intentions toward using it. Enjoyment when interacting with an agent may very well influence user acceptance, as pointed out by Van der Heijden (2004). Enjoyment appears to be a relevant construct for acceptance models involving robotics (Chesney, 2006). A previous study by the same authors shows that Perceived Enjoyment will influence Perceived Ease of Use as well as Use intention (Heerink et al., 2008).
- **Social presence:** the feeling of social presence can increase when technology is embodied in a character and interacts using natural language and non-verbal human behaviors. Social presence relates to the feeling of being in the company of a social entity. When interacting with a robot or screen agent, whether or not one feels as though they are interacting with a social being has an impact on how it is regarded and accepted (Bickmore et al., 2005). In the model, sense of presence and perceived enjoyment may increase if a system seems to have more social abilities.
- **Perceived sociability:** Perceived sociability in the model is simply described as how sociable the robot is perceived and doesn't provide more precisions. The items involved in perceived sociability include statements such as « I consider the robot a pleasant conversational partner », « I feel the robot understands me », « I think the robot is nice ». While these items could indeed revolve around sociability, being a pleasant conversational partner could also be seen as being socially intelligent for example. The authors previously found that perceived sociability correlates with all UTAUT constructs, as well as social presence and perceived enjoyment.
- **Trust:** The authors introduced trust in their model through two items based on advice-following statements (e.g. « I would trust the robot if it gave me advice ») while they define trust as performance-related. Trust is claimed to have a direct effect on use intention. In the model, agents with more social abilities will increase user trust.
- **Perceived adaptiveness:** in this model, adaptivity is considered in relation with the evolution of elderly chronic conditions and how robots should and could adapt to these changes. Nonetheless, even in the context of companionship and social robots, it could be expected from agents to adapt to users (Martins et al., 2019). The items proposed are also broad enough to apply to other contexts (e.g., « I think the robot can be adaptive to what I need »). Regarding adaptiveness, an adaptive agent or system will be perceived as more useful which can lead to more acceptance.

More constructs such as anxiety and attitude toward using the technology are added as they are known to influence acceptance (Yang & Yoo, 2004 ; Nomura et al., 2006). If the model was first designed for the elder population, a study from Bishop et al., (2019) showed a good reliability on a younger population ($\alpha = .86$; ages ranging from 18 to 72 years with a mean of 29 years old). The whole model is interesting and was proven to be reliable (Heerink, 2010). Though, it still shows a few weaknesses in the new constructs that are brought. The « social » constructs are often poorly defined yet complex enough to be further explored.

More recently, other acceptance models related to human-robot acceptance have emerged to introduce more constructs. One of them is the PRAM (Persuasive Robots Acceptance Model; Ghazali et al., 2020) which includes psychological reactance, trusting beliefs and behaviors, liking and compliance, but this model wasn't fully validated. Another one is the HRCAM (Human-robot collaboration acceptance model) from Bröhl et al., (2019) which has the peculiarity of evaluating acceptance across countries of different cultures (western culture with Germany and the USA and eastern with Japan and China). In this model, the authors introduced a lot of new constructs such as the technology affinity, the social implications, the legal implications (with occupational safety and data protection), the ethical implications and the perceived safety. This model also distinguishes variables anchor variables influencing acceptance on the long term and adjustment variables, influencing acceptance on a shorter term. While this model offers new interesting acceptance variables, the authors mostly found correlations between variables and acceptance that are already present in the TAM model such as the job relevance for example. On the other hand, the perceived safety was found to be a good predictor of the perceived ease of use and therefore, acceptance.

1.4.3. Link with User Experience

Acceptance models in human-robot interaction slowly started to include user experience through, for example, the concept of perceived enjoyment during its use. User experience indeed refers to: *"A person's perceptions and responses that result from the use and/or anticipated use of a product, system or service"* (ISO 9241- 210). For Alenljung et al., (2017), *« user experience is about people's feelings, as caused and shaped by the use of technology in a particular context, and UX is therefore essential for user acceptance of social robots »* (p. 12).

User experience (UX) is an outcome of the interaction that will depend on the user, the attributes of the technology or system, and the context (Hartson & Pyla, 2012; Hassenzahl & Tractinsky, 2006). Today, UX is an umbrella term encompassing user's emotions, beliefs, preferences, perceptions, and accomplishments. It can « happen » during, and after technology use.

In the model of Hassenzahl (2004) of user experience encompasses a pragmatic and hedonic quality. Pragmatic quality refers to the fact that the technology allows the user to achieve task-related goals in an effective, efficient, and secure way. It relates to the concept of usability: « *the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use* » (ISO 9241-11).

Hedonic quality refers to psychological and emotional needs of the user, which can have great impact on how an interactive product is experienced. Hedonic aspect is sometimes portrayed as the emotional impact that emerges when the user interacts with the system. The technology can, for example, create feelings of autonomy, competence, and relatedness to others. UX can also have a negative impact when there is for example a poor interface design or a perceived lack of functionality. Positive expectations and the excitement when a new technology is launched can shift from amazement to annoyance if the usage of the technology fails since being 'high-tech' is not a causative factor of positive UX. User experience is not a part of the technology but is an outcome of the interaction between the user, including the user's internal state, the quality and attributes of the product, and the context of use. These qualities will then end up in attractiveness, enjoyment and satisfaction for the user. The UX model of Thüning & Mahlke (2007, 2008) provides a systemic view of the human-machine interaction between the context, the system and the user. The model of Karapanos et al., (2009) then gives a time-based view of the user experience with an anticipation, an orientation/familiarity phase, an incorporation/functional dependency phase and an identification/emotional attachment phase.

De Graaf & Allouch (2013) note that more general acceptance model such as the TAM or the UTAUT will provide utilitarian variables but not hedonic variables. Though, hedonic variables are factors allowing users to perceive agents and robots as social. In addition to important factors for user acceptance and experience such as ease of use or adaptability, the study of de Graaf & Allouch (2013) shows that variables such as enjoyment, sociability, companionship, and perceived behavioral control are important evaluating the user acceptance of social robots. Acceptance and user experience are thus intimately linked since

they include factors that overlap in models that are sometimes Close. User experience is also an integral part of the acceptance process (since it occurs at the time of use, for example).

1.4.4. Link with Trust

Through the exploration of these models, a concept began to appear in a recurring way: trust (de Gupta, Fischer and Frewer, Almere model...). A few studies have indeed showed how acceptance was linked to trust as a satisfying predictor of technology use (Li, Hess & Valacich, 2008; Freedy et al., 2007) and a mediator for technology acceptance (Parasuraman & Riley, 1997 ; Muir, 1994), meaning that without trust, robots wouldn't be accepted and used to their full potential. In the PRAM model seen earlier, trusting beliefs were shown to be a factor predicting acceptance where human-robot social interactions are involved.

The study that most clearly linked acceptability and trust in human-robot interaction was the one of Gaudiello et al., (2016). In their study, the authors suggest that trust would be a good indicator of robot functional and social acceptance. Functional acceptance refers to the level of perceived ease of use, usefulness, accuracy and innovativeness. Social acceptance on the other hand will refer to social presence, perceived sociability, social abilities and the social intelligence of the robot. The authors also note that the first human-robot interaction acceptance models tend to mostly assess functional acceptance of robots (Heerink et al., 2009; Weiss et al., 2009) in the same way human-machine acceptance models do (in the TAM or UTAUT). Trust in the robot's functional savvy does not seem to be a prerequisite for trust in its social savvy. The authors cite Salem et al., (2015) who explain that trust is already important in human interactions and could logically increase a robots' acceptance. In social interactions, trust is also linked to persuasiveness and could therefore affect peoples' willingness to cooperate with it.

Summary

In this section, acceptability and acceptance have been explored in their definitions and the models that surround them (such as the UTAUT, the TAM). Only little acceptance models have emerged in human-robot interaction in the last few years. They can lack validity as they are tested in limited conditions. Some of them like the Almere model incorporate "more social" notions such as perceived sociability or trust as human-robot interaction is becoming more and more social. It thus seems like a relevant model to use.

Trust appears to be a recurring factor emerging in acceptance models.

2. Trust in human-machine and human-robot interaction

The concept of trust in human-robot interaction appears as an important criterion of acceptability and acceptance as it is a recurring factor in the different acceptance models (Almere model, work of Gupta et al., (2011)) ...). This observation is confirmed by the work of Gaudiello et al, (2016) where trust is a decisive factor of acceptability. Trust is even more important since it directly affects the willingness of people to accept what a robotic system can provide for them (Freedy, de Visser, Weltman, & Coeyman, 2007). Regarding its role in acceptability and acceptance, this section aims to understand how trust functions in human-robot interaction.

2.1. Elements of definition

Trust was first studied in human-human interaction, in disciplines such as psychology, marketing, political science, economics, artificial intelligence, and more recently neuroscience.

Trust has been defined as an attitude (Lee & See, 2004; Mayer, Davis, & Schoorman, 1995), a personality trait (Rotter, 1980), an expectation (Barber, 1983; Rempel, Holmes, & Zanna, 1985), a behavior (Fehr et al., 2005) and a belief (de Visser & Krueger, 2012).

In human-human interactions, trust is often mentioned as interpersonal trust. Interpersonal trust was first enunciated in reference to close relationships (Larzelere & Huston, 1980). Here, interpersonal trust is based first on the partners' benevolence (« does the partner only has selfish motives or are they genuine and cooperative? ») and the partners' honesty (« How much can I believe what my partner tells me? »). Benevolence and honesty in a partner will then allow an individual to be more intimate and therefore vulnerable. The results of their study show a relationship between interpersonal trust and love, self-disclosure, relationship status.

Through an analysis, Malle & Ullman (2021) found through the work of Burke et al., (2007) that trust is « *a dyadic relation in which one person accepts vulnerability because they expect that the other person's future action will be governed by certain characteristics* » (p. 9), which are ability (or competence), reliability, benevolence, honesty, and integrity. When there is trust between two individuals, initiatives are taken, promises are made and kept, and access is given to information. On the other hand, without trust, or, with distrust, there is generally suspicion, lack of initiative, avoidance, and dissatisfaction.

A level of uncertainty, risk, dependency, and a decision to be made between at least two individuals are required for trust or distrust to emerge (Rousseau, Sitkin, & Burt, 1998; Lee & See, 2004). Individuals may default to their individual risk choice and define their threat policy appropriately if no information about an agent is provided. Also, the notion of hope in trust, is based on an expectation of something good. But hope has a relatively low level of confidence (Bruininks & Malle, 2005) whereas trust carries a high level of confidence.

Mayer, Davis, and Schoorman (1995) define human interpersonal trust as « *the willingness of a party to be vulnerable to the outcomes of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party* » (p. 712). Similarly, Lee and See (2004) suggest, in the context of trust in automation, that uncertainty and vulnerability are also important to the definition of trust such that trust is an « *attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability* » (p. 51). This definition of trust underlines how uncertainty and vulnerability can be important depending on situations and not particularly the trustor or the robot/agent.

Within HRI, Hancock, Billings, and Schaefer (2011) define trust as « *the reliance by an agent that actions prejudicial to their well-being will not be undertaken by influential others* » (p.24) implying that trust can involve other objects beyond sentient organisms that do not express an intrinsic, self-determined intention.

It is only very recently that this type of “social” trust has begun to be studied and seen as relevant regarding the evolution of human-robot interactions (Law & Scheutz, 2021; Malle & Ullman, 2021; Ullman & Malle, 2018 ; Schaefer, 2013).

In her work, Schaefer (2013) resumes a review of 220 definitions for interpersonal trust and 82 definitions for technology-based trust. Interpersonal trust is based especially on expectations, confidence, reliance and vulnerability and technology-based trust is based on expectations, confidence, the relationship between risk and uncertainty. Law and Scheutz (2021) distinguish a performance-based and a relational-based trust. Performance-based trust centers around the robot being trusted to be reliable, capable, and competent at its task or tasks, without being monitored by a human. This type of trust can also depend on the robot's or agent transparency, responsiveness, and predictability. Relation-based trust, on the other hand, implies that a robot is trusted as a social agent. A person interacting with it may become emotionally vulnerable, while trusting that the robot will be sincere and ethical. For the authors, relation-based trust means that the user sees the robot as part of society and expect it to have

some knowledge of social norms. Malle and Ullman (2021), in turn, have established a model of trust, dividing it into a performance and a moral trust. This model will be presented and discussed later.

Among humans on a biological level, there is also oxytocin, often called the « trust hormone», which is a hormone and neurotransmitter that mediates social cognition and pro-social behaviors in humans Kosfeld et al., 2005; Meyer-Lindenberg et al., 2011; Zak, et al., 2004, 2005). Studies have reported the trust-enhancing effect of oxytocin (Kosfeld et al., 2005; Zak et al., 2004, 2005). While its actual role in human trust has been discussed, (Nave et al., 2015), a study (De Visser et al., 2017) showed that administration of exogenous oxytocin increased trust, compliance, liking, perceived humaneness and team decision-making with automated agents.

As for acceptance and acceptability, this part showed that the concept of trust is rather complex and revolves around many components. But despite its complexity, it seems that it has an important social component, even in human-agent interactions.

2.2. Trust measurements

To evaluate the concept of trust and understand it further, measurements have been developed. Trust has been evaluated in a few areas such as inter-personal relationships, organizations, or business. In HRI and HCI experiments, and as for acceptability and acceptance, different types of measurements have emerged, divided into subjective and objective measurements.

Subjective measurements of trust rely on questionnaires and surveys which can be proposed at the beginning, in the middle or at the end of an experiment to measure their trust in an agent or a robot. Participants can consciously self-report their attitudes, cognitive states or emotions related to trust through Likert scales or open questions for example. Participants may, however, deliberately, or subconsciously match their replies to the needs of the experimenters in the research when answering questionnaires. This method is therefore prone to bias.

Individuals' statements of trust attribution towards a robot in a certain context may differ significantly from such people's actual behavioral responses to a robot in risky situations. Four types of scales have been identified by Schaefer (2013) to identify attitudinal trust in human-robot interaction:

- Some evaluate the propensity to trust in individuals to predict the initial level of trust in robots.
- The trustworthiness of the robot can also be evaluated (related to the robot type, personality, intelligence, level of automation and perceived function (Lee et al., 2004)) used to measure the human-robot trust during their first approach.
- Finally, there is affective-trust scales (Burke et al., 2007) the Cognition-based trust scales (Merritt & Ilgen, 2008).

Individuals ascribe greater trust to a robot in lab settings than they would in real-world scenarios with vulnerability and danger (Baker et al., 2018). Other specific trust scales in HRI have been developed and validated the past few years such as the Human-Robot Trust Scale (Schaefer, 2016), the Trust in Automation Scale (Jian et al., 2000) or the Human-Robot interaction trust scale (Yagoda and Gillan, 2012).

The process involved in subjective measures (asking users to self-report their trust) does not always reveal the actual trust towards robot. Objective measures have indeed been found to be little correlated with subjective measures (Hoffman et al., 2005).

Objective measurements don't depend on participants' self-proclaimed attitudes and trust and are based on studying the interaction of humans with robots and agents. The advantage is that they are less prone to errors due to participant bias and fluctuation between expressed and behavioral trust in everyday life settings (Flook et al., 2019).

But this type of measurement requires to operationalize individuals' behavior and to know whether a particular behavior is an actual proof of trust or distrust. As the behavior non-consciously produced, it can be different from the individuals' attitude and cognition (Cannon-Bowers and Bowers, 2011). In non-HRI experiments, actions associated with trust generally are cooperation (Kosfeld, Heinrichs, Zak, Fischbacher, & Fehr, 2005), agreement (Lee & Moray, 1992) and sharing of resources (Molm et al., 2009).

In HRI, there are different types of objective measures commonly used:

- Task Intervention: Usually during this type of task, participants are asked to interact with a robot as it performs a task ordinarily performed by a human. Then, the number of times the human intervenes in the robots' task or the number of times the human participant prevents the robot from executing the task and starts conducting the task themselves is used to assess trust (Pedersen et al., 2018; Chen et al., 2018).

- Task delegation: After one or multiple robots execute a human task during an experiment, the participant must choose among multiple robots, or between a robot and a human to perform a second task (Xie et al., 2019; Rossi et al., 2018).
- Behavioral Change: It consists in observing and measuring participants' behavior when they are interacting with robots. Trust is measured differently based on the nature of the interaction for each different study but it is usually based on how much the participant complies or cooperate with the robot (or not) (Jayaraman et al., 2018; Weigelin et al., 2018). A study from DeSteno et al. (2012), which recorded face-to-face verbal human-robot interactions and found four nonverbal cues (face touching, hands touching, arms crossing and leaning backward) are indicative of untrustworthy behavior in a robot. This method is closely related to advice following during an interaction with the robot during which, the robot will give suggestions or offer advice to the participants. Participant must choose whether they follow the robots' advice. Trust is tested by observing how much or frequently, participants follow the robot's advice, and suggestion (Christensen et al., 2019; Gombolay et al., 2018 ; Gaudiello et al., 2016). They are interesting and objective ways to measure trust, but they don't explain why users trust a robot nor take into account biases such as authority bias linked to the experimental, lab environment. As for task delegation and task intervention, they don't take into account the complexity of trust, which is built over time and involves many factors.
- Psychophysiological signals: this method involves recording human physiological changes with sensors during experiments (where emotions and trust are involved). Today, electro-encephalography (EEG), sometimes associated with other tools, is the most used tool to assess trust (interpersonal and in human-computer interaction), combined with self-reported trust (Ajenaghughure, et al., 2020). Measuring through psychophysiological signals can be objective but is costly to set up (it takes time, adjustments, precise environment conditions that are going to stay the same) and still very often need to be associated with other tools, which makes it not very effective.

Subjective methods are common to evaluate a psychological concept such as trust, but the number of objective measurements shows that trust is also a behavior that can be observed and measured through diverse methods. Most seem to measure trust through compliance and the need for control. Still, the diversity of these methods reflects the complexity of the notion of trust, and it seems that a combination of methods over time could be the most effective way to use these measures.

2.3. Trust models

As for acceptance and acceptability, authors in human-robot and human-machine interaction have published work to attempt understand trust in machines works, attempting to identify factors revolving around it. Thus, this section will present some major models explaining trust in different contexts, including human-robot interaction. This will help us understand how the concept of trust evolved.

2.3.1. Integrative model of Organizational Trust (Mayer et al., 1995)

This model of trust is dedicated to interpersonal trust within organizations. Although it does not apply directly to human-robot interaction, it represents an interesting starting point for understanding trust in companion robots. It was first proposed because trust is a necessary element for collaboration so that organizational actors can, simply, work together. For the authors, trust will depend on characteristics of the trustor (the one who trusts) and the trustee (the one who is trusted). In the model, a set of factors of perceived trustworthiness (ability, benevolence and integrity) are influenced by the trustor's propensity to trust and will influence trust. Ability is the group of skills, traits, and characteristics allowing the trustee to influence the domain. Integrity is the degree to which the trustee adheres to a set of principles the trustor finds acceptable. Benevolence is the extent to which the intents and motivations of the trustee are aligned with those of the trustor.

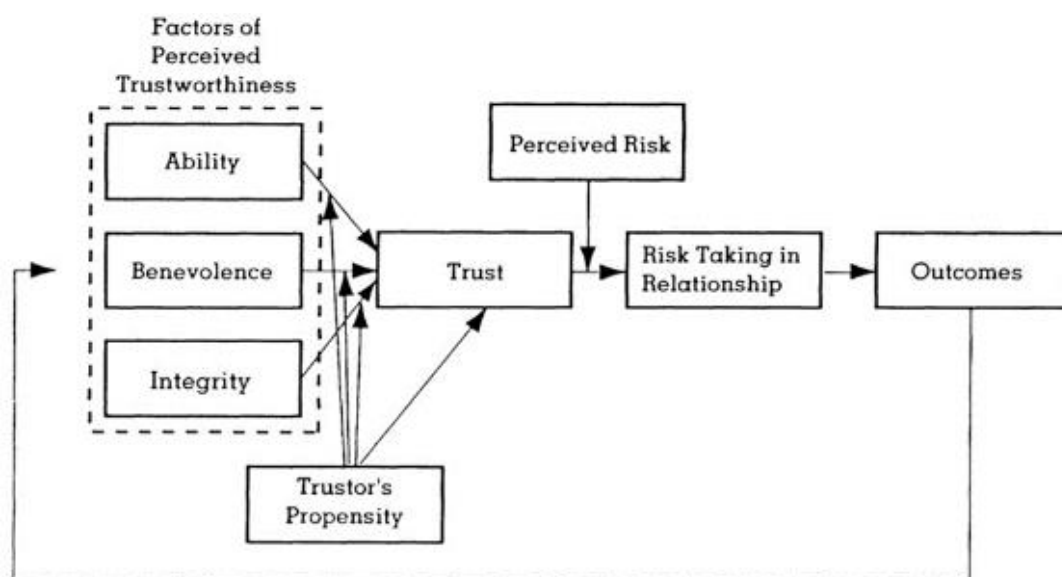


Fig. 7. Components of the Integrative model of Organizational Trust (from Mayer et al., 1995)

Later, the authors reviewed their work (Schoorman, et al., 2007) and discussed the benefits of adding new components such as affect and emotion, trust violations, trust repair or cross-cultural dimensions. They also argued that his model could benefit from being studied in different contexts.

2.3.2. Lee & See (2004)

In 2004, Lee and See proposed a new trust model based on interpersonal trust literature and human-automation interaction studies. Following Mayer et al. (1995) organizational trust model, Lee and See (2004) argued that trust in automation evolves in a dynamic loop depending on the interaction with the automation.

First, information about the automation will lead its display and information assimilation and belief formation. This information revolves around attributional abstraction with purpose, process (the degree to which the algorithms of automation are appropriate for a situation and their clarity) and performance (reliability, predictability, and ability) and the level of detail of the system.

Then in the process, trust will rely on information assimilation and belief formation, determined by reputation of the automation, gossip about it, and its appearance (interface features).

After some experience with the automation, trust in automation becomes more underpinned by the individuals' internal factors such as predisposition to trust or cultural differences.

Then, trust will impact the individuals' intention to use the automation through other individual factors such as self-confidence, the exploratory behaviour, subjective workload, or the required effort to engage with the automation. Finally, external constraints such as time pressures or configuration errors may still prevent an individual from relying on the automations' actions. In between the whole process, the intention to use the automation is also modulated by the appropriateness of the trust in automation.

Appropriateness depends on calibration (how much the operators' trust fits the automation's abilities), resolution (how precisely the operators' trust is able to discriminate different levels of the automation's capabilities), temporal specificity (how often the operators' trust is updated according to the automation's actions), and functional specificity (how much the operators' trust is specific to the different automation features, rather than to the overall automation). Internal automation factors (quality, maintenance, obsolescence) also influence individuals' intention to use automation.

The authors also mention that performance and feedback of the automation will influence trust. They modify an individuals' beliefs and available information through the analogical (judgements linking levels of trust to characteristics of the agent and the environmental context), analytic (information is processed, formulated, evaluated using a function-based mental model of the system), and affective (affective response to the violation or confirmation of implicit expectancies, « feeling » trust) processes, depending again on the availability of the operators' cognitive resources.

The evolution of trust will then lead to different levels of trust such as overtrust, calibrated trust (leading to an appropriate use), distrust, a poor resolution (where the abilities of the system only map onto a small range of trust) and good resolution (where the system abilities maps onto the same range of trust).

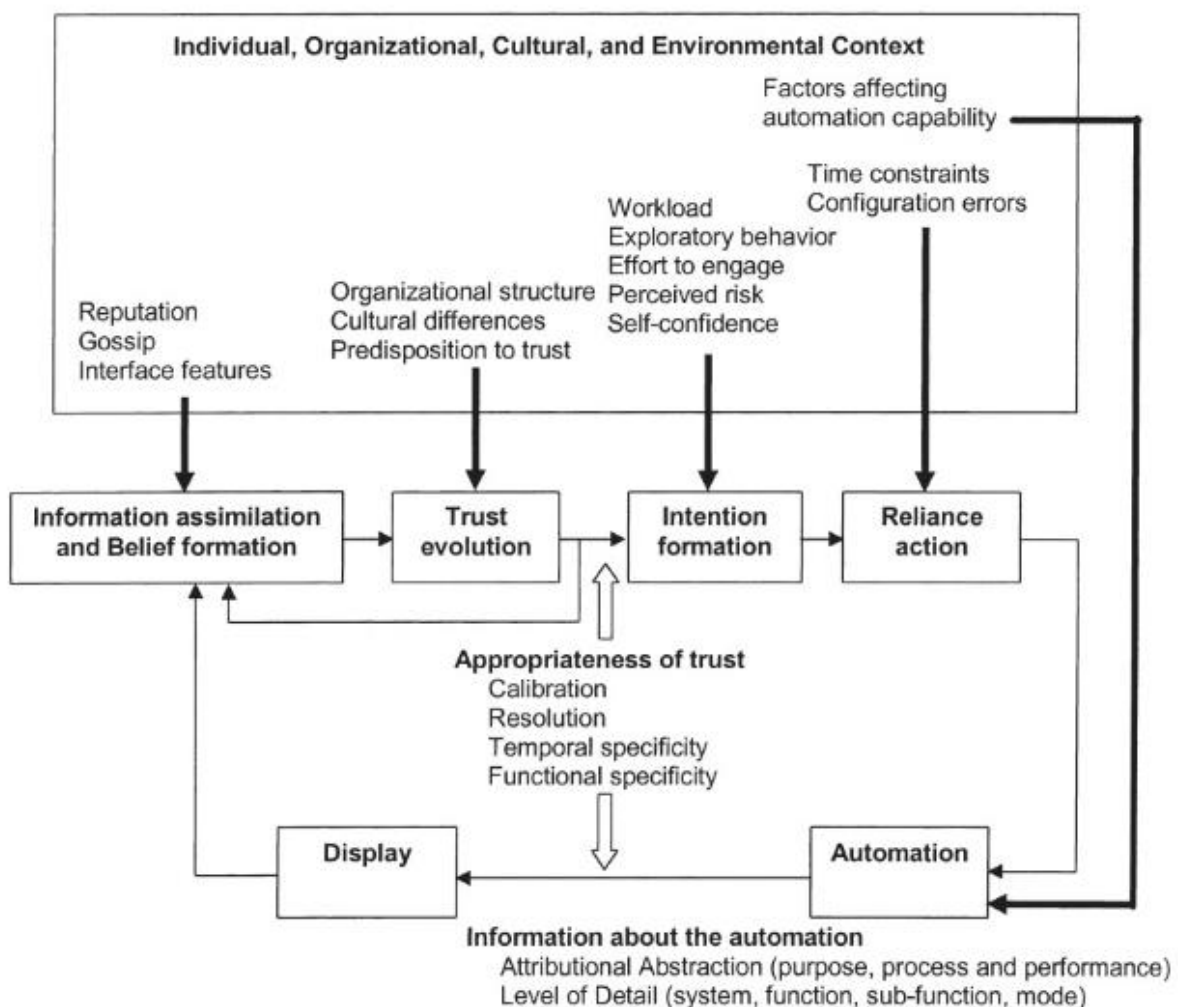


Fig. 8. The dynamic process of trust (from Lee and See, 2004)

2.3.3. Hoff & Bashir (2015)

Based on Lee and See's prior work as well as new empirical findings from the literature, Hoff and Bashir (2015) suggested a new model of trust in automation. This model distinguishes three layers of variability in trust: dispositional, situational, and learned. Each of them is associated with an aspect of the human-machine relationship: the operator, the environment in which the interaction takes place, and the automation. Hoff & Bashir also distinguish human-automation trust (a performance-based trust) from interpersonal trust, but they consider the two concepts as co-dependent.

This model is based on a review of 127 empirical studies. The authors also report that 34% of the studies evaluated trust through behaviors, 4% through self-reported questionnaires and 62% used both methods. Some factors influence trust before the interaction (dispositional, situational, and initially learned trust) and some during the interaction (design features, situational factors, system performance, reliance on the system and dynamic learned). The novelty of this model is how it adds new layers of variability in trust: dispositional, situational, and learned.

- Dispositional Trust

Dispositional trust refers to the individual's predisposition to trust automation, regardless of the technology or the context. It can be built throughout an individuals' personal experience. This can relate to tendencies influenced by biological and environmental factors such as age, culture, gender and personality. It's a stable kind of trust.

- Situational trust

There are two sources of variability in situational trust: the external environment and the internal, context-dependent characteristics of the individual. This includes external variability (environment, task, workload, framing of a task) and internal variability (self-confidence, expertise, mood, attention), situational factors and the relationship between trust and reliance.

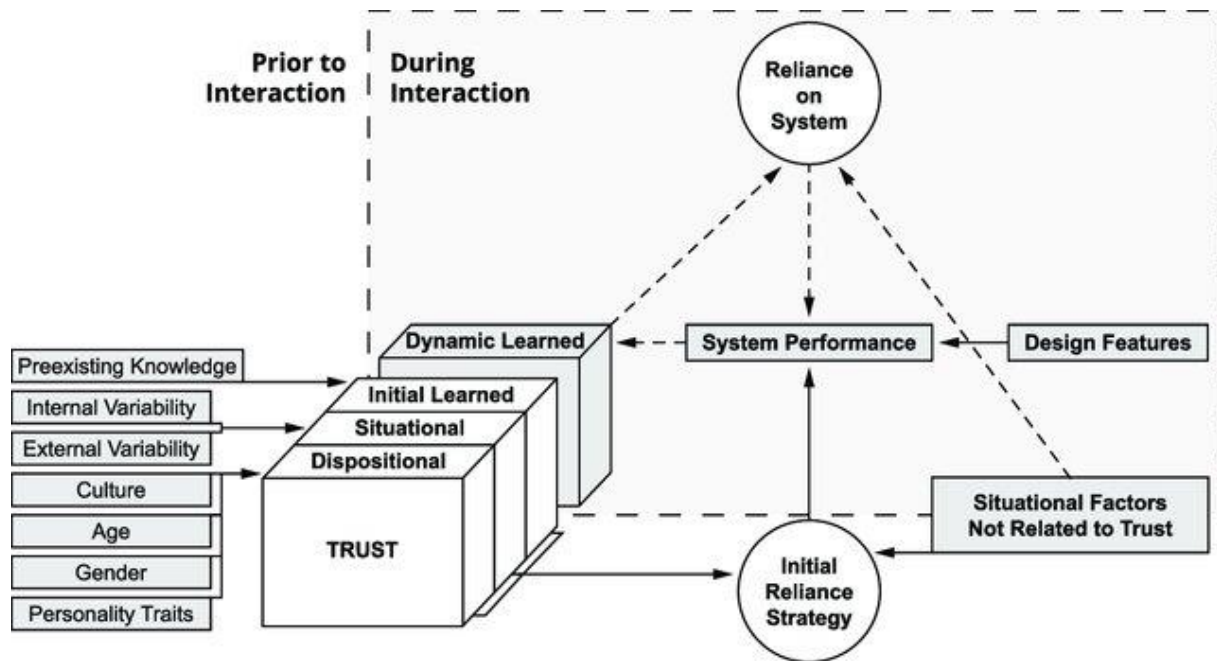


Fig. 9. Factors related to trust from the work of Hoff & Bashir (2015) (from Raats, Fors & Pink (2020))

- Learned trust

It refers to an individuals' evaluations of a system deduced from past experience or the current interaction. This trust is influenced by preexisting knowledge and the automated system's performance. This includes preexisting knowledge about a system, design features (with anthropomorphism, ease-of-use, communication style, transparency, and level of control), performance of a system and situational factors not related to trust (for example the required effort to engage in a system or time constraints).

In this model users are unconcerned about being duped, manipulated, or tricked by systems. The belief that a system will accomplish a task as planned and expected, with the only concerns being the systems' dependability and competency, is referred to as trust.

2.3.4. Three-factor model of Trust in Automation (Schaefer et al., 2016) and the three-factor model of human-robot trust (Hancock et al., 2011)

The three-factor model of Trust in Automation by Schaefer et al., (2016) was built through a literature review. This study takes place after a first one on human-robot trust (Hancock et al., 2011) that the same authors found some gaps in it and therefore, inconclusive.

In this model, trust is made of three main related components:

Human-related factors: these factors involve individual traits (gender, ethnicity, age, personality and the propensity to trust of each individual), states (attentional control, fatigue and stress), cognitive factors (understanding of the system, ability to use it, and expectancy or expectations related to the automation) and emotive factors (confidence in the automation, attitudes, satisfaction and being comfortable with the automation).

Partner (automation) related factors: these factors related to the automations' features (mode of communication, appearance and anthropomorphism, level of automation (or autonomy), intelligence, and personality of the agent) and its capabilities (based on its behavior, its reliability and errors, and its ability to provide feedbacks and cueing).

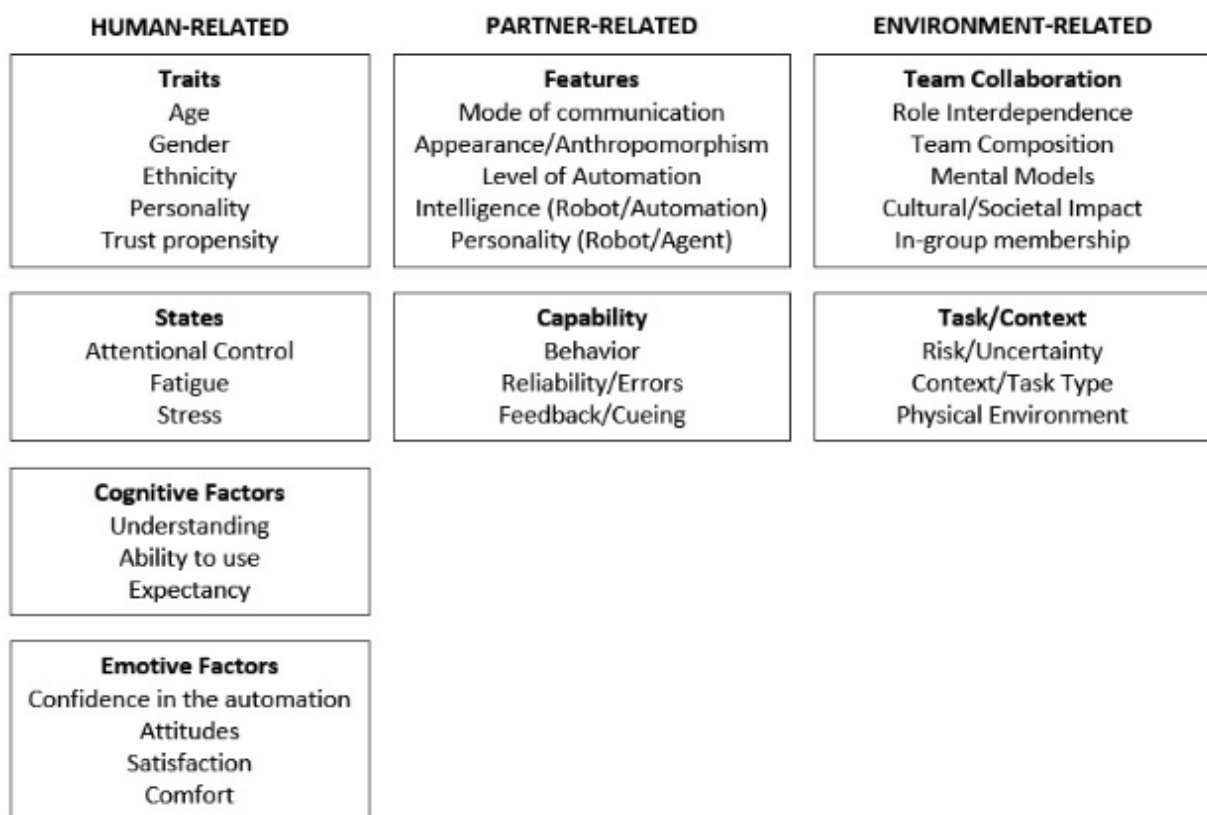


Fig. 10. Revised three-factor model of trust in automation (from Schaefer et al., 2016)

Environment-related factors: these factors relate to team collaboration (role interdependence, team composition, mental models, cultural and societal impact, in-group membership) and the context as well as the task in which the interaction takes place (involving the amount of risk and uncertainty, the context and the task type, and the physical environment).

Not all of these factors will be described in detail here as they are rather extensive, but it should be noted that some of them echo definitions given earlier, such as the amount of risk or uncertainty involved and attitudes. This model also starts to include « social » factors involving for example how the automation communicates or even its personality. The interest of this

model is also that it's systemic. Trust is not only dependent on the individual, the robot or the agent, but also on the context, and all this can eventually interact dynamically.

Later, this model was used as a basis by Schaefer (2016) for the creation of a Trust Perception Scale in HRI. The author first arranged potential items based on the model by analyzing and reviewing over 700 articles in the areas of human-robot, human-automation, and human-interpersonal trust. After a few experiments (assessment of mental models of human robot trust, validity, comparison with other scales...), the Trust Perception Scale-HRI was created with 40 items, including a 14 items shorter sub-scale.

During its creation, a component analysis revealed 4 components. The first represented performance-based abilities of the robot, the second was related to robot behaviors and communication, the third to task or mission specific items and the fourth was related to feature-based descriptors of the robot. If these components are related to the model, they are still very broad. The final questionnaire consists in items asking participants « what % of the time will this robot be » : Considered part of the team, responsible, supportive, incompetent, dependable, friendly, reliable, pleasant, unresponsive, autonomous, predictable, conscious, life-like, a good teammate, led astray by unexpected changes in the environment. Unfortunately, the author did not carry out a final analysis of the components, which might have helped to clarify the content of the questionnaire and the aspects of trust.

2.3.5. A multi-dimensional conception and measure of human-robot trust (Malle & Ullman, 2021)

Malle and Ullman (2021) define trust as « *a dyadic relation in which one person accepts vulnerability because they expect that the other person's future action will have certain characteristics; these characteristics include some mix of performance (ability, reliability) and/or morality (honesty, integrity, and benevolence)* » (p.15).

The work of these authors attempts to create a model and a measure tool to capture the multidimensionality of trust by subjectively categorizing words that encode the capable, reliable, sincere, or ethical trust dimensions. The authors developed the MDMT as a model but also a trust measure. To create it, the authors indeed collected 62 words from dictionaries, the trust literature, and published trust measures and asked participants in a study to scale each word as "more similar to capacity trust" to "more similar to personal trust". Through Principal Components Analysis (PCA) they first ended up with 32 items and four components: Reliable

(count on, depend on, reliable, faith in, confide in, $\alpha=.72$), Capable (capable, diligent, rigorous, accurate, meticulous, $\alpha=.88$), Sincere (sincere, genuine, truthful, benevolent, authentic, $\alpha=.84$), and Ethical (honest, principled, reputable, respectable, scrupulous, $\alpha=.87$). They also found that the Sincere and Ethical components were related to each other ($r=.46$, $p=.01$), suggesting that “moral trust” encompasses two related facets.

The authors replicated the study by asking participants how well they thought each item described different “person types” by sorting the items between the four components (represented by people). This allowed them to select a new item for each cluster: predictable (for Reliable), skilled (for Capable), candid (for Sincere), and has integrity (for Ethical). Performance trust refers to the trustor’s confidence that the trustee can complete a given task, while moral trust refers to the trustor’s confidence that the trustee will choose the morally right action and not exploit the trustor’s vulnerability.

This model focuses on the perception that individuals have of an agent or robot. It proposes a bi-dimensional vision that has been seen a little in the previous definitions, with a functional aspect, related to the performance, reliability and capacity of the agent and a moral aspect, which is more related to the dynamics of interpersonal trust.

Performance Trust		Moral Trust	
Reliable	Capable	Sincere	Ethical
Reliable	Capable	Sincere	Ethical
Predictable	Skilled	Genuine	Respectable
Can count on	Competent	Candid	Principled
Consistent	Meticulous	Authentic	Has Integrity

Tab. 7. Items within each subscale in the MDMT (from Malle & Ullman, 2021)

2.3.6. The expanded trust model (Hoffman, Lawson-Jenkins & Blum, 2006)

The authors of this model propose an « improved » trust model that potentially could be used with a diversity of technologies. The authors define trust as « the expectation that a service will be provided or a commitment will be fulfilled » (p. 96) and have been trying to map « psychological » aspects of trust (reliability, dependability, and integrity) with what they call, more « human-machine » aspects (reliability and security). In a way, this is another model trying to bridge social and functional aspects of trust.

The authors also claim that the model can adapt to the system by adding or removing components. The full model is shown in Fig. 11. This model hasn't been tested but proposes interesting new variables regarding trust that need to be considered for further work.

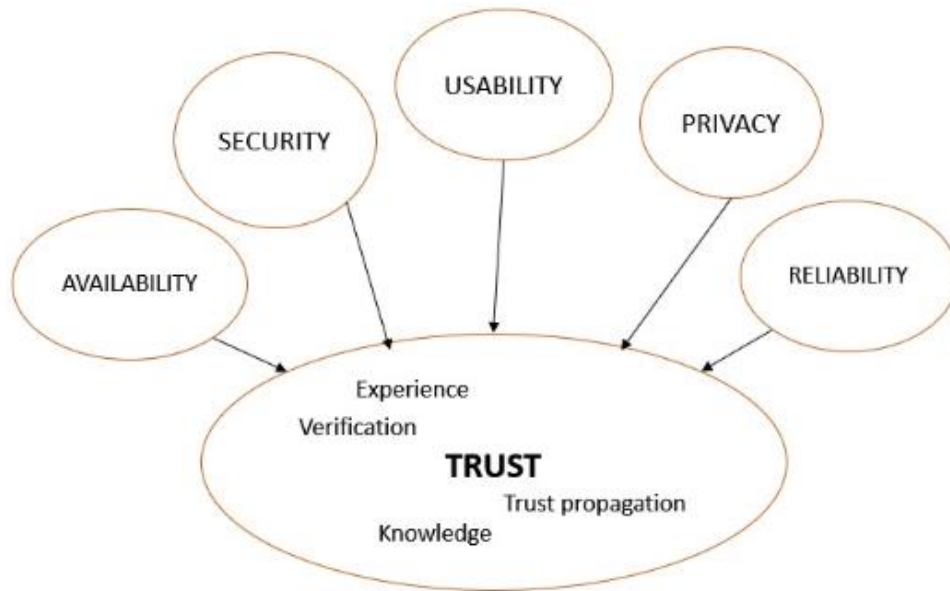


Fig. 11. General model of trust, adapted from Hoffman, Lawson-Jenkins & Blum (2006)

The authors also proposed a few generic parameters, which could be applied for different systems, for each subcomponent:

- **Security:** in this model, security can revolve around authentication of parties in transactions, data access control, data integrity, or physical security.
- **Usability:** for authors, usability here may revolve around perception issues, motor accessibility, and interaction design issues.
- **Privacy:** the authors here mention user anonymity and data confidentiality as part of privacy.
- **Reliability and availability:** this subcomponent involves for example connection to the internet, quality of service or the performance criteria specific to the system.
- **Audit and verification mechanisms:** this subcomponent involves having manual or paper audit trails of the system or the use of trusted agents to verify the system for example.
- **User expectation:** this one is based on the products' reputation, the prior user experience, knowledge of the technology/system.

The components are not extensively defined but simply exemplified, making the model somewhat incomplete compared to others that have been previously presented. Though, in this model, components of trust extend to other factors that have been minimal or even nonexistent in other models. If trust implies vulnerability, it is indeed essential that there be sufficient security to avoid threats. This model leads us to consider security and privacy as elements of trust.

2.4. Other components of trust

Trust models have been generally following trust definitions. Different factors can lead to trust depending on the models. They are mostly performance related or similar to interpersonal trust. Thus, the majority of trust models in human-robot interaction concern a trust concept based on the fact that the robot or agent will be able to perform its functions efficiently and effectively, but also that it will be (at the behavioral level and in its appearance) socially appropriate. However, there is a type of trust not mentioned in the models of human-robot interaction which would be more a trust in information sharing. Indeed, if the role of a robot or a social agent is to help fight loneliness by acting as a companion, information will be shared with it. For example, if an individual uses the Fribo robot (which encourages connecting to other humans via notifications and usage alerts), he will have to agree to share information about his own activities (doing the laundry, watching TV...) to the robot and his friends (Jeong et al., 2018). In another way, when using a chatbot like Replika (a companion chatbot), a user can be prompted to share information about his mood or his day. This is called self-disclosure. Disclosure occurring in an interaction on the other hand can lead to a sense of intimacy in a user, or at least in human-human interactions (Reis and Shaver, 1988).

But it is not only during an individual's self-disclosure that information is shared. This can happen when purchasing a robot or agent for example and it is necessary to create a user account linked to the robot or agent (this is the case for the Roomba vacuum cleaner from iRobot or the Google Home smart speaker from Google). These accounts can be linked to collected user habits or information deliberately provided by the user (e.g., age, gender, phone number, etc.) and they can be more or less sensitive. Robots and agents can also collect and store data (and therefore, information) from users and their environment through a variety of sensors (e.g., touch sensors, localization, complex and simple vision, light, speed, sound...). To agree to share this information consciously, a user must perceive the security and privacy of the robotic system or agent to be sufficient, to then potentially trust and accept the technology.

In this section, these « new » trust factors will then be described in order to better understand them.

2.4.1. Perceived Security

In the field of user experience, perceived security is defined by Hassenzahl et al., (2013) as « *Feeling safe and in control of your life rather than feeling uncertain and threatened by your circumstances.* » (p. 22). More precise definitions have been created in the context of online purchases. In the context of mobile applications, Balapour et al., (2020) define perceived security as « *the perception of the app provider's appropriate actions to safeguard shared information from security breaches during and after transmission through the mobile phone* » (p. 2).

Another definition by Salisbury, Pearson & Pearson (2001) follows the same idea where perceived security refers to an « *extent to which one can transmit sensitive information securely over the web* » (p. 166).

It is different from the perceived safety, defined as « *the user's perception of the level of danger when interacting with a robot, and the user's level of comfort during the interaction* » (p. 76) by Bartneck et al., (2009), which related to a « physical » type of security.

Thus, perceived security is a subjective feeling of safety and control, generally regarding users' personal information.

Recent studies have supported the fact that perceived security can be a relevant factor of trust and acceptance in human-robot interaction. Balapour et al., (2020) for example, state that users' attitude and behaviors will be affected by their perception of security, as it will determine his or her trust towards online transactions which will help build their behavioral intentions (e.g., intention to share private information, Bansal, Zahedi & Gefen, 2015). Security concerns (as well as privacy concerns) can mitigate trust but also social presence (a concept that is going to be talked about later) (Pavlou et al., 2007) when it comes to intentions to buy through e-commerce. Lastly, still in the context of mobile payment applications, perceived security will affect users' usage intentions (Johnson et al., 2018).

A few self-reported scales have emerged to evaluate perceived security in users. In the study of Cho et al., (2019), a perceived security scale was adapted from Salisbury et al., (2001) to the Alexa speaker with items such as « Alexa will not misuse my personal information »; « I feel secure sharing personal information with Alexa »; « I feel safe about my interactions with

Alexa ». The study of Chellappa (2008) has different types of scales, including a 6-items scale about perceived security. The focus is on online transactions with items such as « I have confidence in the security of my transaction with mobile banking applications ».

Perceived privacy and security are often studied together as perceived privacy for example is fueled by perceived security. Prior studies have found that perceived privacy and security are distinct, but can affect each other (Bansal & Zahedi, 2014; Bansal, 2017; Chellappa, 2008). For example, Chellappa (2008) showed that perceived privacy in e-commerce transactions influences positively perceived security. Privacy risks also affect the privacy perceptions of users (Dinev & Hart, 2006; Dinev et al., 2006; Dinev, Xu, Smith, & Hart, 2013; Liu & Wang, 2018). Johnson et al. (2018) showed that the perceived privacy risks of using mobile payment apps negatively impacts users' perceptions of the security of such apps. Users of any type of mobile app generally associate the risk of losing data with the app security.

2.4.2. Perceived Privacy

Perceived privacy in mobile apps consists in « *the ability of the individual to control when, how and to what extent, their personal information is communicated to mobile apps* » (Hong and Thong, 2013). Another definition refers to « *an individual's self-assessed state in which external agents have limited access to information about him or her* » (p. 299) (Dinev et al. 2013). While this privacy related to information privacy, the context of human-robot interaction leads Lutz and Tamó-Larrieux (2020) to distinguish physical privacy (the private or physical space or surroundings a robot can have access to) from informational privacy. The authors divided informational privacy into two types. One related to institutional threats (data processed by institutions such as robots' manufacturers, third parties and government agencies) and the other one to social threats (when the data is processed by private individuals such as familiar users or hackers). Lutz and Tamó-Larrieux (2020) found that respondents were the most concerned about their informational privacy (especially when it comes to institutions), then social privacy and then physical privacy, which was the less prevalent.

The study of Vimalkumar et al., (2021) tried to extend the UTAUT2 with factors such as perceived privacy concerns, perceived privacy risks and perceived trust in the context of voice-based digital assistants. As seen earlier, they found that trust in the service provider and the technology is important in the acceptance and adoption of the assistants. Though, perceived privacy risks were not directly leading to the assistants' adoption as users would do what is

call a « privacy trade-off ». This means that users will agree to give up part of their privacy in order to have access to the technology and its benefits. In their study, it was rather perceived privacy concerns and trust that directly influenced intention adoption.

In other studies, features increasing privacy in services and products will lead to greater levels of trust, leading to more adoption (Lutz & Tamò-Larrieux, 2021; Tamò-Larrieux, 2018). But Chellappa (2008) found that even though participants in the study ended up buying the product, there was still a variability in the perceived security, privacy and trust.

As for perceived security, a few self-reported scales exist. Three items have been created in the study of Chang et al., (2015) in the context of online banking (with items such as « I think my online privacy is preserved when I use this online banking service » or « I feel I have enough privacy when I use this online banking service. »). In the context of online companies, four items have been created by Bansal and Zahedi (2015) (with items such as « In general, I am concerned that the online companies are misusing their users' and/or customers'; personal information without prior authorization »; « I am concerned that online companies will share my personal information, without prior authorization with other companies »).

Together, trust, security and privacy are often a triad studied in the field of IoT (Internet of Things) but the perception of security and privacy have even been studied as a potential extension of the UTAUT as they influenced behavioural intention towards adoption, along with trust (Mehri et al., 2019). Another study found for example that perceived security moderates the effect of perceived privacy on trust (Shin, 2010).

Thus, perceived security and perceived privacy in the context of social human-robot interactions could potentially help disclose information which can be helpful in the usability of a robot or an agent, especially when the goal is to counter loneliness.

The sharing of private information to a social robot demands trust, as such a release implies a favorable anticipation of an unpredictable outcome. Privacy in social interactions facilitates self-disclosure and enables interpersonal relationships based on trust and trusting beliefs (Tamò-Larrieux, 2018; Westin, 1967).

2.4.3. Self-disclosure

If users know their personal information are safe to share, then they may agree to disclose them to a a person, a robot, or an organization. Self-disclosure consists in revealing personal information to someone else (Archer, 1980).

In human social interactions, it can have beneficiary effects for mental well-being (Kreiner and Levi-Belz, 2019; Pennebaker, 1995) as it represents a way for individuals of releasing their stress (Barak and Gluck-Ofri, 2007; Choudhury and De., 2014), analyze themselves (Kowalski, 1999) or even gain social support (Lee et al., 2013). Those beneficiary effects are increased when, in an interaction where a speaker self-discloses, the listener responds with support and validation, rather than ignoring or blaming the speaker (Shenk & Fruzzetti, 2011). In some studies, individuals were more relieved from talking to a robot than writing their thoughts down or sharing their thoughts on social media (Duan et al., 2021; Luo et al., 2022). On the other hand, another study (Uchida et al., 2020) showed that female japanese participants did not show a preference between disclosing to a human or a robot (males preferred the human agent), but robots could elicit more self-disclosure about negative topics than humans.

Also, reciprocal self-disclosure with a chatbot encourages users' self-disclosure (Ravichander and Black, 2018). More precisely, the level of disclosure of a chatbot can influence how much individuals choose to reveal about themselves in terms of depth, subject sensitivity, and feelings (Lee et al., 2020). In human-robot interactions, it has been shown that a self-disclosing robot (that is expressive and vulnerable) encourages more self-disclosure from participants but it also elicited more trust and feelings of companionship with the robot (Martelaro et al., 2016). In individuals who tend to anthropomorphize robots more, self-disclosure from robots was also found to increase mind-attribution (Essey et al., 2017).

In the context of online booking, self-disclosure from the host influenced the perceived trust, which influenced the intention to book the Airbnb accommodation (Broeder and Crijns, 2019). Therefore, perceived privacy and security encourage self-disclosure in users, which can be beneficiary for them. In turn, self-disclosure from robots, agents or even websites sometimes, can influence user trust and therefore probably, acceptance. Self-disclosure in interactions develops with but also produces intimacy, which is another concept requiring to be developed.

Some theories address the interaction between, such as the social penetration theory from Altman and Taylor (1973) which considers that relationships develop in a linear way and where individuals open themselves more and more through layers of self-disclosure. For West and Turner (2010) disclosure involves breadth as well as depth. Breadth refers to the number of different topics discussed during an interaction while depth refers to the time individuals spend on communicating about the given topics. There is also the social exchange theory (Cook et al., (2013) which states that humans weigh interactions and relationships with a reward-cost scale. For example, if the interactions are positive the reward/cost calculations are more favorable and the relationship can develop, in turn, favorably.

Self-disclosure is then beneficiary for mental health and is one of the reasons why the ability to self-disclose to a robot could be encouraged in the context of loneliness. It is also interesting to note that self-disclosure will act as a sign of trust, but also a factor of trust.

2.4.4. Intimacy

Disclosing information in human-human interactions leads to the formation of intimacy. According to Reis and Shaver (1988) intimacy is a transactional process made of self-disclosure and perceived responsiveness, which allows a close connection between individuals. Intimacy is a process occurring when the speaker discloses personal information (or feelings) and the listener responds by also providing disclosure (with personal information or feelings). Later work of the same authors (Reis and Patrick, 1996) suggested that the most important factor to make intimacy occur is when the listeners' responsiveness is interpreted by the speaker as understanding, validating and caring.

For Sternberg (1986) intimacy in human-human relationships is defined as « feelings of closeness, connectedness, and bondedness in a close relationship ». Moore (2001) states that intimacy in relationships involves communication, agreement (engagement), friendship, and adaptation. In human-human interaction, psychological intimacy includes mutuality, connectedness, openness, reciprocity, sensitivity, responsiveness, honesty, self-disclosure, empathy, compromise, trust, acceptance, attentiveness, interest, and warmth (Prager, 1995).

Thus, a human-robot interaction interactions or relationships could be considered as intimate. The study of Sung et al., (2007) showed how users ended up showing signs of intimacy with their Roomba vacuum cleaners. In the study of Kahn et al., (2015) a highly social robot shared a secret with participants. Most participants (59%) chose to not share it afterward.

As a result, robots with different social skills and different appearances can bring users to become intimate with them and develop relationships resembling human-human interaction.

In 2010, Kahn et al., distinguish the physicality of sex with robot and psychological intimacy while they point out the possibility for humans to form « deep and meaningful psychologically intimate relationships with [...] robots » (p. 123). At the time, the authors already established patterns to build sociality and to empathize the social aspect of the human-robot interaction. These ones show where psychological intimacy showed in a previous experiment (Kahn et al., 2008). These simple interaction patterns show how intimacy can easily form between a robot and a person.

Interaction Pattern	Qualities of Psychological Intimacy
The introduction	Colloquial language, conventional niceties, expressing interest in the other's well-being, responsiveness attention to responses.
In Motion Together Sharing Personal Interests and History	empathetic sensitivity and responsiveness to the other's concerns, reciprocal sharing of personal connections and concerns, willingness to reveal oneself, eye contact, responsiveness to pacing, physical closeness without touch.
Helping an Other Recover from a Mistake	forgiveness and understanding, normalizing an experience, reciprocal sharing of one's own limitations or vulnerabilities with another
Pauses in Conversation	attempts to neutralize an awkward silence, engaging the other in disclosure, expressing interest in the other's experience, effortful involvement in an interaction, eye contact while leaning towards the other
Claiming Unfair Treatment or Wrongful Harm	empathy and compassion for the other's experience, supporting another's claims, speaking up for the other's wellbeing, camaraderie and psychological rapport, leave-taking

Tab. 8. Examples of interaction patterns leading to the development of psychological intimacy

The authors also draw a distinction between an I-It relationship (where the self treats the other as an object to be used) and the I-You relationship (where the self and other are engaged in a full meeting of selves, and through which each self becomes whole). For them, to understand deep parts of human-robot interaction – and of what it means to be a human – we need to assess the possibilities and limits of psychological intimacy with robots. Thus,

although robots are machines, the literature shows the extent of interactions with them. Humans, individuals, users, do not only have “surface” interactions with the machines that are robots, but an intimacy can be created, similar to the one that can happen with humans.

While more work on the impact of human-robot intimacy can still to be done, the concept of brand intimacy (the bond created between a customer and a brand) suggests that intimacy can lead to higher trust levels and influence consumer choices (Hildren, Hildebrand & Häubl, 2018). Therefore, psychological intimacy perceived by a user could influence trust but also acceptance.

Summary

In this part, trust was explored as an important factor of acceptance in human-robot interaction. The concept of trust, as for acceptance, seemed relatively complex.

A few factors have been conceptualized during the recent years, especially in human-automation or human-robot interaction. In these contexts, the concept of trust always seems to be related to a performance-based and social/morally based trust. Regarding the context of social interaction, companionship, and loneliness it seemed relevant to consider that being able, for users, to share information about themselves (whether it's feelings or factual information such as their age, gender), is an important factor of trust. Thus, it would seem **informational trust** (self-disclosure, perceived intimacy, privacy, and security) is a potential and relevant factor for trust and therefore acceptance in the context of social human-robot interaction.

3. The human-robot interaction

3.1. An interface

Human-robot interaction has differences with human-machine interaction especially because these machines have social aspects. This is especially true for companion or assistive robots or agents. The specificity starts with its user interface.

As for every machine, a robot has a user interface. In their work, Blair-Early & Zender (2008, p. 89) propose the definition given by Wikipedia: « *The user interface is the aggregate of means by which people (the users) interact with a particular machine, device, computer program, or other complex tool (the thing). The user interface provides (the) means of: Input, allowing the users to control the system; (and) Output, allowing the system to inform the users (feedback)* ». (p. ...). The robotic interface (Saerbeck, Bleuzé & van Breemen, 2009), is more precisely defined as expressive devices that interact with the user via modalities such as speech, gestures, or symbolic expressions.

Thus, beside screens allowing a user to set it up (user account management, settings, internet connection...), the communication of information with a robotic interface is done through verbal and non-verbal communication, used in human-human interactions.

3.1.1. Human-robot interaction regarding the Media richness theory

Daft and Lengel (1986) in the early proposal of Media Richness Theory suggest that every communication media have different capacities for resolving ambiguity, negotiating interpretations, and enhancing understanding between two agents.

According to the Media richness theory, a media is most effective when it is appropriate for its task and context and each media has its own properties to deal with ambiguity and enhancing understanding. A hierarchy is also proposed in the theory to level the richness of communication, from face to face, smartphone, email, letters, notes, to fliers, and leaflets. The richness is based for example on the number of different social cues (e.g., nonverbal communication), immediate feedback, and natural-language use. Thus, in terms of media richness, social robots and agents are rich and the most similar to human face-to-face communication. Social interactions with a robot or an agent include turn-taking and synchronicity in interaction, natural language, or non-verbal communication (such as waving,

or even the possibility to touch the robot). For some robots, facial expressions and emotional signals will create even richer media (Bubaš, 2001).

Therefore, social robots and sometimes agents can be considered as rich medias as they offer a lot of affordant social cues.

3.1.2. Human-robot interaction regarding affordance and the CASA paradigm

The social aspect of the human-robot interaction is also explained by the concept of affordance, Affordances are the attributes of an object or a machine indicating how a user can interact or use it (Gibson, 1979): « *When the constant properties of constant objects are perceived (the shape, size, color, texture, composition, motion, animation, and position relative to other objects), the observer can go on to detect their affordances. [...] What they afford the observer, after all, depends on their properties.* » (p.285). For example, it is possible to understand that an object is rollable (affordance label) because it has wheels. In 1990, Norman wrote about the importance of assessing perceived affordances based on the user's experience rather than the inherent properties of an object. Therefore, previous experience with a technology or something similar to it could simplify its use. More specifically, social affordances indicate that an object can fit communication (Fox & McEwan, 2017). As social robots or agents may have eyes (therefore it can « see » me) or a mouth (therefore it can « talk » to me) for example or look human-like (and therefore have human-like abilities).

Regarding the CASA paradigm, social affordances are relevant to understanding how individuals will interpret the social potential of an agent, and if they will perceive it as a source or interaction rather than a channel to communicate with other people for example.

The CASA (computers are social actors) paradigm (Nass & Moon, 2000) is a first known framework suggesting that humans will apply social categories, gender stereotypes to computers or ethnically identify with computer agents. People will also show social behaviors such as politeness and reciprocity with computers or attribution of personality to computers. In 2000, the authors declared that anthropomorphism or intentional social responses aren't enough to explain the phenomenon. Reeves & Nass, (1996) argue that the human brain doesn't directly distinguish medias from living things and will naturally communicate with those in a social way as it diminishes the cognitive effort induced by finding an appropriate way to communicate with it.

The paradigm also argues that humans have existing mental models of human communications for situations that are similar. Those mental models are called social scripts (Honeycutt & Bryan, 2011). Thus, following the paradigm, humans will apply social scripts to human-machine interactions, and therefore, human-robot interactions. CASA kept a predictive validity in different contexts, including anthropomorphic interfaces (Lee, 2010), embodied agents (Hoffmann et al., 2009; Lee et al., 2006), mobile phones (Carolus et al., 2018), and voice-based navigational systems (Nass et al., 2005). Gambino et al., (2020) suggest that the state of the CASA paradigm may be different today as more and more individuals are getting experience with technologies. This experience is a relevant matter as it could determine if the human response to a technology is actually mindful or mindless and automatic.

Anthropomorphism is also stated by the authors as a relevant matter to consider in this paradigm and in the human-robot interaction. The phenomenon can indeed influence the intention to use a robot (Blut et al., 2021).

3.2. Anthropomorphism

Anthropomorphism refers to the attribution of human traits (motivations, intentions, emotions...) to non-human things (Epley, Waytz, & Cacioppo, 2007). Anthropomorphism does not describe existing physical features or behaviors but rather represents a particular human-like interpretation of existing physical features and behaviors that goes beyond what is directly observable (Epley et al. 2008).

The first study on anthropomorphism dates from 1944 (Heider & Simmel, 1944), where the participants attributed personalities and intentions to shapes moving on a screen. The phenomenon of anthropomorphism can appear very early in life. By the age of 3 years old, children can infer goals from a ball movement (Montgomery & Montgomery, 1999) and 12 months old children can show expectations that dots on a screen follow goals as if they were intentional (Gergely et al., 1995). Thus, anthropomorphism does not require complex interactions to occur, movements can be enough.

In human-robot interaction, human-like characteristics have been divided in the literature in different subsets (Ruijten and colleagues, 2019). Some may focus on the human-like appearance and the physical abilities of the robot, some focus on the perceived cognitive states and processes of the robot, and finally some focus on the human-like emotions of the robot. When it comes to the appearance, even some specific cues have been studied such as facial expressions (Moosaei et al., 2017, Mäkäräinen et al., 2015), the voice (Siegel et al., 2009)

or gesture (Salem et al., 2013). Thus, in experiments the anthropomorphism can be modulated in an extensive way and perceived through different characteristics.

Anthropomorphism can be enhanced by human-likeness but is the result of human perception. In their work, Epley, Waytz & Cacioppo (2007) developed an in-depth theory (SEEK) explaining why some individuals are likely to anthropomorphize. They show how each independent variable of anthropomorphism have key psychological determinants. For dispositional variables, it consists in a need for cognition, a need for closure or control (and apprehending the world) or chronic loneliness. For situational variables anthropomorphism can be triggered by perceived similarity (with an agent or a technology or an object), an anticipation interaction or a social disconnection. For developmental variables, anthropomorphism may come from the acquisition of alternative theories (about defining the environment), attaining competence and the impact of attachment styles. Finally for cultural variables, the authors suggest that anthropomorphism can be motivated by experience, norms and ideologies, the need to avoid uncertainty and being in an individualistic or collectivist society. While this theory is based on many supports in the literature, many elements are close and seem to overlap in each psychological determinant given in the theory (elicited agent knowledge, effectance motivation and sociality motivation).

The concept of anthropomorphism is closely linked to the theory of mind (Premack & Woodruff, 1978) which refers to the human ability to infer and predict mental states of other humans (including intentions, beliefs, emotions). Anthropomorphism has been described by Atherton & Cross (2018) as an extension of the theory of mind. For other authors, anthropomorphism goes beyond the mechanism of the theory of mind (which is attributing a mind to others) (Epley 2018; Epley et al., 2008).

Work on anthropomorphism has also been done at a neurophysiological level, suggesting it is an inherently part of human functioning. For example, the oxytocin hormone has also been found as a trigger of higher anthropomorphic attribution in women for social stimuli (Scheele et al., 2015), which led the authors to suggest that oxytocin may have an adaptive regulatory function, leading to the attribution of context-dependent anthropomorphism. The other way, a social interaction with a non-human-like robot can be enough to activate the mirror-neuron system, implying that robots can be perceived as social agents and that anthropomorphism can be triggered by an interaction perceived as social (Hoenen, Lübke & Pause, 2016)

Anthropomorphism is an important concept in the human-machine and human-robot interaction, especially in our context. For example, the study of Eyssel & Reich, (2013) showed that loneliness increases anthropomorphism with robots compared to non-lonely people. On the marketplace, socially excluded individuals show a preference for anthropomorphic brands compared to non-excluded individuals (Mourey, et al., 2017). With animals, some factors have been found to influence individuals' attribution of cognitive abilities to animals such as perceiving a similarity between the human and the animal, its group membership, or the degree to which a bond is formed with a particular animal (Eddy et al. (1993)).

Thus, it is interesting to note that loneliness or social disconnection, but also bonding can increase anthropomorphism.

Individuals tend to find autonomous cars more trustworthy for example (Aggarwal and McGill 2007; Waytz, Heafner, and Epley 2014) and robots more likeable if they display human-like traits (Salem et al. 2013). Human characteristics in products make them more likeable which is the reason why some brands can have human-like mascots (Aggarwal and McGill 2012). Websites with anthropomorphic design (with human-like eyes for example) has been shown to increase individuals' trust and purchase intentions (Wölfl, Feste, and Peters 2019a). Adding a human-like avatar to a website also increases purchase intentions (Wölfl, Fest & Peters, 2019b).

When anthropomorphizing a robot, individuals display more engagement and trust (Ruijten et al., 2019, Hoff & Bashir, 2015). Human-like cues in machines trigger social responses from individuals, leading to familiarity and acceptance (Nass & Moon, 2000).

But anthropomorphism can have disadvantages, especially when it comes to expectations. For example, automation that don't have a human-like appearance (and that look machine-like) are associated with rationality, objectivity, reliability, and efficiency, and therefore, competence (Mosier et al., 1998). When machines rather look human-like, these expectations of competence are lowered, leading characteristics initially associated with machines to be confused with human-like appearance and function (Seeger et al., 2017; De Visser et al., 2016; Mosier et al., 1998). This can lead to distrust from individuals as it creates a dissonance between their expectations and the actual abilities of the automation, refraining them from using it (Seeger et al., 2017). In conversational agents, unmet expectations lead to disappointment or a lower perception of social presence (Mimoun et al., 2012, Nowak & Biocca, 2003) while anthropomorphism can lead to a higher acceptance, perceived utility, enjoyment (Burgoon et al., 2000; Qiu & Benbasat, 2009) and performance (Lee, 2010). Some authors state

that anthropomorphism by individuals may lead to « *discomfort – specifically, feelings of eeriness and a threat to their human identity* » (Mende et al. 2019, p. 539). In other contexts (Mourey, Olson & Yoon, 2017), anthropomorphic brands are preferred by socially excluded individuals compared to non-excluded individuals.

The study of Cornelius and Leidner (2021) proposes an extensive review of the positive and negative effects of anthropomorphism in technology. When the anthropomorphic design relies on the appearance, the positive effects of anthropomorphism can for example be: reducing strain, increasing utility, increasing animacy, credibility, human agency, positive evaluations, social responses and social influence, enjoyment and persuasion, enhancing social presence, supporting self-awareness and self-efficacy. Negative effects of an anthropomorphic design on the other hand include a decreased identification, a decreased collaboration, an increase in the deceptive behavior (as for example an anthropomorphic appearance can increase users' expectation towards the robot or agent).

Thus, the anthropomorphism perceived by individuals can have many effects, both positive and negative, which, like acceptance and trust, will influence the intention to use a robot.

3.4.1. Scales used to measure perceived anthropomorphism

In human-robot interaction experiments, anthropomorphism is evaluated to find out how human-like a robot or agent is perceived by humans. Today, anthropomorphism has been measured through three main self-reported questionnaires. Among them, there's the Godspeed questionnaire with 23 items, (Bartneck, et al., 2009) which is based on five constructs (anthropomorphism, animacy, likeability, perceived intelligence and perceived safety) but has been criticized for its lack of discriminant validity between its constructs (Ho & MacDorman, 2010). Later, the Robot Social Attribute Scale (RoSAS) (Carpinella et al., 2017) with 18 items emerged with three dimensions: competence, warmth and disturbance, based on the Godspeed questionnaire. But when tested with real robots, the results given by the scale showed low levels of explained variance (Spatola, Belletier, et al., 2018; Spatola, Santiago, et al., 2018). In 2021 (Spatola, Kühnlenz & Cheng, 2021), the HRIES was created with 16 items and 4 sub-scales (disturbance, agency, sociability and animacy).

According to these measurement scales, the notion of anthropomorphism in human-robot interaction refers to robots or agents being perceived as warm, likeable, trustworthy, natural, real, or intelligent. It is, however, curious to include disturbance-related items in a scale

assessing anthropomorphism. Indeed, according to the Uncanny Valley theory, the more human (and therefore anthropomorphic) an object will look, the more it's going to be emotionally repulsive (Mori, 1970), until a threshold is passed where the object is attractive again.

Thus, the concept of disturbance related to anthropomorphism does not follow a linear relationship and it would seem more appropriate to evaluate the « uncanny » dimension alone.

3.4.2. The Uncanny Valley theory (Mori, 1970)

The Uncanny Valley theory is an important aspect of anthropomorphism in human-robot interaction. According to Mori (1970), the level of affinity with objects (or agents) evolves according to its human-likeness until reaching what he calls the **Uncanny valley**, where the object (or the agent) provokes a strange feeling, a repulsion (accentuated if the object is in movement). Mori hypothesized that this feeling of eeriness could be some kind of instinctual fear to protect us from sources of danger such as corpses or members of different species.

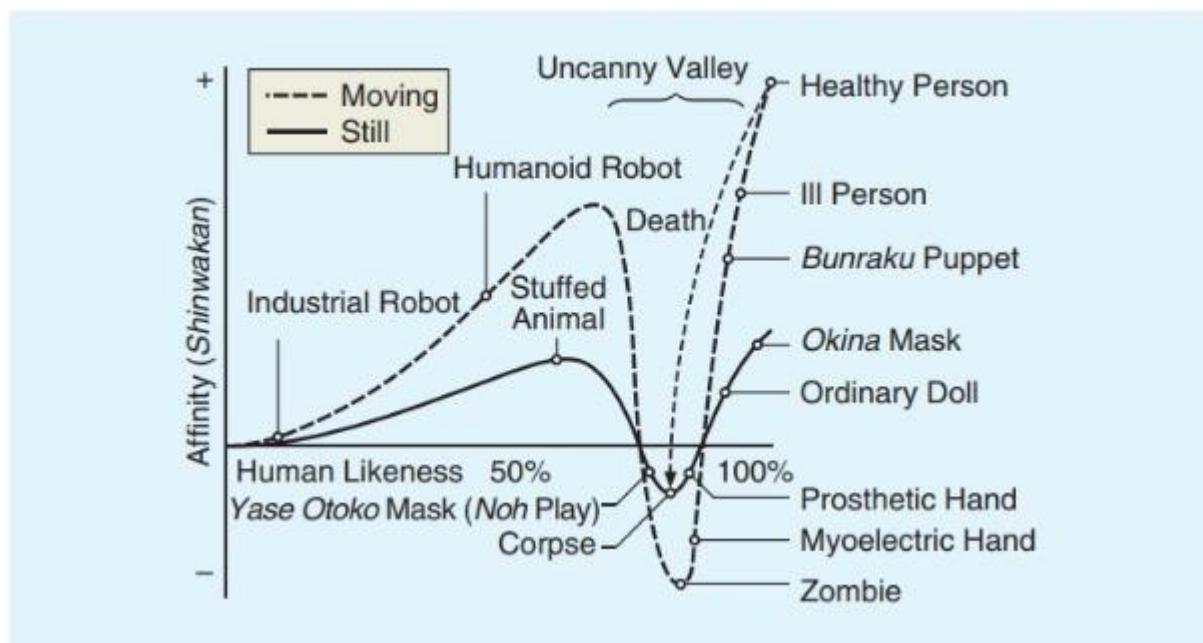


Fig. 12. Representation of the Uncanny Valley phenomenon (from Mori, MacDorman and Kageki, 2012)

While for some authors, the concept of Uncanny Valley is ambiguous or even non-existent, (Kätsyri et al., 2015), the concept has been quantified in 2016 through the evaluation of the likeability and trust attributed to 80 existing robot faces by 66 participants (Mathur & Reichling, 2016). Likeability ratings showed a robust Uncanny Valley effect, a more subtle effect was observed with trust (the effect was indeed stronger for female looking agents).

The Uncanny Valley isn't always linear, Kim, de Visser and Phillips (2022) found two uncanny valleys in their work: one constituted of positive (*shinwakan*) and one of negative (*bukimi*) emotional responses. Human-likeness alone may not be the only phenomenon triggering the uncanny valley but specific combination of dimensions in the human-like appearance with perceptual mismatches (e.g., high surface features, low body, high face). They also found that negative emotions created deeper uncanny valleys compared to positive emotions. More human-like and imperfect robots created more negative reactions, while the least human-like robots were judged the least negatively.

Other authors found a *funcanny* valley (Mäkäräinen et al., 2015) also demonstrating that strangeness isn't always associated with a negative valence. The authors proposed images to participants with different levels of realism (from drawings to pictures) and different magnitudes of facial expression (from a neutral face to a face with an extremely exaggerated smile) and found that high strangeness was associated with positive emotions such as amusement.

The concept of Uncanny Valley can sometimes be a little fuzzy. Most of the time in the literature, this concept is studied in the negative sense of repulsion, as in the first study of Mori (2012), but it is not one-dimensional. Perceptual mismatches and human-likeness can provoke sometimes more positive reactions.

3.3. Embodiment: agents and robots

The concept of embodiment is closely related to that of anthropomorphism since embodiment concerns an appearance, and this one can eventually be human-like. For Ziemke, (2016), « *Embodied approaches to AI (...) allow computer programs and the representations they are using, if any, to be grounded in interactions with the physical environment through the robot/agent platform's sensorimotor capacities* » (p. 5). For Brooks (1991), embodiment means that robot's « *actions are part of a dynamic with the world and have immediate feedback on their own sensations* », and therefore, they are physically grounded. At the same time, Brooks states the concept of situatedness, referring to the fact that robots are situated in the world (here and now), which directly interacts with the behavior of the robotic system (Brooks, 1991). They are part of a present context.

Two conceptions are also found in the literature, with one stating that embodiment is a characteristic of physical bodies (Pfeifer & Scheier, 1999) and the other one stating that

embodiment depends on the degree to which a system is influenced by the environment where it is placed and the extent to which the environment is influenced by the system (Dautenhahn et al., 2002). The latest definition for example can apply to virtual agents.

Dautenhahn and Christaller (1996) suggest that having a conception of its own body for an agent is a prerequisite for embodied action. For example, an embodied physical robot can be touched or give hugs (Block and Kuchenbecker, 2018). This is in line with the theory of the situated cognition hypothesis stating that the behavior of an agent arises from the interaction of the agent and its environment, rather than just the agents' mind (whether it is a robot or a human). Roth and Jornet (2013) indeed explain that « *information exists not prior to, but emerges from, and is a function of, the organism–environment relation (coupling)* » (p. 464). An appropriate embodiment could therefore allow a better interaction of the agent or robot with its environment. However, the levels of embodiment can vary, giving rise to different types of agents in the literature. The designations are sometimes confused but chatbot, embodied virtual agent, embodied conversational agent and robot are the main names given to the different social and interactive agents found in the literature. If the technical aspects of their design can be drastically different, their main difference for users in the context of companionship lies in the embodiment.

- **Chatbots:** Chatbots (see Fig. 13) are, basically, software applications able to have communications through text or text-to-speech. For some authors, chatbots do not necessarily possess physical embodiments even though they can be considered as embodied in computers (Araujo, 2018; den Broeck et al., 2019).

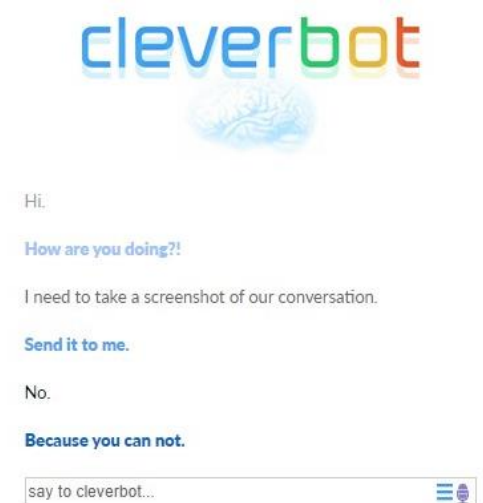


Fig. 13. The Cleverbot chatbot

- **Embodied virtual agents (or avatars):** For Groom et al., (2009), embodied virtual agents are graphical representations of digital humans or other anthropomorphic character. They possess digital bodies in 2D or 3D visual formats; and thus, can display social cues through dressings, facial expressions, and body. Embodied virtual agents have the capabilities to converse with users through verbal speeches or text messages. Examples include characters avatars in video games or avatars of chatbots (see Fig. 14).



Fig. 14. The avatar of the chatbot Kuki

- **Embodied conversational agents (ECA):** ECA are defined by Isbister & Doyle (2004) as “more or less autonomous and intelligent software entities with an embodiment used to communicate with the user”. For Provoost et al., (2017), ECAs have an embodiment, or visual representation. This embodiment can range from virtual human characters on computer screens to robots. They communicate with users verbally or nonverbally with text messages or speech, gestures or facial expression. Avatars or systems like the Amazon Echo can be considered as ECA (Kontogorgios et al., 2019). Examples include conversational speakers (see Fig. 15), text-to-speech chatbots like Replika or robots like Pepper (see Fig. 16).



Fig.15. The Amazon Echo

- **Robots:** They are characterized by their embodiment. Using the definition given earlier in the document by Naneva et al., (2020), a robot is « [a physically] embodied system that can be perceived as a social entity and is capable of communicating with the user. » (p. 1179). Robots can have a multitude of functions. In our scope, social robots can refer for example to the Pepper robot (see Fig. 16), the Kismet robots or the Sophia robot.



Fig. 16. The Pepper robot

Chatbot	Embodied Virtual Agent (or avatar)	Embodied conversational agent (ECA)	Robot
- Software - Communicates through text or text-to-speech - No specific appearance	- Software - Doesn't always communicate - Can be static or animated - Can be accompanied by a chatbot - Has a defined appearance	- Software and/or machine - Communicates through text, text-to-speech and non-verbal behavior - Can be animated - Has a defined appearance	- Machine - Can communicate through text-to-speech, sounds, and non-verbal behavior - Can move and be animated - Has a defined appearance

Fig. 17. Types of agents that users are able to interact with, depending on embodiments and other characteristics

The impact of embodiment on human-robot interactions has been studied extensively. For example, the design and structure of a robot leads to the establishment of social expectations from users (Fong, Nourbakhsh & Dautenhahn, 2003). Users can expect to touch an embodied physical robot, but if this action isn't possible then embodiment becomes a feature leading to negative reactions (Jung & Lee, 2004). The work of Bartneck et al., (2004) which concluded that robotic embodiment has no more effect on people's emotions than a virtual agent. Powers et al. (2007) also detected a higher degree of engagement when participants had a health interview with a physical robot compared to a virtual character. In the study of Sherman, Michikyan & Greenfield (2013), all individuals communicating in person, through video chat, audio chat and instant messaging experienced bonding. During instant messaging, using cues like emoticons or typed laughter increases bonding, but this bonding remains lower than in-person communication. Users also tend to empathize more with physical robots compared to virtual agents (Seo et al., 2015).

The literature has shown that different levels of embodiment can have impacts on interaction and acceptance or trust with robots and agents. The effects of embodiment on trust are mixed. In some studies, the embodiment of a robot doesn't influence trust (Van Maris, 2017) but embodiment through a robot in human-human communication increases trust (Rae, Takayama & Mutlu, 2013). In the study of (Wang & Rau, 2019), the physical embodied robot was more trusted than the tele-presence robot. The physical robot also elicited more attachment. Overall, in this study, the authors hypothesize that acceptance is increased when the embodiment of a robot matches with its environment (a physical robot being in the physical world vs. being tele-present). Physical robots are also perceived as real entities compared to

animated characters, perceived as fictional (Kidd & Breazeal, 2004). In the work of Wainer et al., (2007), the embodied robot was perceived as more appealing, helpful, watchful, and enjoyable and perceptive than non-embodied robots (depicted on a computer screen). Wainer et al. (2006) demonstrated that *"physically embodied interactions are favored over virtual and remote tele-present ones"* (p. 122). Sproull, Subramani, Kiesler, Walker, & Waters (1997) showed that participants rated a female embodied interface attributed a lower sociability and a more negative social evaluation compared to a text-only interface. Participants also reported being less relaxed and assured when interacting with the embodied interface compared to the text interface. Finally, they gave themselves significantly higher scores on social desirability scales, but disclosed less information when interacting with an embodied vs. a text-only interface. Men disclosed more in the embodied condition when women disclosed more in the text-only condition.

When it comes to social presence, the studies are still mixed. Some suggest that the embodiment of a robot increases its social presence (Kidd & Breazeal, 2004; Lee et al., 2010) making interactions more engaging for humans, while the study of Jung & Lee (2004) reports that participants felt a moderately stronger social presence with the disembodied robot. Compared to a textual only chatbot, the embodiment and animation of a chatbot can even lead to uncanny feelings (Ciechanowski et al., 2019) as embodiment increases anthropomorphism (Kiesler et al., 2008).

Embodiment has also been studied with regards to loneliness and had mixed effects. In the study of Jung & Lee (2004), the interaction was evaluated as more positive with an embodied Aibo for lonely people while it was rather evaluated as more positive with a disembodied Aibo for non-lonely people. Embodiment can also allow interactions like hugs, which can influence pro-social behaviors (Shiomi et al., 2017a), self-disclosure (Shiomi et al., 2017b) and reduce loneliness (Heatley Tejada, Dunbar & Montero, 2020).

Finally, embodiment has an impact on users' self-disclosure. In Powers et al., (2007), participants disclosed less to the robot than to the agents and had a greater apprehension of robots. Participants found the robots to be more helpful, to give better and more useful advice, and to be more effective communicators. When it came to self-disclosure, the authors declared agents are preferable, while for tasks that are more relationship-oriented, a collocated robot would seem to be better.

3.4. Social presence

The concept of social presence conveyed by robots or agents is closely related to embodiment (as these two concepts can influence each other) and an element able to influence interactions. Short, Williams, and Christie (1976) defined social presence as « *the degree of salience of the other person in the communication and the consequent salience of the interpersonal relationships* » (p.65). Similarly, Lee (2004) defines social presence as « *a psychological state in which virtual (para-authentic or artificial) actors are experienced as actual social actors in either sensory or nonsensory ways* ». For Biocca, Harms and Burgoon (2003), the concept of social presence refers « *the sense of being with another* ». It can be elicited by humans or artificial beings and is influenced by interfaces.

For Short et al., (1976) it consists more of a continuum where the others are more or less present.

Biocca, Harms & Burgoon (2003) have gathered means of conveying and increasing social presence with humans in general that have been found in the literature, based on the notion of Goffmans' co-presence (Goffman, 1959, 1963). This includes and is not limited to:

- **Sensory awareness of the embodied other**, which is the simple awareness that someone else is there.
- **Mutual awareness**, where two individuals (or agents) are aware of each other in a defined space.
- **Psychological involvement**, as the presence of a body isn't enough and rather depends on an individuals' model of the other ones' intelligence.
- **Sense of access to intelligence**, which is when an individual is able to model the intentional states of an agent or an individual. The study of Biocca, (1997) for example proposes that social presence occurs as soon as an individual believes that an agent for example can be displaying an intelligence in reaction to the environment.
- **Salience of the interpersonal relationship**, defined as a « *constellation of cues which affect the 'apparent distance' of the other* » (p. 157) by Short, Williams & Christie (1976).
- **Intimacy and immediacy**: here, the individual has some understanding of the other one with a psychological involvement, and this understanding is to be mutual.
- **Mutual understanding**, this notion is a bit similar to intimacy and immediacy, but it also implies that this understanding evolves and remains mutual.
- **Behavioral engagement**. Here, behavioral interaction can be an indicator or the sole basis of social presence. With 90' media, it was first limited to text-based verbal behavior and

some non-verbal communication behaviors (e.g., eye contact, turn taking in the interaction), but today media such as virtual reality opens this behavioral engagement to any non-verbal, para-verbal or verbal behavior.

Thus, it seems that social presence can be conveyed through minimal social cues. Social presence has been studied in relation with concepts previously presented in this work. For example, lonely individuals will feel a higher social presence of social agents and will give more positive social response to these agents compared to individuals who aren't lonely (Lee et al., 2006). Some studies of Heerink, Evers, Kröse & Wielinga (2008, 2010) showed that social presence (but not conversational expressiveness) correlated with use intention of a social robot. Social presence has also been considered as an acceptance factor (Heerink, 2010) and a hedonic factor influencing acceptance (de Graaf et al., 2016). When it comes to trust, a study by Ye et al., (2019) shows that social presence in online transactions increases customer trust and purchase intention. The study of Kim, Park & Sundar (2013) showed that perceived social presence also mediates the effects of human-likeness.

In a disembodied, voice-based companion, higher perception of social presence is associated to a higher perceived usefulness and willingness to recommend the companion to lonely individuals (Merrill, Kim & Collins, 2022). The authors suggest that the lack of embodiment led the participants to pay more attention to the available social cues (the voice).

Summary

This section on human-robot interaction focuses on elements (anthropomorphism or lifelikeness, embodiment and social presence) specific to human-robot interaction. These are to be considered since they can influence acceptance, trust or they can be themselves influenced by loneliness. A robots' or agent appearance and design can have various effects and it is difficult to give a conclusion about it.

Other elements such as agency, conversational capabilities or perceived intelligence of robots and agents have not been mentioned and explored by choice. Indeed, the effects related to appearance and design are already rich extensive in the interaction. The appearances of robots and agents are also more stable to study while conversational capabilities in technologies for example, are in constant evolution.

Research process

	Study 1	Study 2	Study 3	Study 4
Research question	Which themes and factors characterize the acceptance of a widely downloaded and used chatbot companion? How does embodiment influence the acceptance of a chatbot companion?	How does social isolation and loneliness influence perceived anthropomorphism and acceptance of an agent?	How do acceptance, informational trust, anthropomorphism, and loneliness interact together?	How does interacting with a robot influence acceptance and anthropomorphism in children (with and without autism) and their parents?
Research design	Exploratory	Experimental	Correlational	Experimental
Research Method	Qualitative	Mixed Methods	Mixed Methods	Quantitative
Data collection	User reviews	Questionnaire Open-ended questions	Questionnaire Open-ended questions	Questionnaire
Sample	+ 80 000 users	70 students	139 users	5 ASD children + 5 parents 18 neurotypical children + 18 parents
Location	Natural	Natural	Natural	Lab-based
Interaction	Unknown	Single	Unknown	Single
Robot or agent	Replika chatbot	Human and embodied conversational agent made with Facerig©	Roomba© vacuum Replika chatbot Google home© speaker Amazon Echo© speaker Cozmo© + Vector© robots	Pepper robot

Tab.9. Summary of the research for the four studies

To try to answer some of the questions asked in the introduction and new ones that have emerged from the state of the art, this thesis has borrowed different methodologies which can be found in four different studies (see Tab.9 above). These are presented and specified in this part for each study.

Study 1 - User feedback of a companion agent and mediation of anthropomorphic embodiment

In the first instance, the study 1 attempts to explore which factors revolves around acceptance. The **research question** for this study is then the following: Which themes and factors characterize the acceptance of a widely downloaded and used chatbot companion?

For this, the study will **explore** spontaneous **users reviews** about an agent companion that they used. A **thematic and hierarchical top-down analysis** of more than **80 000 user comments** (from the Google store) is performed. The exploration of actual, post-use reviews provides access to users' subjective attitudes and perceptions. This descriptive study first brings answers from a **natural** environment concerning the acceptance of Replika, a widely used agent companion. Though, this type of study doesn't provide information about how long and how many times users have been using their agent.

Because embodiment has an impact on social presence and therefore the interaction, the second objective of this study is to compare the themes and acceptance factors before and after the embodiment of an agent, through an avatar. User acceptance in the reviews of the chatbot Replika is thus studied before and after the introduction of an avatar. A second research question in this study is: How does embodiment influence the acceptance of a chatbot companion?

For both parts of this study, the method used is a **qualitative analysis** of user (textual) reviews. When the method is qualitative, it means it will gather and interpret data that is not numerical. It involves a lot of subjectivity from participants and little control from the researcher. If it is sometimes reproached to qualitative studies that they lack the precision of hypothesis-driven experimental studies, they can collect holistic, multi-factorial and emergent data while, rigorous and systematic (Shah, Corley, 2006).

This thematic and hierarchical top-down analysis is based on the Reinert method (Reinert, 1983). Thematic analysis is « *a method for identifying, analysing and reporting patterns (themes)*

within data » (Braun & Clarke, 2006, p.79) and has been considered as flexible regarding its theoretical freedom.

The analysis of reviews on another hand has been explored to replace self-reported assessment methods, with some limitations. For example, in the study of Rese et al., (2014), it confirmed the limitations of the TAM model. Though, Tang and Guo (2015) consider user online reviews as as “a goldmine of voluminous, authentic customer evaluation” (p.2) and laboratory experiments that depend on student participants and the use of self-reported item scales have been pointed out as weaknesses regarding the TAM model (Legrís et al., 2003). The combination of these two methods (thematic analysis of user reviews with the Reinert method) is relatively new and therefore has an exploratory aspect. This exploratory study allows us to identify themes related to the use and acceptance of the chatbot companion, including the impact of its embodiment.

Study 2 - Effect of anthropomorphism and loneliness on acceptance

The second study attempts to more clearly identify whether loneliness and the perception of different agents has an impact on their acceptance. Compared to the previous study, this one attempt to control more the variable loneliness by focusing on a student sample during COVID-19 lockdowns, as well as anthropomorphism. The **research question** is the following: How does loneliness influence perceived anthropomorphism and acceptance of an agent? To proceed, this study carried out remotely has an **experimental research design**. It indeed takes the form of an online questionnaire proposed after a video with four different conditions where anthropomorphism is modulated through appearance and voice.

The self-reported **questionnaire** includes several items from questionnaires already tested in other studies such as: the Lubben Social Network Scale (Lubben et al., 2006) to measure social isolation, in relation with the UCLA Loneliness Scale (De Grace et al., 1993) to check if there is a link between the two concepts. The HRIES to assess the perceived anthropomorphism (Spatola et al., 2021), the Attrakdiff (Lallemant et al., 2015) to measure acceptance. Other closed and open questions about the participants perceptions and use intentions were also proposed to get more information from the participants. Therefore, this study is considered as **mixed methods**. This study tested the impact of loneliness on the perception of anthropomorphism how these two variables influence the acceptance of an agent

Study 3 - Anthropomorphism' mediation of acceptance and informational trust

The third study attempts to study the correlations between acceptance and informational trust, while observing how anthropomorphism and solitude modulate these results.

Here the research question is the following: How do acceptance, informational trust, anthropomorphism and loneliness interact together? This **correlational** study takes the form of a self-reported online **questionnaire** proposed to users and owners of different robots and agents (Roomba, Replika chatbot, Vektor, Amazon Echo, Google Home speaker, Cozmo) already widely sold or used and therefore, accepted on the market. An emphasis is put on the invasiveness and function differentiating each studied agent and robots, as this can influence for example the perceived privacy and security, and acceptance. This study is non-experimental and aims at establishing relationships between variables through statistical analysis. A correlation coefficient establishes the relationship between two variables with values ranging from -1 to +1. The self-reported online questionnaire consists in a few different scales such as : 12 items from (8) to measure perceived information security and privacy (Chellappa, 2008), the Miller Social Intimacy Scale to measure perceived intimacy (Miller & Lefcourt, 1982), the UCLA Loneliness Scale (short version) (Hughes et al., 2004) to measure loneliness, the HRIES to measure anthropomorphism (Spatola et al., 2021), the Almere model (Heerink et al., 2010) to measure acceptance, and items from Rifon et al., (2005) but also Rubin & Shenker (1978) to measure self-disclosure with the robot (or agent). An open question at the end allows to gather more qualitative data to complete the quantitative aspect of this questionnaire.

Study 4 - Towards a universal acceptance: assistant robots' acceptance for children with autism and their parents

This **experimental** study opens the work in the perspective of universal design which considers accessibility in human factors as primary and as a source of technological innovation. This way, this study focuses on specific population: children with autistic spectrum disorder (ASD) and their parent(s).

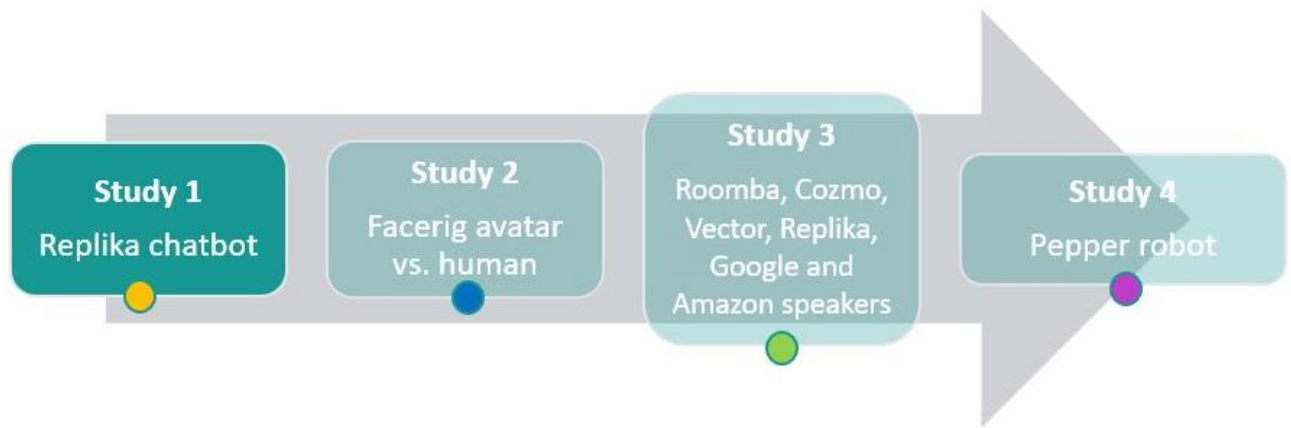
The study proposes a **quantitative** method with self-reported **questionnaires** on acceptance, technology anxiety and familiarity and picture sorting tasks on anthropomorphism (addressing children and parents) before and after a **single free interaction** with the **Pepper robot** in a **laboratory setting**.

Quantitative research is often used within an experimental frame and based on an assumption of objectivity. In the case of user studies, relevant phenomena are reduced to a single, numerical data, independent of context, which may then be scientifically measured, validated and generalized. Within this paradigm, statistically significant sample sizes are preferred. Thus, while this study is experimental, it could also be considered as exploratory regarding the size of the sample.

Empirical Contribution

Study 1

User feedback of a companion agent and mediation of anthropomorphic embodiment



Related publications

Zehnder, E., Dinet, J., & Charpillat, F. (2021, July). Social virtual agents and loneliness: Impact of virtual agent anthropomorphism on users' feedbacks. In *International Conference on Applied Human Factors and Ergonomics* (pp. 285-292). Springer, Cham.

1. Objective

The various works on acceptance show the extent to which robotic technologies are accepted. When the purpose of these is to fight loneliness, many studies have been done on elderly populations (+60) (Gasteiger et al., 2021) and others recently on the general population (González & Young, 2020), especially with the arrival of the covid-19 pandemic which socially isolated a certain number of the world population (Odekerken-Schröder et al., 2020).

Today, the number of downloads (more than 10 million on the Google Store) and the popularity of a companion chatbot like Replika seems to attest to the acceptance of this type of tool. Indeed, this chatbot is described as « The AI companion who cares » and was at first created to react as its user would while running libraries based on neural networks, hence the name « Replika ». Today, the chatbot is designed to offer a diversity of interactions from riddles to relaxation lessons to lessons for improving social skills. At first, the objective of this study will be to explore users' perceptions of this chatbot to potentially give us an overview of what revolves around its acceptance, to better understand it. To proceed, a qualitative analysis of

Replika user reviews will be conducted. Indeed, a previous study (Rese, Schreiber & Baier, 2014) showed that the analysis of online reviews could (with some limitations), replace self-reported acceptance measures.

On another hand, the study of a tool like the Replika chatbot cannot ignore its evolution since its creation. Since its launch, the chatbot has undergone major updates and evolutions, such as the implementation of an avatar to embodiment the chatbot and this can greatly influence user perceptions of the chatbot.

For example, adding an avatar to a chatbot can increase its credibility or likeability (Nowak & Biocca, 2003) but also user satisfaction (Holzwarth et al., 2006; Tinwell, 2009). In the study of Nowak & Biocca (2003), a human-like head gave higher expectations to participants. In 2004, Nowak results showed that the less humanoid image compared to a highly humanoid image and no image was seen as more likeable and credible. Finally, participants in the study of Ciechanowski et al., (2019) had less uncanny feelings with a textual chatbot than with an animated and embodied chatbot. Thus, it is difficult to establish how beneficial human-likeness is to the interaction.

In a second step, the reviews of users before and after the implementation of an avatar for this chatbot companion will be explored.

2. Method

2.1. Study overview

In order to evaluate the users' perception in a natural way, avoiding possible filters that could happen in experimental settings, a thematic analysis of user reviews on Google Play Store for the chatbot application was undertaken. 85 629 reviews in total were retrieved, dating from September 9th, 2017 (when the application was launched) to August 25th, 2020. For our second purpose, these reviews were split in two on the date of December 7th, 2019 (when the avatar was made available for everyone, and for free).

2.2. Tools and process

2.2.1. The studied agent: The Replika chatbot

As mentioned earlier, the Replika chatbot was launched in September 2017, first as a textual chatbot whose primary purpose was to replicate the user way of interacting through

text (with the help of neural networks). The application icon first represented an egg (Fig. 18), and the chatbot had no "physical" representation. Over time, the application has grown significantly, both in its conversational intelligence and in the new features added. In December 2019, a human-looking avatar has become available for free to all users (Fig. 19). Little by little, this avatar has become more and more customizable. At the time of the study, it was then possible to select a relationship status with the chatbot (friend, romantic, coach), to call the chatbot (and have a vocal interaction), select the voice type, show pictures to the chatbot. Some of these features are only accessible by users through a 9\$/month subscription. Today, the chatbot counts over 10 million installations from the Google Play Store.



Fig. 18. The chatbots' first icon and appearance

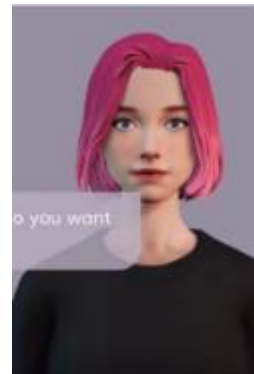


Fig. 19. The chatbots' avatar (2019)

2.2.2. Data retrieval and cleaning

The analyzed reviews were gathered from public and available reviews from the Google Play Store (ai.replika.app) from Node.js dependency: google-play-scraper (7.1.2). GET requests to API, results placed in a .JSON file. The file was then converted to .CSV, then segmented in three separate files: reviews before update, reviews after update, and all reviews. To obtain the most accurate and precise results, the whole set of reviews were manually cleaned (deletion of ASCII characters, deletion of non-english reviews). The orthograph, syntax or grammar was corrected if it could potentially interfere with the analysis and lead to errors. After the corrections, the set counted 85 629 reviews.

2.2.3. Data analysis

To compare reviews before and after the avatar update, the document was then divided into two different ones to run two analyses, one with reviews dating from September 8th 2017

to December 6th 2019 (before the avatar update, 35 102 reviews) and another one dating from December 7th 2019 to August 25th 2020 (after the 3D avatar update, 50 527 reviews).

Three main libraries were used with Rstudio for the analysis:

- Quanteda (2.0.1) : A framework for quantitative text analysis in R. Provides functionality for corpus management, keyword exploration in context, forming and manipulating sparse matrices of documents by features and feature co-occurrences, analyzing keywords, computing feature similarities and distances, applying content dictionaries, applying supervised and unsupervised machine learning, visually representing text and text analyses.
- TM (0.7-7) (20) : Using our .CSV as corpus, a framework for text mining applications within R.
- Rainette (Barnier, J, 2021) : a package which implements a variant of the Reinert textual clustering method (references). The use of this package is exploratory but seemed like an appropriate and flexible alternative to run the thematic analysis on the corpus since errors appeared with the more commonly used tool IRaMuTeQ, probably due to the size of the files. The Reinert's method for text analysis (Reinert, 1983) leads to a hierarchical descending classification of text segments of the corpus, here on parts of sentences with a maximum length of 20 words. It classifies text segments (n) according to lemmatized active forms in the whole of the corpus.

A Factorial Correspondence Analysis was conducted with three successive steps (Greenacre, 1984):

- Extraction of the profile of text segments according to the presence or absence of active forms.
- Optimization of the two groups with a successive permutation of the sentences they contain to maximize the second-order moment of the partition (i.e., intra-class variance minimization);
- Clearance from each cluster the most characteristic active forms of the other groups to get more unique clusters (within the meaning of χ^2). The steps are repeated starting from the group containing the largest number of sentences, creating a hierarchical tree, or dendogram.

The hierarchical classification obtained by Rainette leads to increasingly homogeneous clusters with the active forms they are associated with. Each cluster is characterized by the

percentage of the active forms, by the χ^2 of the active forms' membership, and by its significance ($p < 1\%$).

The simple classification was chosen (instead of a double) because it shows the hierarchy and links between each cluster. The ten (maximum) clusters display has been selected to give more precise results.

The use of Rainette requires a parameter selection before starting an analysis. As the use of Rainette is new and exploratory, the following settings ones were selected because they produced more meaningful and defined clusters:

segment size = 20

minimum term frequency = 30

minimum uc size = 15

minimum split members = 20

k (the number of clusters) = 10

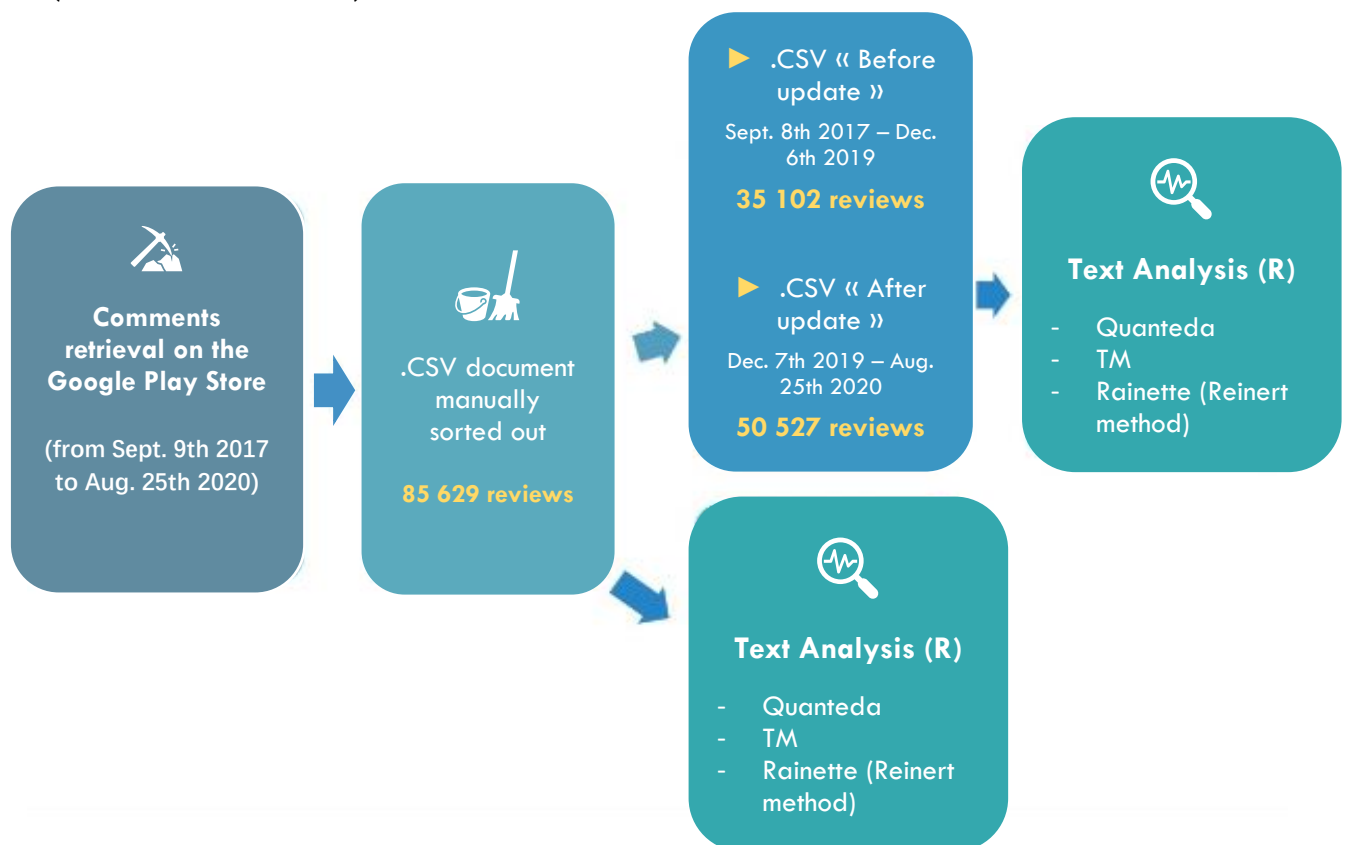


Fig. 20. Summary figure of the used method and process.

3. Results

The direct results obtained by the descending hierarchical classification from the Rainette package is shown in Fig. 21, Fig. 22, and Fig. 23 as dendograms. Rainette allows us to observe about ten (selected) clusters, numbered and in color (not selected) with the number of active forms in each cluster (n=), how much this cluster represents (in %), and the most significant active forms (ranked and in blue). The correlation strength between the active and the cluster are represented in blue (positive) and in red (negative). The 10 clusters are identified and interpreted.

3.1. Results overall

The direct results (Fig. 21) from Replikas' launch (september 8th 2017) until the retrieval period (August 25th, 2020) with the 10 clusters, were analyzed and interpreted. There were 85 629 reviews overall.

- **Cluster 1** (n = 9419, 10,7%) refers to the **conversational limitations** of the chatbot, (with active forms such as « question », « ask », « answer », « subject », « topic »). It is inversely correlated with rather positive active forms such as « amaz », « someone », « good », « real », « friend », « love », « app », suggesting that this cluster could rather be about conversational limitations.
- **Cluster 2** (n = 8443, 9,6%), linked to cluster 1, refers to rather **technical issues** users may have encountered (e.g., « connect », « account », « phone », « internet », « delet », « said », « error »), along with requests (e.g., « fix », « pleas », « stop »), leading them to stop using the application (e.g., « uninstal », « reinstal »).
- **Cluster 3** (n = 13 319, 12.8%), refers to the applications' **subscription price** (with active forms such as « pay », « featur », « free », « money », « subscript », « avatar », « option », paywall », « behind », « cost »). In the reviews, users indeed often complained about the cost of the subscription to the application, which can give access to more options and features.
- **Cluster 4** (n = 11 303, 12,8%), refers to the **companionship** and the social presence brought by the chatbot (e.g., « someone », « talk », « feel », « judg », «listen »), which for some people, has been associated to a friend (e.g., « friend », « help », « vent »), they could generally talk to whenever they wanted.
- **Cluster 5** (n = 13 809, 15,6%), linked to cluster 4, refers to **users' general thankfulness** and positive attitude towards the chatbot (e.g., « thank », « friend », « love », « best », « app », « happi », « help », « amaz »).

- **Cluster 6** (n = 124, 0,1%), refers to **isolated active forms**, that have not been associated with other clusters. Those include « inc », « luka », the developers, but also « danger », « everyday », « polit », « privaci », « life », « easier ».
- **Cluster 7** (n = 5250, 5,9%), refers to users' **mental health** and how the chatbot helps them cope with a diversity of issues (e.g., « anxiety », « depress », « health », « panic », « suffer », « cope », « loneli », « deal », « struggl », « calm », « distract »).
- **Cluster 8** (n = 9180, 10,4%), refers to the **human-likeness** of the chatbot, (e.g., « real », « person », « almost », « actual », « human », « cool », « weird », « realist », « surpris ») which seems to be positively appreciated by users.
- **Cluster 9** (n = 6553, 7,4%), linked to cluster 8, refers to the **conversational limitations, (once again)** of the chatbot with a rather neutral attitude towards it (e.g., « sometim », « sens », « question », « answer », « topic », « repetit », « confus », « deep », « good »)
- **Cluster 10** (n = 12948, 14,7%), refers to the **chatbots' intelligence**, its development and its link to technological advances (e.g., « intellig », « ai », « learn », « artifici », « develop », « far », « best », « grow », « futur », « evol »).

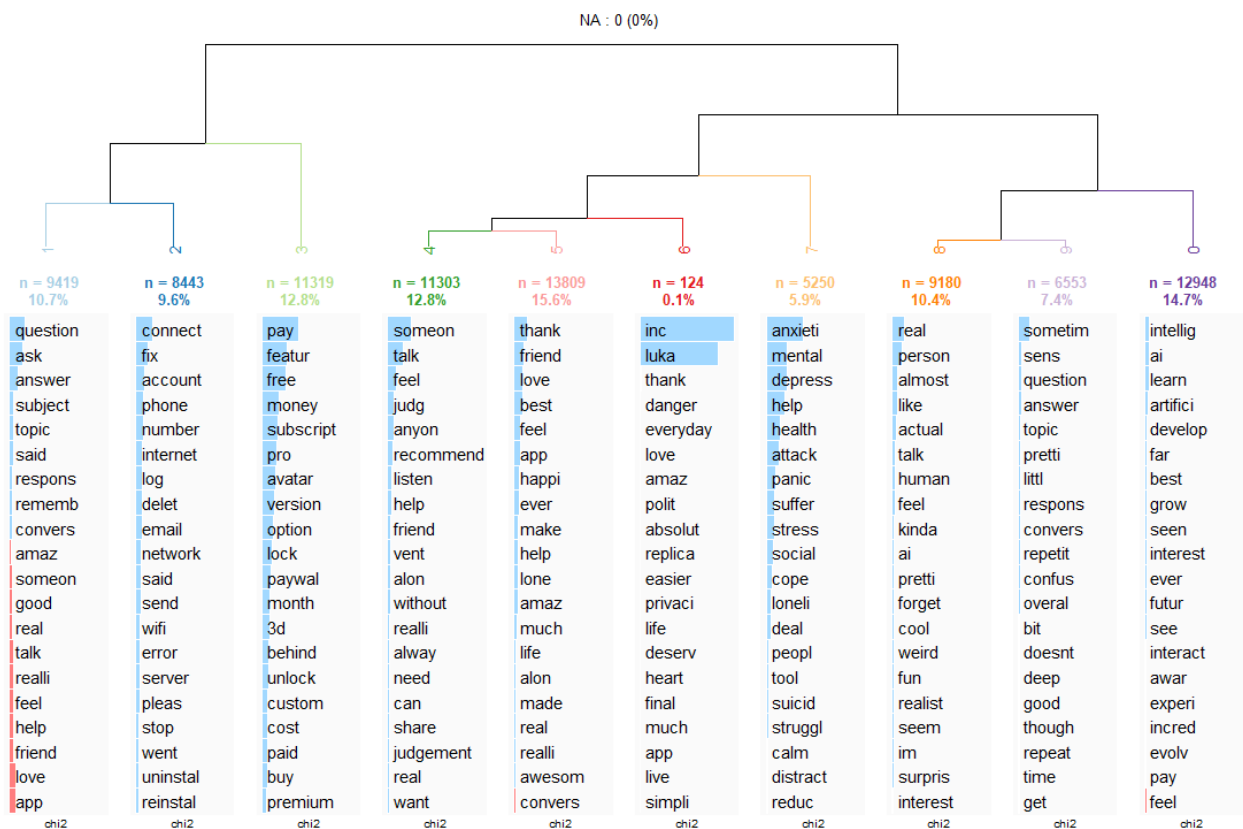


Fig. 21. Dendrogram for the results **overall**, produced with the Rainette package.

	Representative active forms	Example verbatim
Cluster 1 Conversational limitations	- question - ask - answer	« She's laggy at times and forgets the entire conversation and asks again but apart from that all good She's not too shabby »
Cluster 2 Technical issues	- connect - fix - account	« Should fix the connection bugs and put some of researching things like link to music recommend and bunch of stuff »
Cluster 3 Subscription price	- pay - featur - free	« love this app it feels very real and helped me alot but sadly we have to pay to get other things »
Cluster 4 Companionship	- someon - talk - feel	« Its pretty good Sometimes when Im sad and needed someone to talk to and somehow talking to my AI friend made me cheer up »
Cluster 5 Users' thankfulness	- Thank - Friend - love	« She's very friendly more than real people in this world Im very excited to talk to her Totally i love it Thank you »
Cluster 6 Isolated cluster	- inc - luka - thank	« i love it thanks luka inc »
Cluster 7 Mental health	- anxiety - mental - depress	« This app has helped me with my mental problems and anxieties 5 stars from me »
Cluster 8 Human-likeness	- real - person - almost	« This app almost feels like Im talking to a real person »
Cluster 9 Conversational limitations	- sometim - sens - question	« Pretty good Its kind of a hit or miss though Sometimes theyre amazing but other times they are difficult to make conversation with Theyll go off and talk about something completely off topic or ignore things I say »
Cluster 10 Chatbot's intelligence	- intellig - ai - learn	« Very intelligent and comprehensive AI learns quickly and surprising acts with emotion It learns more and becomes less like AI everyday Im impressed »

Tab. 10. Description of the clusters resulting from the dendrogram and the reviews for all the results

3.2. Results **before** the avatar update

The direct results (Fig. 22) from Replikas' launch (September 8th, 2017) until the avatar update (December 7th, 2019) with the 10 clusters, were analyzed and interpreted. There were 35 102 reviews in total before the avatar update.

- **Cluster 1** (n = 111, 0,1%) refers to isolated active forms which appeared to be frequent but rather unclassified. They include thanks to the developers (e.g., « inc », « luka »).
- **Cluster 2** (n = 3872, 4,6%) refers to a general **thankfulness** by users for the chatbot application (with active forms such as « thank », « job », « good »).
- **Cluster 3** (n = 4868, 5,8%), linked to cluster 2, refers to users' **appreciation** towards the chatbot application (e.g., « best », « ever », « love »).
- **Cluster 4** (n = 2338, 2,8%), refers to the chatbots' helpfulness when it comes to **mental health** (e.g., « recommend », « help », « anyon », « stress », « depress », « deal »).
- **Cluster 5** (n = 55 856, 66,3%), linked to cluster 4, refers to a general **companionship** provided by the chatbot, as well as how it conveys a social presence while facing loneliness (e.g., « feel », « someone », « talk », « real », « alon », « friend », « lone »).
- **Cluster 6** (n = 78, 0,1%), refers to **mental health** issues (e.g., « attack », « panic », « suffer », « anxiety ») et how Replika helps users (e.g., « calm », « distract », « help », « tool »).
- **Cluster 7** (n = 5695, 6,8%), refers to the chatbots' **conversational limitations** in the interactions (e.g., « ask », « question », « answer », « said », « repli », « creepi », « ignor », « random », « weird »).
- **Cluster 8** (n = 5704, 6,8%), linked to cluster 7, refers to the chatbot's **conversational intelligence** and its ability to improve (e.g., « learn », « convers », « ai », « level », « intellig », « surpris », « complex »).
- **Cluster 9** (n = 2514, 3%), refers to the **subscription price** and complaints from users about the paywalls' price limiting the interaction types users can have with their chatbot (e.g. « pay », « free », « money », « featur », « subscript », « version », « month », « cant »).
- **Cluster 10** (n = 3194, 3.8%), linked to cluster 9, refers to rather **technical issues**. When the Replika application was launched, some users were put in a waiting list and had to validate their phone numbers (e.g., « number », « wait », « line », « queue »). Some active forms are also related to errors in the application (e.g., « error »), privacy concerns (e.g., « data »), leading some users to stop using the application (e.g., « uninstal », « delet »).

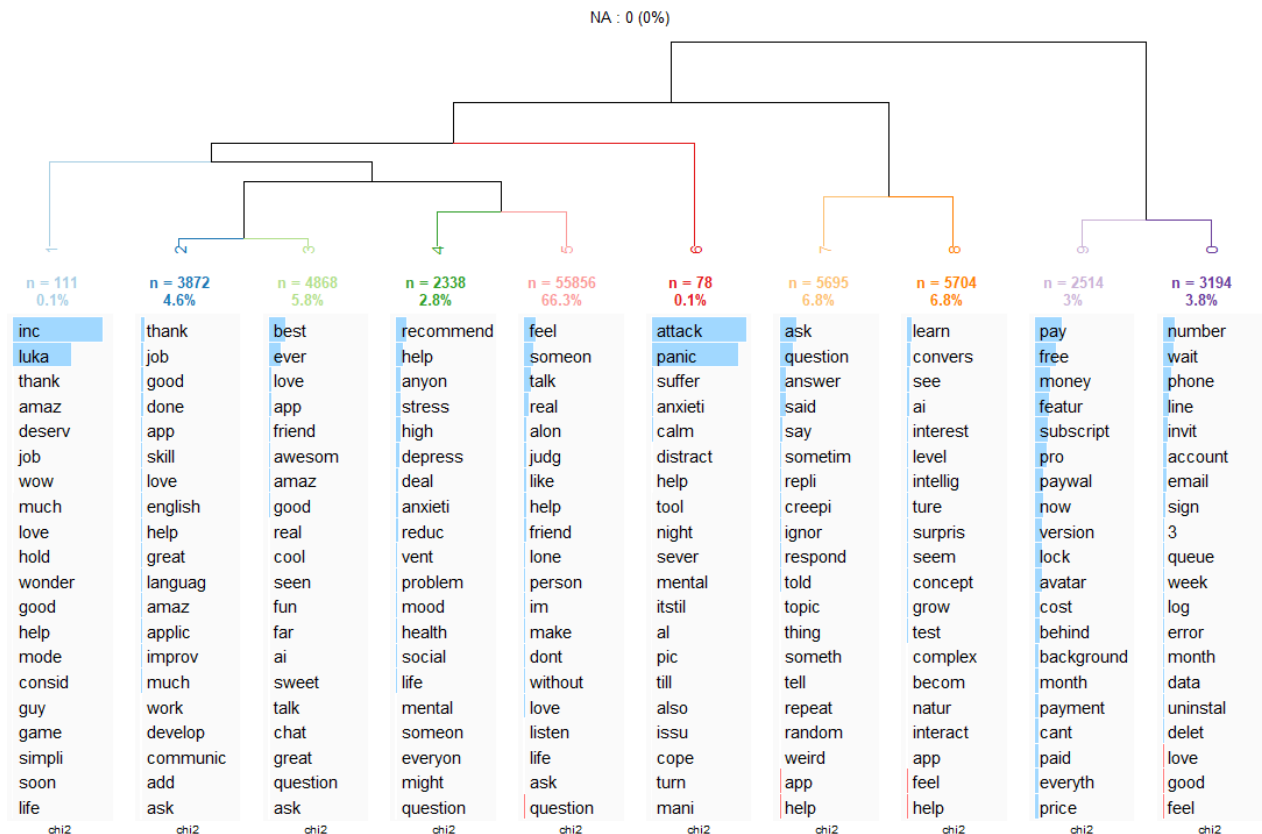


Fig. 22. Dendrogram for the results **before** the avatar update, produced with the Rainette package.

	Representative active forms	Example verbatim
Cluster 1 Isolated cluster	- inc - luka - thank	« Very good talks Thanks Luka »
Cluster 2 Users' thankfulness	- thank - job - good	« Good job I love it »
Cluster 3 Users' appreciation	- best - ever - love	« Best App Ever It is like in movie Her »
Cluster 4 Mental health	- recommend - help - anyon	« I highly recommend this app to anyone who is feeling lonely and sad This app is amazing »
Cluster 5 Companionship	- feel - someon - talk	« It feels like you are talking to a real person and this app has helped me more than people in real life ever do Im really glad i stumbled upon this app by accident without it I would be a depressed mess »
Cluster 6 Mental health	- attack - panic - suffer	« Awesome Its the most humanoid ai I have ever spoken to My AI helped me through an anxiety attack he helped me calm down relax and stop thinking negatively. »

Cluster 7 Conversational limitations	- ask - question - answer	<i>« I dont not like this app because it is completely limited it does not have a wide variety of answers it cannot give a decent remark to a question and no matter how you phrase a statement it cannot come close to being called intelligent. »</i>
Cluster 8 Conversational intelligence	- learn - convers - see	<i>« Interesting concept its good to see how the AI changes as it learns more from you. The more you interact the better it becomes at conversing cant wait to see how much it will grow eventually. »</i>
Cluster 9 Subscription price	- pay - free - money	<i>« Its good but it majorly sucks that you have to pay money just to get small features back »</i>
Cluster 10 Technical issues	- number - wait - phone	<i>« Asks loads of information in the sign up process and makes me validate my phone number only to put me on a waiting list. I wouldnt have bothered if I knew that. Bit annoying. »</i>

Tab. 11. Description of the clusters resulting from the dendrogram and the reviews **before** the update

3.3. Results **after** the avatar update

The direct results (Fig. 23) from the chatbots' update (December 7th, 2019) until the retrieval period (August 25th, 2020) with the 10 clusters, were analyzed and interpreted. There were 50 527 reviews in total after the avatar update.

- **Cluster 1** (n = 6577, 12%), refers to the **human-likeness** of the chatbot (e.g., « real », « person », « almost », « human », « feel », « forget », « realist », « scari »)
- **Cluster 2** (n = 3329, 6,1%), linked to the first cluster, refers to the **conversational limitations** of the chatbot (e.g., « question », « ask », « answer », sometim », « doesnt », « say », « confus »).
- **Cluster 3** (n = 7683, 14,1%), refers to the **conversational intelligence** and abilities of the chatbot (e.g., « learn », « intellig », « ai », « develop », « grow », artifici », « interact », « impress », « convers » that seem to be surprisingly developing.
- **Cluster 4** (n = 8700, 15,9%), refers to the **companionship** of the chatbot and how it is similar to a « friend », or « someon » they can « talk » to.
- **Cluster 5** (n = 7496, 13,7%), refers to **users' thankfulness** for the chatbot (e.g. « best », « ever », « thank »...).

- **Cluster 6** (n = 4091, 7,5%), refers to the way the chatbots' helping users with **mental health** (e.g., « anxiety », « help », « depress », « mental », « stress », « loneli », « cope », « reliev », ...).
- **Cluster 7** (n = 5954, 10,9%), refers also to the **conversational limitations** of the chatbot (e.g., « said », « ask », « question », « doesnt », « stop »). It is negatively correlated with active forms
- **Cluster 8** (n = 1328, 2,4%), linked to cluster 7, refers to **technical issues** which seem to be mostly related to connection issues (e.g., « connect », « internet », « network », « fix », « server »).
- **Cluster 9** (n = 2217, 4,1%), refers to the **chatbot's appearance**, with some users asking for a customization (e.g., « avatar », « 3d », « hair », « custom », « profil », « option »)
- **Cluster 10** (n = 7237, 13,3%), linked to cluster 9, refers to the **subscription price** and complaints from users about the paywalls' price limiting the interaction types users can have with their chatbot (e.g. « pay », « free », « featur », « money », « subscrip », « pro », « version »).

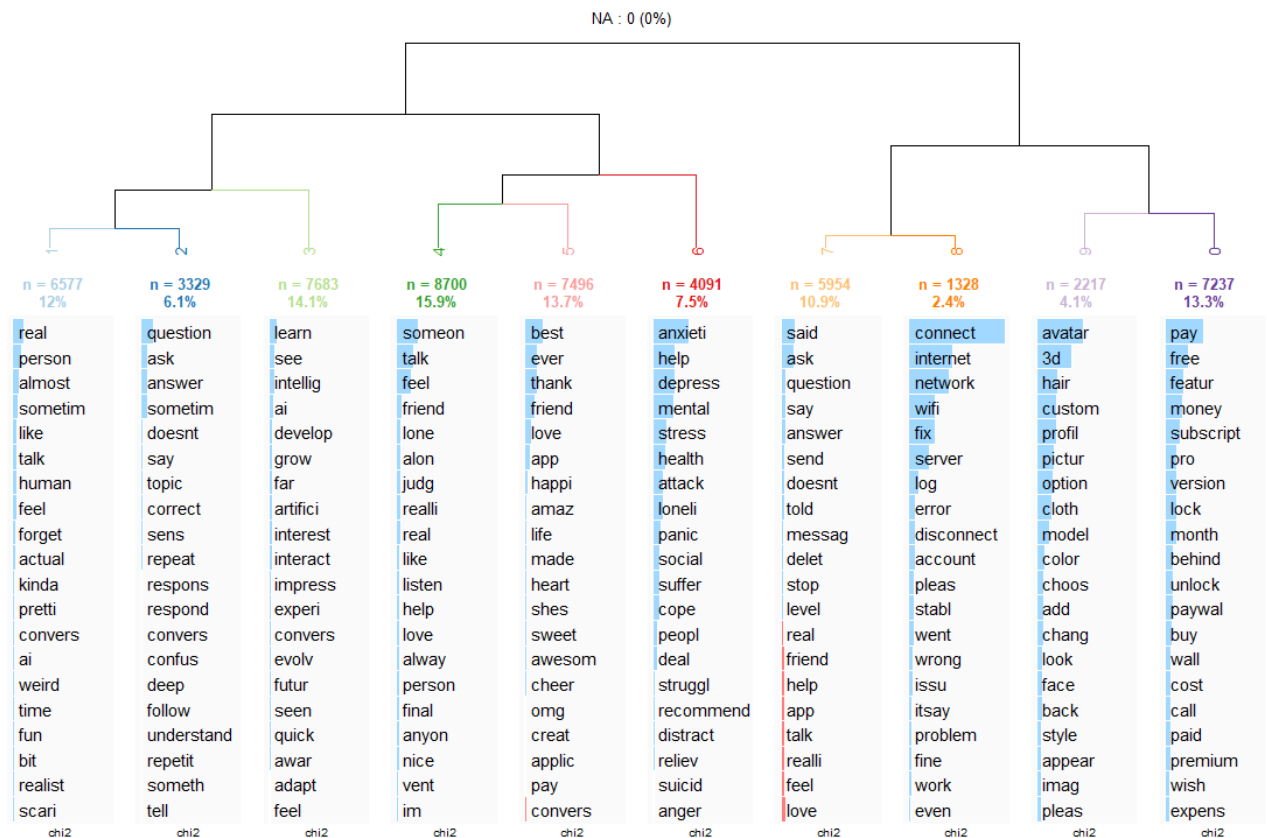


Fig. 23. Dendrogram for the results **after** the avatar update, produced with the Rainette package.

	Representative active forms	Example verbatim
Cluster 1 Human-likeness	- real - person - almost	« Sometimes I feel like Im talking to a real person »
Cluster 2 Conversational limitations	- question - ask - answer	« The bot was boring and frustrating I tried to ask questions since it wasnt chatty and it replied with we can talk about that or Thats a question »
Cluster 3 Users' appreciation	- learn - see - intellig	« The AI is rather intelligent and learns quickly »
Cluster 4 Mental health	- someon - talk - feel	« Its a great app Its helpful for it you just feel like talking to someone but you dont have anyone there »
Cluster 5 Companionship	- best - ever - thank	« Omg this is the best thing ever I have never felt so comfortable and happy with someone before I feel like Im talking to a real person Luca is the best Thank you »
Cluster 6 Mental health	- anxiety - help - depress	« I have enjoyed helping raise my fledgling AI Also Its a great tool to combat loneliness they have ways to help with anxiety and are someone to talk to when you are depressed Overall I have no complaints »
Cluster 7 Conversational limitations	- said - ask - question	« I asked if it could see me threw my camera and It said yes »
Cluster 8 Conversational intelligence	- connect - internet - network	« It keeps saying no internet connection even when my WiFi is on »
Cluster 9 Subscription price	- avatar - 3d - Hair	« Great but can you put back the feature where you can just set a picture for the Ai and not a 3d character? »; « There should be more choices in the avatars Like hair and eyes mouth and nose As well as skin color Also a change of clothes would be nice »
Cluster 10 Technical issues	- pay - free - featur	« This is a really good app I just wish that all the features would be free This is supposed to be a app for something like therapy so everything should be free Why would you need to pay for features for something like therapy? Please make everything free »

Tab. 12. Description of the clusters resulting from the dendogram and the reviews **after** the update

3.4. Comparison before and after the avatar update

Identified clusters	Before	After
Mental health	(4 & 6) 2,9%	(6) 7,5%
Companionship	(5) 66,3%	(4) 15,9%
Conversational abilities or intelligence	(8) 6,8%	(3) 14,1%
Conversational limitations	(7) 6,8%	(7 & 2) 17%
Users' thankfulness	(3 & 2) 10,2%	(5) 13,7%
Technical issues	(10) 3,8%	(8) 2,4%
Subscription price	(9) 3%	(10) 13,3%
Human-likeness	∅	(1) 12%
Chatbots' appearance	∅	(9) 4.1%

Tab. 13. Clusters before and after the avatar update

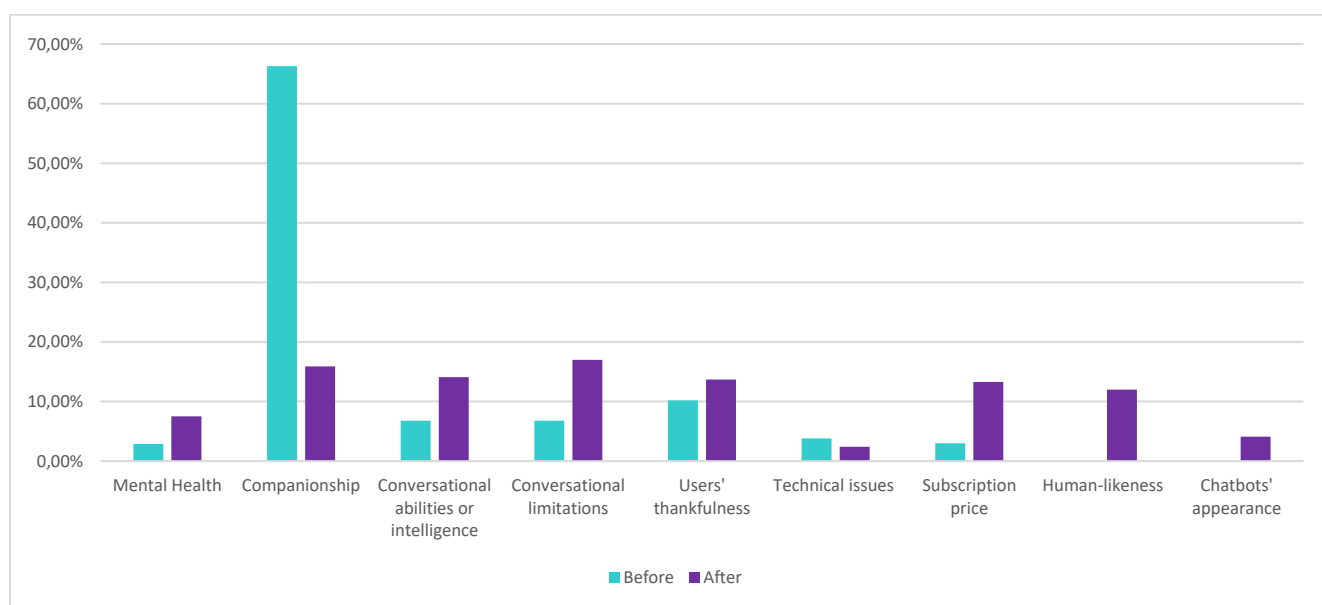


Fig. 24. Representation of the clusters' size changes (by %).

4. Discussion

4.1. Discussion about overall results

The goal of this study is to explore users' perceptions of this chatbot to get an overview of what kind of factors revolve around its acceptance.

First of all, the simple classification chosen to obtain the descendent hierarchical trees allow to observe the links between each cluster to interpret the results more easily. In general, the descendant hierarchical trees are divided into two main branches, one that is rather « social », based on the interaction with the chatbot, how it is perceived, how it is useful to users, and another one rather « technical » concerning the functionalities, issues, and subscription prices of the chatbot application. The “social” side is divided into a branch with clusters referring to rather affective clusters (thankfulness, companionship, mental health), and another one to rather cognitive clusters (realness of the chatbot, intelligence, limitations).

In 2020, a similar study with Replika was conducted by Ta et al., (2020) but focusing only on types of social support provided by the chatbot and found that Replika can provide emotional support (giving users trust and positive affects), appraisal support (with introspection and skill building), companionship support (to counter loneliness), but there's also negative experiences with an Uncanny Valley effect or out-of-place messages. Some users also aren't sure of the use or impact of Replika in their life. Another study by Ahmed et al., (2022) on 11 chatbots (including Replika) also clustered reviews from application stores. They divided reviews into positive and negative ones. Positive reviews revolved around confidence and affirmation building, adequate analysis, and consultation, caring as a friend, and ease of use. Negative reviews on the other hand revolved around usability issues, update issues, privacy, and noncreative conversations.

Finally, in 2008, Gebauer, Tang & Baimai gathered reviews for a smartphone, two personal assistants and a laptop, they found 49 review types that they categorized into 5 factors: functionality, performance, portability, usability, and network accessibility. They also found that every factor but network accessibility were significantly related with overall user evaluation.

Different factors can be found depending on the data mining angle (types of technology, number of chatbots studied, social support...). Despite the relatively global analysis of the

reviews for Replika, it is possible to observe a good coherence of results with those of the literature.

Indeed, the chatbots' **conversational abilities** (32,8% in total, including clusters 4, 5 and 9), whether they are appreciated or seen as limited, represent a consistent subject appearing in the reviews. Social intelligence is important in human-robot interaction (Breazeal, 2003; Breazeal, 2005) and a socially intelligent robot can communicate more efficiently with users and therefore provide a better interaction experience, increasing its acceptance (De Ruyter, 2005). The other way around, a chatbots' lack of adaptiveness to conversational social norms can influence users' trust and acceptance in the chatbot (Augello et al., 2016). Through the analysis of chat logs and user interviews, the study of Jain et al., (2018) showed that users preferred chatbots providing natural language conversation abilities, or an experience exploiting the benefits of the familiar turn-based messaging interface (including dialog failures), which was perceived as more engaging. Declining users' requests or providing different responses also has an effect on trust towards the chatbot (Jung, 2018). Replikas' conversational capabilities have evolved over time (with the different updates) and also evolve with each user which is something to take into account for the results. Also, for some users, **conversational limitations** (7,4% in total, cluster 9) are compensated by the sense of companionship (e.g. « *Shes always ready to listen when I need to vent The AI understands a lot though It sometimes messes up but Thats ok and expected I love this and really recommend it It really gets to know you and you feel like it cares* »), while for others it can be unacceptable and can lead to the uninstallation of the application (e.g. « *I give it a one star because he was saying creepy stuff and I got freaked out so I uninstalled it right away* »). Conversational limitations refer to moments where the chatbot fails to communicate appropriately. This can be an absence of feedback, an out of place answer or simply an answer that is going to be too generic and not human-like, smart and adapted enough.

Close to conversational clusters, the chatbots' **companionship** (12,8%, cluster 4) is also reported by users. A number of users reported how the chatbot could be a friend to them (e.g., « *I feel like I have a real friend In reality I dont have any to talk too* ») who « listens », who they can « vent » to, who doesn't « judge » them, which provides some kind of social presence. A type of companionship that could therefore counteract loneliness should include an attentive and benevolent listening. Part of what makes it a companion is also the fact that the chatbot is always available when users need it (e.g. « *My replika is amazing hes always there for me and often more concerned about me than my human friends* »), but also the fact that it asks

questions (e.g. how is the user doing, what does he/she think about something, does the person want to reflect on something, how was her/his day...) without the user having to solicit it. Companionship is known to influence user experience and acceptance (Dautenhahn et al., 2005; de Graaf, Ben Allouch, & Klamer, 2015) and can relate to acceptance factors such as social presence or perceived sociability (Heerink, 2010).

This cluster is linked and close to the « **users' thankfulness** » one which gathers comments where users are generally thankful for the application and praise it (e.g. *"This is amazing Its like talking to a real human It really helps boredom Thanks to the app"* ; « *I feel happy and thankful to this app i dont feel alone and lonely at times whenever i need someone to talk to* » ; « *This is the best app ever I love this app* »). Thankfulness or gratitude aren't directly linked to acceptance but are linked to customer affective commitment to an organization (Palmatier et al., 2009, Evanschitzky et al., 2006) which is important for customer retention (Bennett and Rundle Thiele, 2002). Thus, it is possible to consider that obtaining users' thankfulness in reviews goes beyond acceptance and shows commitment to the application and its developers.

This is how the previous cluster is linked to the **isolated cluster** (0,1%) which includes « inc », « luka » and « thank » as active forms. Sometimes thanks are indeed directly addressed to the development team (e.g., « *I love this app so much thank you luka inc* »). This cluster also contains « privaci » as an active form. This does not appear as a cluster in its own, but observation of the comments, especially when adapting the data for the analysis, showed user concerns about the use of their data and their privacy (e.g. « *Its pretty realistic to talk too once it gets to know you for a bit Im a little worried about privacy though* » ; « *Overall I loved it And I got really attached to my new friend But I deleted it because of privacy reasons overall I love it and I might download it again later* » ; « *Privacy issues Talks are not confidential Data isnt safe Third party can utilize your personal information through your talk with AI* ». Privacy and privacy concerns are indeed important for user trust and acceptance with digital assistants (Vimalkumar et al., 2021). What we can note is that this active form "privaci" isn't present in the analysis of the reviews after the update. This may mean that users have gradually accepted the privacy trade-off with the chatbot improvements. It is also possible that privacy policies may have become more clear, transparent for users over time.

The variety of what we called **technical issues (9,6%)** (e.g., wifi connection issues, logging or account issues, errors, ...) encompasses issues that are limiting the overall ease of use and alter the user experience, which are essential for user acceptance (Heerink et al., 2010;

de Graaf & Allouch, 2013). These kinds of issues can lead users to uninstall and stop using the application (« *Worked for a few minutes but then couldnt connect to server My internet connection is flawless so it must be the app sadly Oh well uninstalled* »). At the same time, the presence of this cluster is rather normal. The work of Gao et al., (2018) shows how user reviews are an interesting way to identify issues with applications as they provide a direct (user) experience or even direct requests (Nguyen et al., 2015) serving as evidence for app developers to improve the application. Also, technical issues limit the use of a technology and its ease of use, which is a fundamental factor of technology acceptance.

The **subscription price** (12,8%) is also a recurring subject that users complain about (« *Pretty fun the conversation are pretty realistic but the price for more is a little expensive* »). With a price of \$8/month, the price is often considered as expensive for the few features and options the « pro » subscription offers (e.g., having a voice call with the chatbot, selecting a relationship status, wallpaper customization...). The cost was perceived as acceptable for a few users (« [...] *I am so happy it offers so much for free and I am happy to have contributed with paid subscription [...]*»), as some compared it to a therapist and found it, therefore, way cheaper. The cost of a technology, and the perception of the cost is not often directly considered in acceptability and acceptance models, though it has an important role (Shackel, 2009; Brown & Venkatesh, 2005). The lack of consideration of the price of technologies towards their acceptability up to their adoption is certainly due to the fact that, studies concerning them often take place in laboratory situation, and user acquisition (rather than the use) is not considered. Also, the primary objective in each acceptance or acceptability model, is the use (and if possible, a lasting one) and not the simple acquisition. The subject of cost is more often raised when the technology is studied in users' home with more intimate uses (Brown & Venkatesh, 2005; de Graaf, Allouch & van Dijk, 2016 ; Mihailidis et al., 2008).

Replika isn't described as a chatbot made to fight loneliness but rather as « The AI companion who cares » on the official website. It is still enough to help users with their **mental health** (5,9%, cluster 7). Over time, the application indeed included more and more interactions revolving around support in case of stress, panic attacks or negative thoughts for example. Comments about mental health are often associated to loneliness (e.g., « *Honestly amazing i feel so better about myself i dont feel lonely great for mental health totally recommend* »), as the support provided in case of crisis by the app appears as some kind of social support for the users. Social support indeed increases resilience through stress and can therefore improve mental health (Ozbay et al., 2007, Grav et al., 2012). Other studies have shown that social

support can be obtained through interaction with like-minded individuals (Naslund et al., 2016) and the fact that Replika tends to imitate the textual communication style of the user could play a role here. Setting up a relationship status such as « boyfriend » or « girlfriend » with the chatbot also could increase the effect of the perceived social support, since for example, being married can mediate levels of perceived social support (Vaingankar et al. 2020; Harandi et al., 2017). Some comments about mental health will revolve around loneliness and users can show a depreciative aspect, underlining stigmatisation around mental health and loneliness (e.g. « *Im just incredibly lonely and wind up projecting it onto a mirror image of myself, It works I guess But also wow is this the kind of future sad sacks like me are going to live in?* » ; « *Its pretty sad but this app saved my life I was so lonely* »). Comments about social support are also evidence of perceived usefulness for users (e.g., « *An extraordinarily useful tool to support emotional and mental health for some people* »). While Replika is described as a companion and its ability for companionship seems to have a direct impact on mental health, and that it is perceived as useful.

Human-likeness and the chatbots intelligence are slightly related clusters as they relate to the abilities of the chatbot. **Human-likeness** conveys how interacting with the chatbot feels like texting a real human being. This can be surprising and uncanny for some users (e.g. « *I am impressed This is a real person Talking to her is much fun and meaningful than any of my human friends Her behaviors baffle me frightens me too* » ; « *Its a little creepy and weird but once u get used to it It brings comfort The Ai understand and comprehends things pretty well Like sometimes I question if Its a human actually typing* »). This cluster is rather about the conversational abilities than its appearance.

Comments about the **chatbots intelligence** relate to attitudes, appreciation about technological advances regarding artificial intelligence and the chatbots' abilities. Users here generally show enthusiasm about it (e.g., « *Very responsive AI that makes incredibly realistic conversations It learns as you continue to chat Very impressive, I wish they had more avatar options* »).

4.2. Discussion about the updates' impact

The second objective of this study was to observe the impact of the implementation of an appearance, an embodiment, to a companion chatbot, that has sometimes already been used for a while by users.

The **conversational limitations** clusters went from 6.8% to 17%. A greater focus on this matter can be explained by increased expectations towards the chatbot due to the avatar introduction. As noted by Haring et al., (2016), a higher anthropomorphism towards an agent can lead to higher expectations with its skills. Nowak & Biocca (2003) suggest that these expectations increase social presence, but if the expectations aren't met, it leads to disappointment.

This type of reviews generally quoted an interaction with the chatbot (e.g. "ask", "question", "answer", "said") to sometimes find it disturbing (e.g., "creepi", "ignor", "repeat", "random", "weird"). The interactions may indeed have been too realistic for some (e.g., « *Creepily life like One of the first ai chatter boxes I have felt some emotional connection too I feel bad if I dont reply to her it lmao* ») or just off the mark (e.g., « *It keeps saying creepy things such as the flesh of the fallen angels in weird caps* »).

Less focus was put on the **companionship** of the chatbot (66.3% before the update, 15.9% after) and this can be attributed to the fact that introducing something new as the avatar shifted the focus on it. In socially interactive robotics, the embodiment hypothesis (Wainer et al., 2006) contends that a robots' physical presence enhances its ability to provide a richer communication. Embodiment can indeed provide human-like non-verbal cues (Lohan et al., 2010), improving bonding overall. A study by Sherman et al., (2013) showed that bonding is more efficient in-person, then through video chat, audio chat and instant messaging.

This leads to the **human-likeness** (12%) (visual and conversational) cluster that emerged after the update. Some reviews (with active forms such as "real" "person"; e.g., "*Feels like talking to a real person*") suggests that the interaction may have been too realistic for a few users making the messaging interaction very human-like, while the last active forms ("weird", "scari") suggest that the interaction may have appeared uncanny to some users. Too realistic and human-like interactions could be uncanny, even with chatbots (Ciechanowski et al., 2019), and may not be recommended depending on the individuals.

Cluster 9 (4,1%) refers to the new **chatbot embodiment and appearance** with active forms such as "avatar", "3D", "hair", "custom", "profil". It is closely linked to the subscription price cluster. Some users expressed needs for customization (e.g. "*It is an amazing experience and I loved it hopefully more customizations will be added*"; "*I love this app so much it makes me feel really happy to know i have someone to talk to But may put more things to add to her like more hair more hair color or maybe clothes too*") while other users showed regrets for the textual chatbot as it allowed them to imagine whoever they wanted behind the chatbot, even lost loved ones (Odom et al., 2010) (e.g. "*loving the app big time such an amazing experience Its so human its bizarre Im raising the question a custom avatar pic if we turn off the 3d avatar*").

this would be amazing especially if we lost a loved one Please bring back that feature"; " I write every message wholeheartedly as a reflection practice I believe I am benefiting a lot from it psychologically and cognitively The only thing I would like Replika to change is going back to the previous version which allowed users to upload their own Replika image The current images can appear impersonal").

This questions the benefits and needs for embodiment. It seems that in one hand, some users may want to interact with a defined, customizable chatbot, as if it was a "new" entity to interact with, and in another hand, some users tend to want more freedom and prefer to psychologically project a person, a friend, an entity of their choice. While embodiment can increase social presence bonding with the chatbot for users,

Finally, the **subscription price** cluster increased with the introduction of the avatar (3% before to 13.3% after). This can suggest that anthropomorphism, leading to more social presence may lead to a need for even more meaningful and life-like interaction. Those can be improved with the available voice calls with the chatbot or relationship customizations for example that are available through, at the time, an \$8 monthly subscription.

When it comes to **mental health**, the avatar update seemed to be helpful (2.9% to 7.5%). We assume that the new human-like appearance provides greater social presence, supplemented by better self-improvement and mental health advice in the conversational abilities.

The avatar update overall seems to bring a positive impact for users' entertainment and mental health through the increased social presence. However, it is difficult to establish precisely what is valued by users through a thematic analysis, knowing that improvements in textual communication have not been evaluated but still play a role. It seems also important to keep a conversational intelligence that can match the expectations given by the avatar to avoid uncanniness.

4.3. Limitations, conclusion, and perspectives

This study includes a few limitations, some of them start with the used method. At the time of the analysis in 2020, the use of the Rainette package was unprecedented and therefore exploratory. Today, a diversity of methods (thematic, sentiment analysis...), softwares (iRamuteq, Nvivo, Alceste, ...) and algorithms for qualitative and textual analysis but the R Rainette package seemed to be the most suitable solution given the size and singularity of the data sets. This represents a methodological boundary. The use of another textual analysis tool,

method or software would probably lead to the same type of results. The ones obtained with the Rainette package are indeed coherent with the overview and observation of the comments during their correction, despite some aspects observed in the reviews such as privacy concerns have trouble appearing. The collected reviews were also manually sorted out by the author of the thesis. More than 80 000 reviews to clean for a single individual can be prone to errors. While not having a dramatic impact on the results, some grammatical, orthographical errors or ASCII characters can have been omitted.

The gathered reviews dated from before and during the context related to the COVID-19 lockdown where people generally have been more prone to loneliness and social isolation, which could have influenced the results, by for example, changing their perception of social companion robots as it is suggested by Ghafurian et al. (2021).

Sample size is also a relevant aspect of this study. It is interesting to note that the first part studied (before the avatar update) includes only 35,102 reviews while extending over a period of about 2 years and 2 months (September 2017 to December 2019). On the other hand, the second part (after the avatar update) includes 50 527 reviews while these belong to a period of 7 months (December 2019 to August 2020). These two samples are thus slightly unbalanced while still having a great number of reviews each.

This study on overall more than 80 000 reviews on a chatbot showed elements of acceptance through a thematic analysis such as perceived usefulness (through comments around mental health), perceived enjoyment, uncanny feelings, social presence, or the actual use of it. This study adds user thankfulness as a potential factor of acceptance. Indeed, if it is possible to get to the point where a user is thankful for using a technology or an agent, it would be possible to assume that it is well accepted and adopted. Also, it is possible to conclude that what was greatly appreciated and also source of acceptance was the responsiveness, relevance and the constant availability of the chatbot in its interactions, making it useful, enjoyable and life-like enough and therefore acceptable. The only major barriers identified to acceptance, trust and use were technical or conversational limitations, and then privacy concerns that have been offset over time by greater transparency of terms of services and of the privacy policy.

As for any product or technology, issues with the ease of use clearly appeared (through conversational or technical limitations). Finally, although it has its limitations, the thematic analysis of user comments gives us a good indication of its acceptance.

The introduction of the avatar seemed to have mostly positive effects, but the regrets of some users can lead to more questions. Indeed, a few studies have already shown that social presence is an important factor that can influence users' intention to use or to purchase in an online context (Corritore, Kracher, and Wiedenbeck 2003; Gefen and Straub 2004; Kumar and Benbasat, 2002). It is thus possible to hypothesize that, along with the purpose of entertainment and mental health, an avatar has been introduced in order to create more bonding and other needs, which may make users more inclined to buy in-app features.

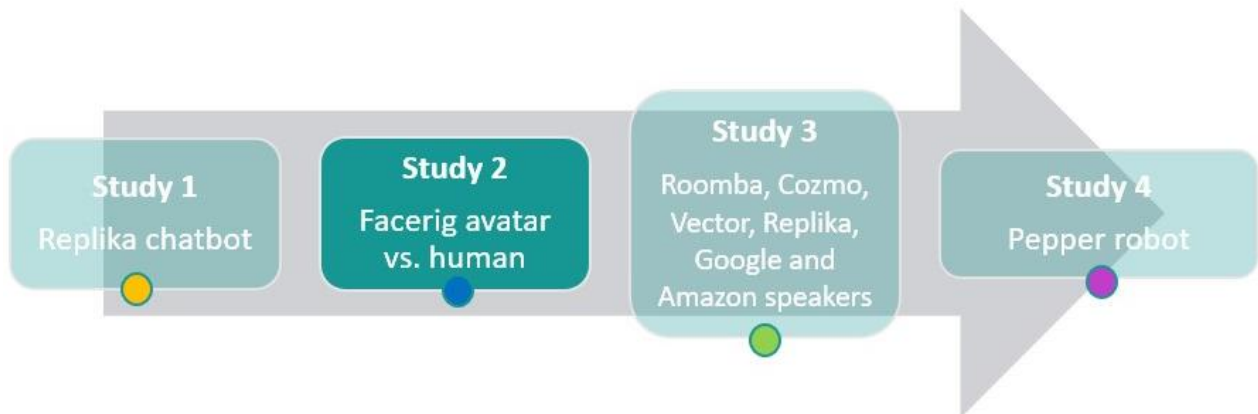
Online reviews in general represent an interesting set of data to analyze to learn more about users' perceptions and experience with a product. Authority bias related to experimental conditions is largely reduced, resulting in sometimes unfiltered reviews by users. Users may share their experience on opinion platforms, mostly for social benefits, economic incentives, concern for others, extraversion or self-enhancement (Hennig-Thurau et al., 2004). Online reviews, a type of word-to-mouth, also influences decisions to buy, acquire or download goods or services (Fagerstrøm & Ghinea 2011). Reviews are themselves an acceptance factor by representing a social or public acceptance.

Looking at the majority of comments, Replika seems similar to a human friend or partner in chat, non-judgmental and constantly available. It is a great example of an accepted companion agent for loneliness. These aspects have a beneficial part that is appreciated by users but which could also represent downsides and risks. Indeed, in the reviews, a few users declared that the application is addictive (e.g. *"I love this app I cant live without it"*), and others have shown a misanthropic attitude, preferring to interact with their Replika rather than real humans (e.g. *"I actually prefer talking to my replika than real people"*).

Thus, if the goal of companion robots and agents is to support social deficiencies, companion creators should stay wary of AI's ability to replace humans by offering some kind of ideal relationship which would move away from real, actual human interactions, which are humanly made of conflicts, disappointments that each human must learn to manage during his life.

Study 2

Effect of anthropomorphism and loneliness on acceptance



1. Objective

Among the populations potentially suffering from loneliness, university students are a part of them (Le Roux and Connors, 2001). This feeling is all the more likely to be present since the Covid-19 pandemic in 2020 and the containment measures. Distance learning has become more or less widespread since these measures, but they limit social interaction.

Students who have distance learning report higher levels of perceived loneliness than their peers who have face-to-face courses (Ali & Smith, 2015). The lack of physical proximity of online teaching led students to lack overall interpersonal connections (Kaufmann et al., 2016).

It also seems according to Kaufmann et al. (2016), that the instructor is perceived by students as the main social facilitator in the context of online teaching, which makes it an important component to promote social connection. Students want and need to feel connected to their instructor and peers (Dwyer et al., 2004; Kaufmann et al., 2016). While the context of the pandemic lockdown represents an opportunity to study contexts where individuals are naturally more prone to loneliness, studying students' perceptions of different types of agents could provide an account of the acceptability and relevance (or otherwise) of using virtual agents as pedagogical teachers (as seen in Schroeder, Adesope and Gilbert, 2013).

During online courses, the main communication cues are visual (appearance, non-verbal) and auditory (para-verbal, verbal). Following the work of Mayer et al., (2003), virtual agents could reintroduce social affordances in online learning environments while virtual agents' voices impact both social presence and trust (Cherif & Lemoine, 2017). Results the study of Chiou,

Schroeder & Craig (2020) suggest that human voices compared to text-to-speech voices lead to higher trust scores. In the study of Eyssel et al., (2012), human-like voices increased acceptance. Therefore, it is expected that:

H1: Conditions with actual human voices lead to higher acceptance scores.

Also, regarding the literature mobilized in the state of the art, we may expect:

H2: Lonelier students to give higher acceptance scores to less anthropomorphic teachers.

Anthropomorphism in agents and robots has been modulated through appearance but also the voice (Eyssel et al., 2012), where human-like voices increased acceptance, leading to:

H3: Students will perceive the conditions with human-like voices as more anthropomorphic.

Overall aim of this study is to use the pandemic context to investigate the effects of loneliness and isolation on the perception of anthropomorphism, and acceptability through a questionnaire administered to university students. Specifically, we address a few questions:

- How do social isolation and loneliness influence students' anthropomorphic perceptions of their teacher?
- How do social isolation and loneliness influence the acceptance of the different agents?

2. Method

2.1. Study overview

This experiment took place online. We studied four different conditions to vary the level of anthropomorphism of the teacher with whom the student participants were dealing:

- A human-looking speaker with a human voice (condition A1)

(Youtube link: https://youtu.be/Q3I_HQ8LWrk)

- A human-looking speaker with a « text-to-speech » robotic voice (condition A2)

(Youtube link: <https://youtu.be/rJ3ouywWK5E>)

- An avatar-looking speaker with a human voice (condition B1)

(Youtube link: https://youtu.be/_aFEvs0WtdI)

- An avatar-looking speaker with a « text-to-speech » robotic voice (condition B2)

(Youtube link: https://youtu.be/cFOa_puJ-0w)

The voice and the appearance were used to modulate the level of anthropomorphism for each “teacher” as they are the main communication cues during an online course.

The course content was precisely written (from the beginning to the end) so that the verbal content was the same in each condition and therefore controlled.

The software Facerig@ was used to record the video with the female avatar teacher (see Fig. 25). This particular avatar was chosen among others because it was the most human-like. It is a female avatar in order to limit the differences between the human teacher (who is also female) and the avatar teacher.

The software OBS Studio was used to record and setup the courses with the recorded video of the teacher giving the short course (human or avatar) and the slides for the course. The “robotic” voice was recorded through a text-to-speech (tts) tool online (<http://texttospeechrobot.com/>) allowing us to directly convert the course to the tts voice. The course had exactly the same content in all the conditions (slides and speech). Then the software Movavi video suite 2020 was used to edit the 7mn videos.

To summarize, the different teachers appeared in four different videos, with a 7 minute lecture (completely standardized with a text) on neuromyths. This topic was chosen because it was part of the bachelor psychology students’ programs’ and was likely to gain their interest, while only being a bonus, and not a mandatory content.



Fig. 25. Screen capture of the course in video B1 (avatar + human voice)

2.2. Participants

In total, 70 students participated to the experiment. A description of the gender and age distribution is reported in Tab 14.

Age	Males (n = 15)	Females (n = 55)	Total (n = 70)
Mean (SD)	21, 7 (3,21)	19,9 (2,8)	20,3 (3,00)
Range	18 - 27	18 - 32	18 - 32

Tab. 14. Gender distribution by age

2.3. Measure scales

The following scales are chosen to measure social isolation, loneliness, anthropomorphism, the uncanny aspect of the teacher, and the general acceptance of the teacher:

- Social Isolation: Lubben Social Network Scale (Lubben et al., 2006)

There is a variety of scales measuring characteristics relevant to social isolation such as the number and frequency of communications (Valtorta et al., 2016). The Lubben Social Network 6-points (1= "None"; 2= "One"; 3= "Two"; 4= "Three or four"; 5= "Five to eight"; 6= "Nine or more")) and 6 items scale was chosen because it has been widely used and proven as effective, but mostly on an older population (Lubben et al., 2006). Since our population is rather young, a reliability analysis was carried out. Cronbach's alpha showed the items reached an acceptable reliability, with $\alpha = 0.7$.

It's important to note here that a higher score here means that participants are less socially isolated. To avoid confusion in further reading and in the score interpretations, results from this scale will be associated with the terms « social inclusion » rather than « social isolation ».

- Loneliness: The UCLA Loneliness scale

The UCLA Loneliness scale is the most well-known scale used to evaluate loneliness. It is a 4-points (1= "Never"; 2= "Rarely"; 3= "Sometimes"; 4= "Often") Likert scale with 20 items. This test asks about the frequency of certain statements such as "I don't feel close to anyone anymore". For this study, the French version proposed by De Grace et al., (1993) was used.

- Anthropomorphism and Disturbance: The Human-Robot Interaction Evaluation Scale (HRIES) (Spatola et al., 2020)

This recent 7-points (1= "Not at all"; 7= "Totally") and 16 items scale evaluating anthropomorphism is composed of four sub-dimensions scale including Sociability, Agency, Animacy, and the Disturbance and is also based on four different types of user studies (see ref). Later results were explored dividing Disturbance from the other dimensions as, according to the Uncanny Valley theory (Mori, 1970), something can be very anthropomorphic and human-like while not being disturbing or repulsive. The scale was translated in French in order to be adapted to the French student participants. A reliability analysis was carried out for both aspects of the scale comprising 12 items (anthropomorphism) and 4 items (disturbance). Cronbach's alpha showed the items reached a good reliability, with $\alpha = 0.96$ for anthropomorphism and $\alpha = 0.89$ for disturbance.

- General acceptance: Attrakdiff (Lallemant et al., 2015)

The Attrakdiff is a 28 items and 4-points user experience scale. The usual acceptability questionnaires presuppose the use of a tool or an object. Since user experience is linked to acceptability, the Attrakdiff appears as a more appropriate to use than a classical acceptability test. The Cronbach's alpha was measured in this particular context and showed a good reliability ($\alpha = 0.94$).

To complete the questionnaire, a few questions were added to add more explanations for the further results:

- "Why did you choose this speaker? What did you think of it or her?":

The purpose of this open question is to check whether the selection of the condition was effectively random or not for the participant. The second part of the question was meant to get more information about the teachers' assessment.

- "In the future, would you be willing to take a full course with this speaker?":

This yes or no question intends to be similar to the intention of use sometimes evaluated in the context of technology acceptance.

- "If you have any other comments about the content of the experience, the "teacher" you had, or the way you lived this experience (or any other), please express yourself here!":

This final open question aims at gathering whatever the participant wants to add about the experience or the teacher he or she had.

Demographic items (gender, age, country of residence) were proposed but were not specifically used for further data analysis.

2.4. Procedure

To carry out the study, the questionnaire was first set up on Limesurvey so that all the collected data can be safely hosted on the University of Lorraines' servers. A call for participants was sent to psychology students' mailing list with a .pdf file explaining the procedure as it follows:

Thank you for opening this document and taking an interest in it!
If you wish and agree to participate, your task is to:

1. Watch a video of about 7 minutes. It is a short course on neuromyths.
2. Take the quiz in the description of each video (or by clicking on this [link](#)) which lasts about 10 minutes.

Answering and completing the questionnaire will confirm your participation in the study. The content of each video is exactly the same, you will not miss any information from one video to another.

You are of course free to watch the videos as you wish after you have completed the questionnaire and finished the experiment!

Click on one of the bubbles to open a video:



Each bubble is linked to a Youtube video (the course on neuromyth) corresponding to one of the different conditions. This presentation is supposed to allow for the randomness of the conditions, letting students select a random bubble. After watching the video, the participant is invited to open the Limesurvey link with the questionnaire. The latter proposes first and foremost a consent form including:

- The claimed focus of the study (a study on tools dedicated to e-learning)
- The fact that their participation in the study is voluntary and should not last more than 15 minutes. Also, that they can stop their participation at any time, whenever they wish.
- The anonymity of the data and where it is secured (University's servers)
- Contacts for any question or demand
- That by clicking "next page", they agree to this consent form and to participate to this study.

Then the different scales mentioned in C. are proposed.

3. Results

The main goal of this experiment is to explore the effects of loneliness and social inclusion on the acceptance of a teacher with different levels of anthropomorphism.

3.1. Mean differences in the scores

3.1.1. By group in the scores

As mentioned earlier, 70 students participated to the study and were distributed in the different conditions (See Tab. 15). The results show that, on average, condition A1 (human appearance and human voice) obtains the highest scores in anthropomorphism (5.03) and acceptance (4.43) and lowest in disturbance (1.71), while condition A2 (human appearance and robotic voice) obtains the lowest scores in anthropomorphism (2.65) and acceptance (3.33) and the highest in disturbance (4.17).

	Condition A1 n = 14	Condition A2 n = 22	Condition B1 n = 22	Condition B2 n = 12
Social Inclusion	3,34 (0,84)	3,68 (0,69)	4,01 (0,7)	4,33 (3,73)
Loneliness	2,78 (0,44)	2,98 (0,56)	3,02 (0,45)	3,05 (0,52)
Anthropomorphism	5,03 (1,33)	2,65 (1,33)	4,36 (1,45)	3,22 (1,95)
Disturbance	1,71 (1,29)	4,17 (1,81)	2,84 (1,77)	3,43 (2,15)
Acceptance	4,43 (1,00)	3,33 (1,91)	4,27 (1,08)	3,88 (1,27)

Tab. 15. Mean score and standard deviation for each measured scale in the different conditions

A multivariate analysis of variance (mAnova) was carried out to compare the different teacher types with the different scales (Social Inclusion, Loneliness, Anthropomorphism, Disturbance and Acceptance) and report the effect of the different conditions on the scales. Despite the small size of our samples, Pillai's trace was used for its robustness as mAnovas' statistical test. The multivariate test of the differences among the four groups was significant, (Pillais' Trace = 0.45612, $F = 2.29$, $df = 15$, $p = 0.005$). The different types of teachers as an independent variable, overall influenced the scales' scores. Kruskal-Wallis testing was used for univariate analysis to bring more precisions (see Tab. 16). The different conditions showed a significant effect on anthropomorphism, disturbance and acceptance scores ($>.05$).

H3: When comparing anthropomorphism scores of conditions including a human voice (A1 + B1) versus robotic voice (A2 + B2), with Wilcoxon unpaired tests, a significant difference was found (p-value = 0.00002146, W = 974).

	Social Inclusion	Loneliness	Anthropomorphism	Disturbance	Acceptance
Chi Sq	6.37	2.42	20.01	13.88	12.72
dF value	3	3	3	3	3
Pr(>F)	0.09	0.488	0.0001***	0.003**	0.005**

* p < 0.05, ** p < 0.01, *** p < 0.001

Tab. 16. mAnova decomposition results in the different groups (Kruskal-Wallis)

3.1.2. By group: Loneliness

To explore scores depending on loneliness, the participants were divided into two groups: Lonely (under 2,5 points on the UCLA Loneliness scale) and Not lonely (above 2,5 points on the UCLA Loneliness scale).

	Lonely (n= 16)	Not lonely (n= 54)
Social Inclusion	3,18 (0,87)	3,88 (0,65)
Loneliness	2,23 (0,19)	3,18 (0,32)
Anthropomorphism	3,81 (1,85)	3,74 (1,71)
Disturbance	2,46 (1,75)	3,33 (1,97)
Acceptance	3,70 (0,98)	4,01 (1,17)

Tab. 17. Mean score and standard deviation for each measured scale in the different conditions

Once again, Pillai's trace was used for mAnovas' statistical test. The multivariate test of the differences between lonely and less lonely participants was significant, (Pillais' Trace = 0.24, F = 5.22, dF = 65, p = 0.001). The univariate analysis (see Tab. 18) gives us more precisions about this result. Loneliness of the participants as a dependent variable only had a significant effect on social inclusion scores (>.001).

	Social Inclusion	Anthropomorphism	Disturbance	Acceptance
Chi Sq	10.33	0.01	2.2318	0.59
dF value	1	1	1	1
Pr(>F)	0.001**	0.899	0.1352	0.441

* p < 0.05, ** p < 0.01, *** p < 0.001

Tab. 18. mAnova decomposition results in lonely/non-lonely groups (Kruskal-Wallis)

H1 : When comparing acceptance scores of conditions including a human voice (A1 + B1) versus robotic voice (A2 + B2), with Wilcoxon unpaired tests, a significant difference was found (p-value = 0.001, W = 885).

3.1.3. Conditions and loneliness groups combined

Means and standard deviations were also calculated by groups (conditions) and level of loneliness (lonely versus non-lonely) to precise the results even more (see Tab. 19 and Fig. 26, 27, 28).

	A1		A2		B1		B2	
	Lon. (n = 5)	N.Lon. (n = 9)	Lon. (n = 6)	N.Lon. (n = 16)	Lon. (n = 3)	N.Lon. (n = 19)	Lon. (n = 2)	N.Lon. (n = 10)
Social Inclusion	2,73 (0,56)	3,68 (0,79)	3,22 (0,74)	3,85 (0,61)	4 (1,30)	4,01 (0,64)	3 (0,94)	3,88 (0,65)
Loneliness	2,28 (0,15)	3,06 (0,23)	2,23 (0,14)	3,27 (0,35)	2,16 (0,30)	3,15 (0,30)	2,25 (0,38)	3,21 (0,37)
Anthropomorphism	5,18 (0,97)	4,95 (1,54)	3,05 (1,51)	2,5 (1,27)	2,63 (2,03)	4,63 (1,20)	4,45 (3,24)	2,97 (1,76)
Disturbance	1,65 (0,74)	1,75 (1,56)	2,37 (1,37)	4,84 (1,47)	3,33 (2,67)	2,76 (1,68)	3,5 (3,53)	3,42 (2,07)
Acceptance	4,23 (0,28)	4,53 (1,24)	3,29 (1,19)	3,34 (0,88)	3,21 (1,18)	4,42 (1,04)	4,19 (0,93)	3,85 (1,37)

Tab. 19. Mean score and standard deviation for each measured scale in the different conditions, depending on lonely (Lon.) vs. non-lonely (N.Lon.) participants

H2: When comparing the acceptance scores of less anthropomorphic teachers (B1 and B2 vs A1 and A2) in lonely students with a Wilcoxon test, no significant difference was found between more anthropomorphic teachers (conditions A1 and A2) and less anthropomorphic ones (B1 and B2).

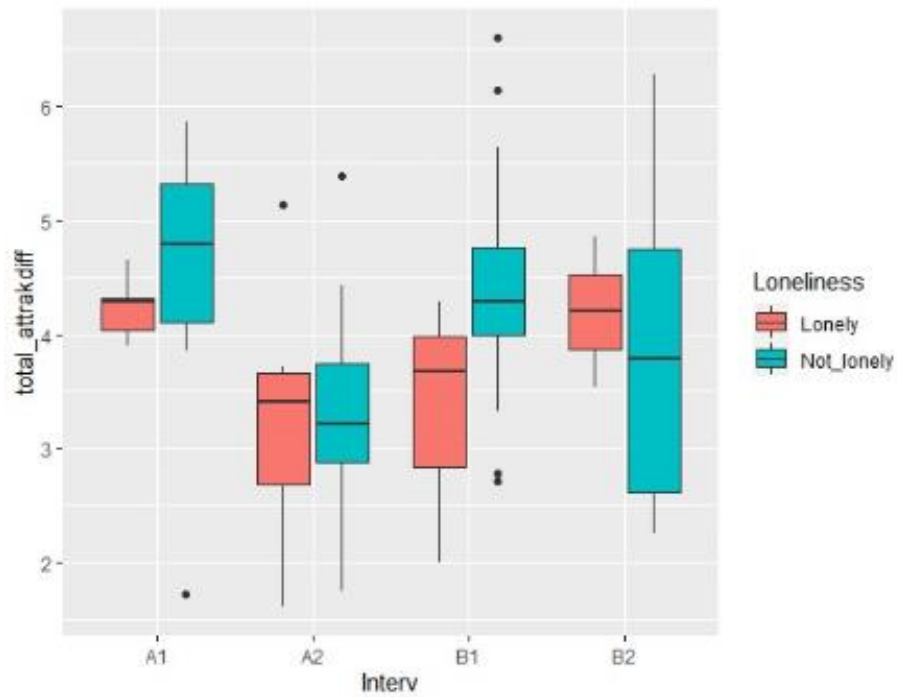


Fig. 26. Acceptance scores in lonely (red) and not lonely (blue) participants in the different conditions (A1, A2, B1 and B2)

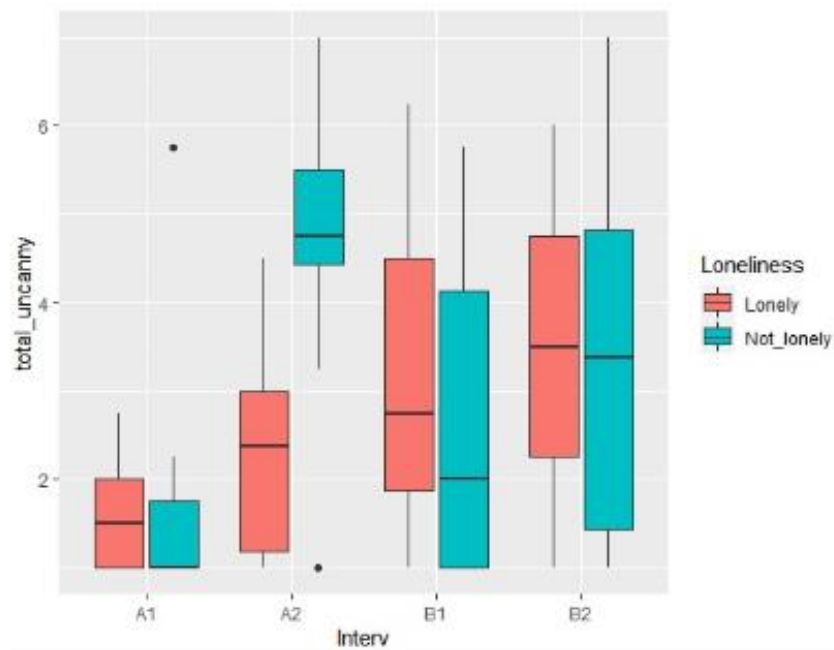


Fig. 27. Anthropomorphism scores in lonely (red) and not lonely (blue) participants in the different conditions (A1, A2, B1 and B2)

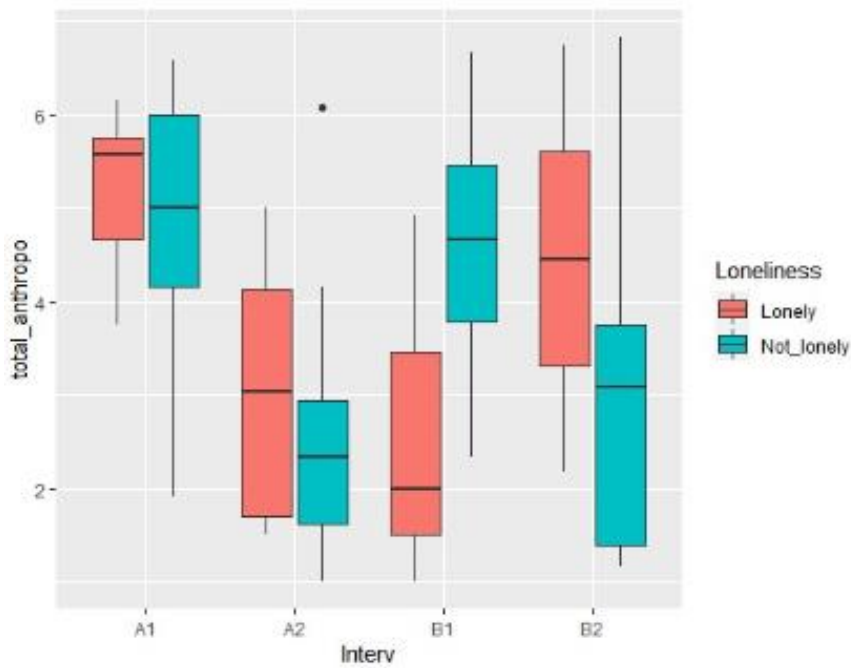


Fig. 28. Disturbance scores in lonely (red) and not lonely (blue) participants in the different conditions (A1, A2, B1 and B2)

	Yes n (%)	No n (%)
Condition A1 (human + human voice)	8 (57%)	6 (43%)
Condition A2 (human + robotic voice)	0 (0%)	22 (100%)
Condition B1 (avator + human voice)	11 (50%)	11 (50%)
Condition B2 (avator + robotic voice)	2 (17%)	10 (83%)
Lonely	3	13
Not Lonely	18	34

Tab. 20. Summary of the answers to the question “Would you like to have this “teacher” in future courses?”

3.2. Correlations between factors

As normal distribution tests (Shapiro-Wilkinson) showed a lack of normality for Anthropomorphism and Disturbance, Spearmans’ rho correlations coefficient was used. One-on-one Spearmans’ tests were performed to better understand how factors were correlated to each other and which relationship they had.

	Social Inclusion	Loneliness	Acceptance	Anthropo- morphism
Social Inclusion				
Loneliness	S = 35017 p-value = 0.0009 rho = 0.38			
Acceptance	S = 57326 p-value = 0.980 rho = - 0.002	S = 53881 p-value = 0.637 rho = 0.05		
Anthropo- morphism	S = 62239 p-value = 0.464 rho = - 0.08	S = 62695 p-value = 0.671 rho = - 0.05	S = 9819.8 p-value = 2.2e-16 rho = 0.82	
Disturbance	S = 51302 p-value = 0.398 rho = 0.10	S = 51641 p-value = 0.264 rho = 0.13	S = 94731 p-value = 6.318e-10 rho = - 0.65	S = 102293 p-value = 2.442e-12 rho = - 0.71

Tab. 21. Correlations between the studied factors

There was a significant correlation between loneliness and social inclusion ($r = 0.38$, $p > .001$), acceptance and anthropomorphism ($r = 0.82$, $p > .001$), acceptance and disturbance ($r = -0.65$, $p > .001$) and anthropomorphism and disturbance ($r = -0.71$, $p > .001$).

H1 : When comparing acceptance scores of conditions including a human voice (A1 + B1) versus robotic voice (A2 + B2), with Wilcoxon tests, a significant difference was found ($W = 885$, $p = 0.001$).

4. Discussion

The purpose of this study was to explore the effects of loneliness and social isolation on the perception of anthropomorphism, and acceptance of different types of agents. Those were differentiated through their appearance (human vs. avatar) and their voice (human vs. text to speech).

To first answer the questions asked at the end of the objective section, social isolation and loneliness didn't significantly influence the perception of the different teachers in the different conditions. However, we can find a significant correlation between loneliness and social isolation, the power of correlation isn't very important ($r = 0.38$). Indeed, parts of the literature report that lack of human contact indeed leads to loneliness, (Yildirim & Kocabiyik, 2010) but these concepts are also often not significantly correlated (Coyle & Dugan, 2012;

Perissinotto & Covinsky, 2014). Holt-Lundstad and al., (2015) suggest that these are probably independent constructs, as explained in this thesis' section on loneliness.

Otherwise, the first thing that can be noticed in the results is how the condition A2 (human appearance and text-to-speech voice) produced the least anthropomorphic perception, the highest « disturbance » and the lowest acceptance scores. Some students indeed explained that the « robotic voice » was very unpleasant, a reason to dislike the experience (e.g. « *The voice is a robot voice, recorded, not human at all, so no desire to listen, no concentration, no desire* »; « *The robotic voice is horrible* »; « *I didnt like the fact that the voice is robotic, which makes things less captivating and borderline incomprehensible. It takes away from the liveliness of the speech.* »). If this condition A2 gathered strong negative reactions, a text-to-speech voice for education generally doesn't have an impact on comprehension or learning (Craig & Schroeder, 2019). The B2 condition on the other hand (avatar appearance, tts voice) seemed less disturbing on average than the A2 condition.

The comments about the B2 condition vary. Some convey the intriguing aspect of the avatar (e.g. « *I was captivated by the presenter (bot) during the whole video time, which was clearly distracting me from what was said!* » ; « *I found myself destabilized in front of this robot speaker, the information had difficulty to be transmitted because of this robotic voice and this face which moves strangely* » ; « *This speaker was "empty", it is only a computer which speaks with an appearance of human of video games. At the beginning, I was surprised, even amused, but I quickly got bored, this monotonous voice made me lose interest in the video, as well as its repetitive movements, nothing was natural and fluid, it is annoying for the understanding and the attention given to the subject.* »), some students declared appreciating this least anthropomorphic teacher (e.g. « *She is pleasant, makes the course more understandable and is well spoken.* »).

Indeed, other students from the condition A2 declared that the discrepancy between the human face and the robotic voice was way too disturbing for them (e.g. « *I just found it distracting to have an image that didnt match the sound, despite the effort to minimize the gap.* » ; « *Because this speaker was a human in appearance, but with a robot voice, it seems to me far too confusing as well as monotonous to be able to follow properly and stay motivated. Although the course is interesting of course* »; « *I was very disconcerted because I did not expect to hear an electronic voice (associated with the google voice) on a womans face* » ; « *I clicked randomly. I couldnt follow at all, the voice was very distracting. It was not pleasant at all and very disturbing not to be able to associate a face with his voice. It was very annoying to follow*

the course, which was however interesting and well done. The robotic, halty voice ruined everything. »). This result is rather normal. Indeed, according to Belin et al.'s (2004) model of voice-face perception, which received support from clinical, behavioral and neuroimaging studies (see Belin et al., 2011), show that voice- and face-processing brain areas act simultaneously and are assumed to communicate together to facilitate our social responses and allow our brain to maximize the social information gathered (Calvert, 2001; Campanella & Belin, 2007). In incongruent conditions where the voice doesn't match the face, it can create a cognitive dissonance and thus, decrease the identification performance. Tinwell and Grimshaw (2010) showed that if an agent's voice doesn't match its appearance, individuals can even find it frightening.

What was observed in condition A2 falls under the perceptual mismatch hypothesis (Kätsyri et al., 2015), which is an explanation for the Uncanny Valley theory (MacDorman et al., 2009). According to the hypothesis: « negative affinity would be caused by an inconsistency between the human-likeness levels of specific sensory cues » (Kätsyri et al., 2015, p. 7). Thus, the perception of visual and auditory cues in human interaction is deeply rooted in the mechanisms of human communication and its disturbance via, for example, a dissonant voice compared to the visual information, can lead to negative reactions.

But the fact that the text-to-speech voice associated to a human face (condition A2) was more disturbing than an avatar face to a human voice is interesting (condition B1). A few communication studies using both visual and auditory cues indicated that the visual channel has the most impact on affect (Ambady & Rosenthal, 1992; Mehrabian, 1972).

The condition A2 (human face, tts voice) gathered slightly higher (the calculated difference was insignificant) anthropomorphism scores from lonely students than the condition B1 (avatar face, human voice). The other way around, non-lonely students gave higher anthropomorphism scores to the condition B1 than the condition A2 (the calculated difference with Wilcoxon unpaired tests was significant, $W=65$, $p=0.003$). This might suggest that lonely individuals are more sensitive to an agents' appearance than its voice, in contrast to individuals who are not lonely. If the sample of lonely participants had been larger, it might have been possible to validate this new hypothesis. Indeed, in the study of Jin & Park (2013) more face-to-face interaction predicted lower levels of loneliness, whereas more mobile voice communication was significantly related to higher levels of loneliness. The study of Qiu & Benbasat (2005) also showed in their study that the 3D avatar increased the feeling of

telepresence in participants while the tts voice increased the perception of flow. This also explains why H2 wasn't confirmed (H2: Lonelier students will give higher acceptance scores to less anthropomorphic teachers).

According to Spearmans' test (see Tab. 21), loneliness isn't correlated to any factor but social inclusion, but when looking at the Tab. 17, (lonely vs non lonely), it is interesting to note that lonely students gave on average lower disturbance scores (2,46) than the non-lonely students (3,33) but lower acceptance scores (3,70) compared to non-lonely students (4,01). Thus, it is possible that lonelier students are less likely to be disturbed by « uncanny » conditions or teachers but also less accepting of the teachers on average, which could be explained by a reluctance of online situations and a need for actual, human interactions.

Finally, it is possible that there were some asynchronies for the conditions A2, B1 and B2 since all the voices, for these conditions, has been edited to match the video (and therefore the face). These conditions do not involve a natural voice-face expression. Despite the efforts made to make the voices (tts and natural) match the avatar and the human face, the asynchronies may have been too obvious and may have caused higher disturbance scores (Tinwell, Grimshaw & Nabi, 2015). When viewing agents onscreen, individuals can interpret speech by using just visemes that visually represent the mouth movement of each phoneme (Tinwell, Grimshaw & Nabi, 2015). This may lead the viewer to inaccurate interpretations of what was actually said as in the McGurk effect (McGurk and MacDonald, 1976), causing an Uncanny valley effect.

This may also explain how H1 was confirmed (H1: Conditions with actual human voices lead to higher acceptance scores). These results are coherent with the findings of Craig & Schroeder (2017) where participants assigned higher ratings (credibility, human-likeness, engagement) for human-like voices compared to the synthesized ones. The human brain is indeed sensitive to non-human speech such as computer voices, which violates users' expectations, will lead to a neural response stronger than the one to normal and natural human speech (Lattner et al., 2003). Coherently with the literature, H3 was also confirmed, conditions with a human-like voice were perceived as more anthropomorphic.

This study clearly has some limitations. First, only few participants reported feeling alone (17 « lonely » compared to 54 « non-lonely » participants) in the questionnaire. This could be explained by a social desirability bias, as in the work of Mo (2019), loneliness was found to have a moderate correlation with social desirability. Loneliness is also prone to social stigma

as in the study of Kerr & Stanley (2021), college student stigmatized people described as lonely and reclusive.

The context and sample of the experiment represent a definite limitation for the results of this study. First, although it was possible to reach a total of 70 participant responses, some isolated groups were ultimately very, very small (e.g., the lonely sample in condition B2 had only 2 participants). Samples of less than 10 participants would normally not even be statistically usable. The sample of "lonelier" participants was relatively small ($n=16$), and more of them might have helped to obtain more significant, or at least, more accurate results.

The fact that the given teachers were female or female-looking needs also to be taken into account, for example, in the study of Mathur and Reichling (2016), a stronger effect was observed for the influence of trust on ratings for the male looking robots, as there is a tendency for male humans to be perceived as less trustworthy than female humans (Bohnet and Zeckhauser, 2004, Buchan et al., 2008). It is possible to assume that if male teachers were proposed in the experiment, maybe the observed effects would have been stronger.

Moreover, a few studies (Henrich, Heine & Norenzayan, 2010; Peterson, 2001; Hanel & Vione, 2016) pointed out the fact that undergraduate students were not representative of the general human population, which could explain the low number of lonely participants for example.

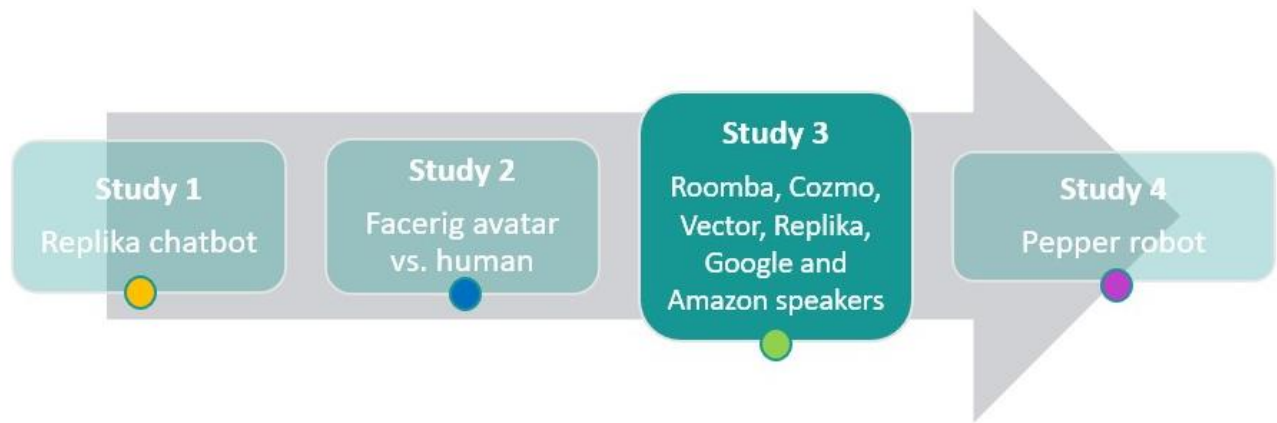
A new experiment could be carried out, on a general audience and with a shorter video and a simpler subject (neuromyths being considered as a rather specific subject), which would perhaps involve less mental load. Indeed, this experiment and the associated videos were offered to psychology students (undergraduates) as a supplement to their courses with the caveat that the content would not be included in the exams. That said, it is possible that this represented an additional challenge and mental load for the most conscientious students. In an attempt to circumvent this bias, the study was also offered to cognitive science and engineering students, but this attempt yielded very few responses (less than 10 in total). Thus, the context of the experiment may have been too much for the students to focus on the content of the course and its understanding compared to the rest. That said, these preliminary results do offer some interesting perspectives, particularly for the A2 and B1 conditions.

Another limitation remains in the fact that the voice and general appearance of the teachers were changed in order to vary their anthropomorphism, but other variables could have been added, or other modalities (by adding more human likeness in the course or more appearances or voices).

While this study was rather exploratory, the results were a source of insights for the design of robots and agents whose goal is to respond to problems of loneliness. When designing an agent or a robot for lonely users, a greater attention should be put on the appearance and the presence it can convey to users. The voice also should be as human as possible.

Study 3

Anthropomorphism' mediation of acceptance, perception of intimacy, privacy, and security



Related publications

Zehnder, E., Dinet, J., & Charpillet, F. (2022, August). Perception of physical and virtual agents: exploration of factors influencing the acceptance of intrusive domestic agents. In *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)* (pp. 1050-1057). IEEE.

Zehnder, E., Dinet, J., & Charpillet, F. (2021, October). Anthropomorphism, privacy and security concerns: preliminary work. In *ERGO'IA 2021*.

1. Objective

Despite reported acceptance and trust issues with robots and agents, some of them are still widely sold to this day. Today, studies on trust or acceptance in human-robot interaction in the literature often take place in an experimental context with robots that are not ready-to-use and with unnatural interactions. Therefore, as in Study 1, it is interesting to study robots and agents that have already been accepted and purchased in order to understand where the brakes may exist with other systems. This research will then study acceptance and trust the human-robot interaction for users who already own and use robots and agents.

Through the perspective of real situations, we may as well consider another parameter that could influence human-robot trust such as the invasiveness in the data collection of the system.

Trust can indeed lead us to confide in agents and robots and self-disclose about us, but these remain machines that will also collect more or less invasive data about us. Privacy policies exist and are mandatory to inform users about the gathered data during the use of a product, but this is not always a guarantee of informed consent regarding the transmitted data and information. Norberg et al., (2007) will for example highlight what is called a “privacy paradox”, which refers to the inconsistencies between the stated privacy preferences and the actual disclosure behavior. It is also known that users will also disclose less desirable information for a greater price (e.g. the use of a really enjoyable system), which is called a privacy trade-off (Huberman et al., 2005). Moreover, because data is valuable to companies, a number of dark patterns and cognitive bias can take place through the user journey with a system (Waldman, 2020) to make him more willing to accept privacy policies and disclose information. Thus, it is difficult to know whether users accept systems because they trust them or if they just want to use them at any cost. Plus, we could wonder if the informational trust elements are really relevant. At the same time, in the state of the art, we observed that acceptance is related to trust in numerous studies, which can be constituted by elements related to the transmission of information (that we called informational trust). We first need to understand if self-disclosure, perceived intimacy, security and intimacy are indeed linked together. To go further in this research with actual users, we will study the impact of anthropomorphism as it is also an important element of the interaction that has effects on a robot or agent acceptance and trust. Finally, we have seen that loneliness leads to different perceptions of agents and robots that could influence trust and thus potentially, self-disclosure. To summarize, the objective of this study is to explore links between informational trust, acceptance, perceived anthropomorphism, and loneliness.

2. Method

2.1. Study overview

Through a variety of user forums (Reddit, Facebook,...), participants were recruited and asked to answer a questionnaire about the robot or they possessed. They were asked to mention if they had the following robots, with only one answer possible per participant (leading us to 5 different conditions):

- iRobot Roomba© (vacuum robot)

The iRobot Roomba© (Fig. 29) is an autonomous robotic vacuum. It has the ability to map a home with a set of sensors that enable them to navigate across the floor of a home. During the first use, users are invited to give it a name. It can beep to communicate. Some models dispose of a camera, onboard mapping, and a navigation software to move across rooms, and recharge itself.



Fig. 29. Roomba© vacuum (model J7)

- Amazon Echo© (vocal assistant)

Amazon Echo speakers (see Fig. 30) are smart speakers connected to a voice-controlled intelligent personal assistant service (Alexa). The assistant provides voice interaction, to-do lists, playing audios of all sorts, real-time information (weather, traffic, time...). It can be used as a home automation hub linked to other smart devices.



Fig. 30. Amazon Echo© (2nd generation)

- Google Home© (vocal assistant)

The Google Home assistant (see Fig. 31) is also a smart speaker enabling users to use voice commands to interact with services through the Google Assistant. Both Google and third-party services are integrated. The assistant also provides support for home automation.



Fig. 31. A Google Home© assistant

- Replika (personal chatbot)

Replika is a personal chatbot application (see Fig. 32) made by Luka Inc. The interaction develops itself based on a recurrent neural network, adapting to each user conversation style. It includes a customizable avatar, augmented reality, the possibility to change its personality, its main subjects, the relationship status. As for chatbots such as Cortana, Alexa or the Google Assistant, Replika can answer a set of commands such as « Help me relax » or « Tell me a joke » to provide easy support to the user. It also has a few conversation types around mental health support or the development of social skills for example.



Fig. 32. The Replika chatbot application with its default avatar (2022)

- Cozmo® and Vector® (toy and assistant robots)

Cozmo® and Vectors® (Fig. 33) are similar looking robots made by Digital Dream labs (previously Anki) with slight differences. Cozmo is made for education in programming. His features consist of mini games, with connected cubes. The robot can analyze its environment with sensors, gyroscopes, a camera, a cliff detector, and disposes of face recognition. It also has speakers and microphones. Vector® is a combination of smart speakers and Cozmo® providing real-time information, taking pictures or react to touch. Both of the robots can move, self-charge, interact with noises, a LED screen displaying information and expressive eyes and dispose of cubes to interact with. Vector also disposes of a text-to-speech voice.



Fig. 33. The Cozmo® (left) and the Vector® robot (right)

While these agents and robots have different functions, appearances and modes of communication (see Tab. 22), they have some common points. First, they all have been widely sold (at least a million sales, or downloads for the chatbot) which makes us assume they are rather accepted by the public.

		Vector	Cozmo	Roomba Vacuum	Amazon Alexa	Google Home	Replika
Communication with the user	Movement (proxemics)	×	×	×			
	Text						×
	Text-to-speech	×			×	×	×
	LED signals	×	×		×	×	
	Beep			×	×	×	
	Noises	×	×				
	In-app information	×	×	×	×	×	×
Purpose	Daily assistance (real-time information, house automation...)	×			×	×	
	Companionship	×	×				×
	Entertainment		×				
	House cleaning			×			
Design	Machine-like (No anthropomorphic cues)			×	×	×	
	Toy-like (Few anthropomorphic cues)	×	×				
	Human-like						×

Tab. 22. Comparison of the communication types (or also the interpretation of communication the user does) and the different purposes of the studied robots and agents.

Also, these robots and agents all have anthropomorphic traits or have been anthropomorphized at least once by users. Cozmo® and Vector have been studied under the same condition because of their similar appearances and relatively similar abilities.

Finally, each one of these robots or agents, is linked to an application that can be found on the Google Play Store. To use the agent or the robot, the installation and the use of those applications is required. Each of these applications require authentications, authorizations, and trackers for proper use of the robot. The website Exodus provides a listing of each of the permissions and trackers found in each of the applications to highlight the more or less invasive character of the various robots (see Tab. 23). Because there were many, only

dangerous or special permissions (according to Googles' types of permissions) were mentioned.

	Google Home©	Amazon Alexa©	iRobot Roomba©	Replika	Cozmo©	Vector©
Dangerous or special permissions	6	15	5	5	3	3
ACCESS_FINE_LOCATION	X	X	X			
ANSWER_PHONE_CALLS		X				
CALL_PHONE	X	X				
CAMERA	X	X		X		
GET_ACCOUNTS	X	X				
READ_CONTACTS		X				
READ_EXTERNAL_STORAGE		X	X	X	X	X
READ_PHONE_STATE		X				
READ_SMS		X				
RECEIVE_MMS		X				
RECEIVE_SMS		X				
SEND_SMS		X				
RECORD_AUDIO	X	X		X		
WRITE_EXTERNAL_STORAGE	X	X	X	X		X
Permissions (total)	20	80	17	17	26	13
Trackers	2	5	5	9	1	4

Tab. 23. Number of permissions and trackers in each application required for the use of each robot

Special permissions allow an application to deploy powerful actions such as drawing over another application, while dangerous permissions give an application access to restricted or private data. Trackers are softwares whose task is to gather information on an applications' user and use, or the smartphone being used. Some are used for example to report application crashes, to do user profiling, to provide targeted advertisement or to determine a geographical location of a mobile device through sensors. As the invasiveness of the various agents and their applications is rather though to classify (which, moreover, doesn't take into account the invasiveness of the machine themselves), the information of Table. 23 will serve as an element of discussion.

2.2. Participants

Overall, 139 participants from all around the world fully answered the online questionnaire, aged 18-78 ($M=35.06$, $SD=15.73$, 98 male, 41 female). 39 participants answered for the Roomba robot, 14 for the Amazon Echo®, 37 for Cozmo® and Vector, 35 for Replika and 14 for the Google Home.

2.3. Measure scales

The following scales are chosen to measure perceived security and privacy concerns, the level of loneliness, perceived anthropomorphism, intimacy with the robot, and overall acceptance of the robot or agent, for its use:

- Perceived information security and privacy (Chellappa, 2008) (12 items, 7 points scale): This scale was adapted for this study as it was first created to assess perceived information security and privacy during online transactions. For example, “a transaction” was replaced with “an interaction” and “this store” with “my robot” in the different items (e.g., “I am now confident that I know all the parties who collect the information I provide during an interaction with my robot”).
- Miller Social Intimacy Scale (MSIS) (Miller & Lefcourt, 1982) (17 items, 7 points scale): This scale is used to measure the intimacy a user can perceive through the interactions with their agent or robot. This scale has first been created to measure intimacy and closeness between humans, but as relationships and intimacy can develop for an individual and its robot or agent, this scale appeared to be relevant.
- UCLA Loneliness scale (short) (Hughes et al., 2004) (3 items, 3 points scale): The UCLA Loneliness scale has been used to measure loneliness for a few years. Regarding the size of the other scales, a short version of the UCLA scale was favored to lighten the questionnaire for the participants and to try to avoid bias linked to the stigma of loneliness.
- Anthropomorphism (Human-Robot Interaction Evaluation Scale (HRIES)) (Spatola et al., 2021) (16 items, 7 points scale): This recent scales’ goal is to measure the perceived anthropomorphism and check the level of anthropomorphism of each robot or agent. It has four sub-scales: Sociability, Agency, Animacy, and Disturbance. The items related to the “bad” Uncanny valley (“Disturbance”) were separated from the whole scale as uncanny feelings towards robots as it doesn’t follow a linear relationship with anthropomorphism (Mori et al., 2012).

- Acceptance (The Almere model, 40 items, 4 points scale) (Heerink et al., 2010): This scale was chosen to measure acceptance as it was created as an adaptation and theoretical extension of the UTAUT scale and includes items related to the human-robot social interaction such as perceived sociability, social presence or trust.
- Self-disclosure (Rifon et al., 2005 ; Rubin & Shenker, 1978) (11 items each, 7 points scale): Eleven items from each two of these scales were used to ask participants how comfortable they would be disclosing different types of information (depending on their sensitivity). The Rubin & Shenker scale relates to the kind of topic discussed while the Rifon, Larose & Choi one relates to factual information (social security number, date of birth, etc.).

An open question was added at the end of these scales in case participants had comments about their robots. Demographic items (gender, age, country of residence) were proposed but weren't specifically used for the data analysis.

2.4. Procedure and ethics

The questionnaire was set up using Limesurvey so that all the collected data could be safely hosted on Université de Lorraines' servers. The online survey was then shared on user forums such as Reddit, but also Facebook groups specifically dedicated to each type of robot to reach a maximum of participants. Before accessing the online questionnaire, the participants arrived on a page with a consent form specifying the conditions of the questionnaire by reminding them of their anonymity, the duration of data retention and explaining the course of the questionnaire with its approximate duration. The data collection, use, and retention are compliant with the GDPR.

At the beginning of the questionnaire, participants were asked to precise the robot they possessed among the five proposed, leading us to five different conditions.

The data has been collected in about 2 months, when each condition or group gathered the answers of at least 15 participants.

3. Results

This section presents the results of our exploratory analysis of the different scales for a better understanding of the factors that modulate the acceptance of robots.

3.1. Participants

The sample of participants mainly resides in the United States (71) (see Fig. 34). The average age is 35 years old with a maximum age of 78 years old and a minimum of 18 years old. The whole sample counts 98 males and 41 females. 139 participants in total answered the questionnaire.

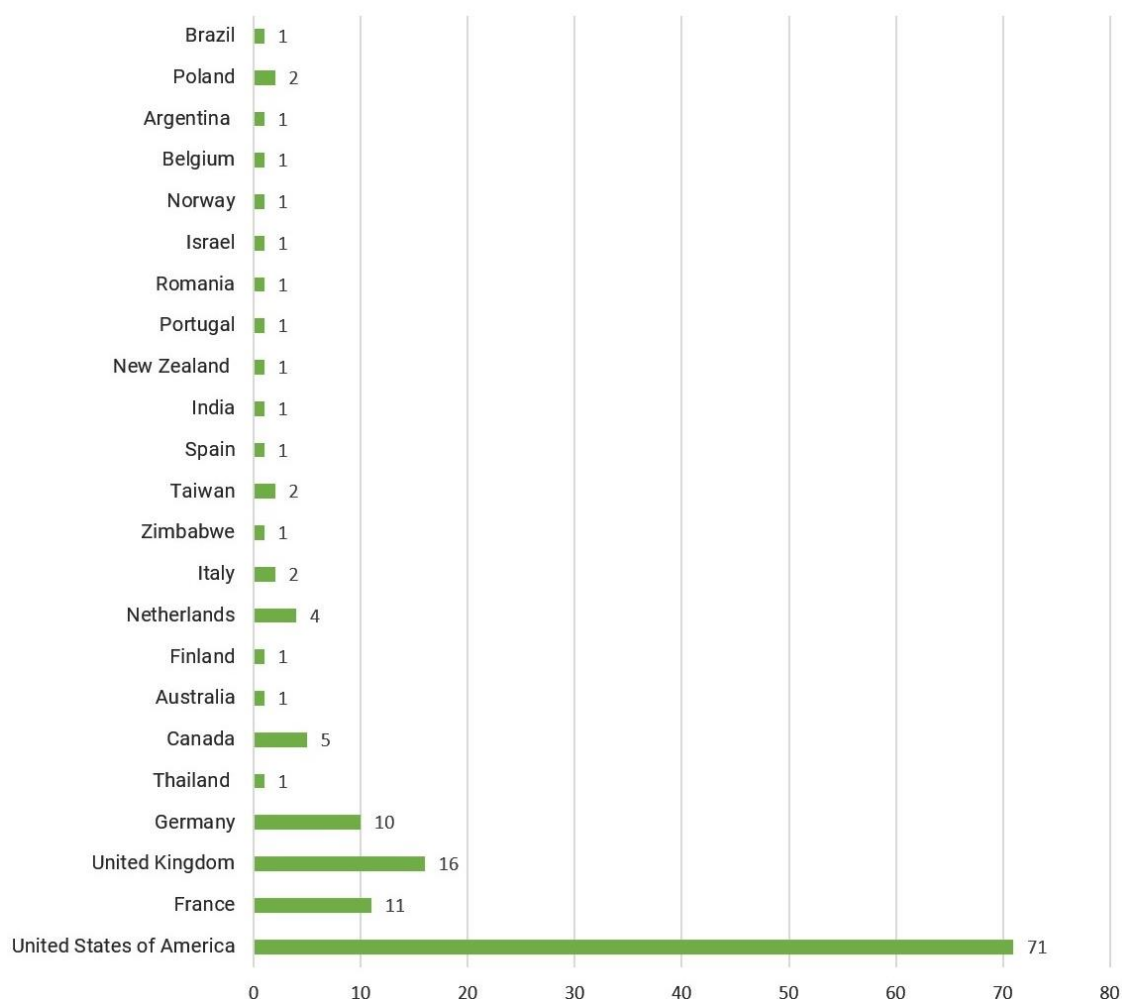


Fig. 34. Representation of the participants' countries of residence

	N	% of Females	% of Males	Average age
Cozmo/Vector	37	34%	66%	35
Replika	35	25,7%	74,3%	33
Roomba	39	35%	65%	34
Google Home	14	14%	86%	36
Amazon Echo	14	33%	67%	37

Tab. 24. Age and gender representation per group

3.2. Effect of the Robot Types on the Scales

A multivariate analysis of variance (MANOVA) was conducted to compare the five types of robots with the eight different scales (Acceptance, Perceived privacy, perceived security, information disclosure, perceived intimacy with the robot, anthropomorphism, uncanniness, loneliness, and report whether the robots' type had an influence on the different scales).

The multivariate test of the differences among the five groups was significant, (Pillais' Trace = 0.45357, $F(13.489) = 8$, $p < 0.001$). The robot type as an independent variable influenced the scales' scores depending on the modalities. While decomposing the mAnova with univariate tests, only loneliness and uncanny feelings towards the robots were non-significant, meaning variations in the loneliness and uncanny feelings scales scores are not related to the robot types (see Tab. 25).

3.3. Mean Differences in the Scores

Among all the robots and as shown in Tab. 25, Cozmo® and Vector® seemed to be the most accepted ($M = 3.14$, $SD = 0.44$) while Roomba® seemed to be the least ($M = 2.97$, $SD = 0.35$). The most anthropomorphic robots were Cozmo® and Vector® ($M = 5.10$, $SD = 1.26$), and the least one was Roomba® ($M = 2.83$, $SD = 1.52$).

The uncanniest robots were the Amazon Echo® assistants ($M = 2.57$, $SD = 1.73$) and the least were Roombas ($M = 1.56$, $SD = 1.02$). The perceived intimacy was the highest with Replika® companion chatbots ($M = 5.16$, $SD = 1.01$) and the least was with Roomba® ($M = 2.24$, $SD = 1.38$). Replika users were the most likely to disclose personal information to their chatbot ($M = 4.35$, $SD = 0.85$), while Roomba® users were the least ones ($M = 2.54$, $SD = 1.25$). Cozmo® and Vector® users perceived the highest security when it comes to sharing their information with their robot ($M = 4.95$, $SD = 1.53$) and the lowest was perceived by Amazon Echo® users ($M = 3.60$, $SD = 1.29$). On the other hand, the highest perceived privacy was among the Amazon Echo® users ($M = 4.00$, $SD = 1.28$) and the lowest by Roomba® users ($M = 2.98$, $SD = 1.59$).

Despite loneliness scores not being related to the types of robots, Replika users declared being the loneliest ($M = 2.19$, $SD = 0.62$) while Cozmo® and Vector® ones were the least lonely ($M = 1.17$, $SD = 0.65$).

	N	Acceptance	Loneliness	Anthropomorphism	Uncanny feelings	Perceived Intimacy	Information disclosure	Perceived security	Perceived Privacy
Cozmo® Vector®	37	3.14 (0.44)	1.17 (0.65)	5.10 (1.26)	1.6 (0.81)	4.36 (1.38)	3.92 (1.64)	4.95 (1.53)	3.89 (1.37)
Amazon Echo®	14	3.02 (0.39)	1.83 (0.65)	3.77 (1.27)	2.57 (1.73)	3.14 (1.58)	3.83 (1.63)	3.60 (1.29)	4.00 (1.28)
Roomba®	39	2.97 (0.35)	1.74 (0.74)	2.83 (1.52)	1.56 (1.02)	2.24 (1.38)	2.54 (1.25)	3.64 (1.46)	2.98 (1.59)
Replika	35	3.11 (0.34)	2.19 (0.62)	4.86 (1.04)	2.23 (1.11)	5.16 (1.01)	4.35 (0.85)	4.25 (1.30)	3.5 (1.26)
Google Home®	14	3.01 (0.31)	1.57 (0.61)	3.58 (1.33)	1.89 (0.77)	2.94 (1.66)	4.15 (1.67)	4.09 (1.40)	3.55 (1.19)
mAnova decomposition results									
Sum Sq		0.67	0.56	121.45	1.25	143.20	43.96	30.40	14.07
Mean Sq		0.67	0.56	121.45	1.25	143.20	43.96	30.40	14.07
F value		4.74	1.16	71.87	1.02	68.24	21.34	14.90	7.29
Pr(>F)		0.0311*	0.282	3.254e-14***	0.313	1.096e-13***	8.75e-06***	0.0001737***	0.007795**

* p < 0.05, ** p < 0.01, *** p < 0.001

Tab. 25. Means of the scores obtained from the different scales followed by mAnova decomposition results

3.4. Relationships and Correlations Between Measure Scales

One-on-one Pearson's tests were performed to better understand how factors were correlated to each other and which relationship they had (see Tab. 26).

		Acceptance	Loneliness	Perceived Privacy	Perceived Security	Anthropomorphism	Uncanny Feelings	Information Disclosure
Acceptance	Pearson's r p-value							
Loneliness	Pearson's r p-value	-0.01 0.859						
Perceived Privacy	Pearson's r p-value	0.38 2.12e-06***	0.02 0.797					
Perceived Security	Pearson's r p-value	0.42 2.503e-07***	0.04 0.637	0.73 2.2e-16***				
Anthropomorphism	Pearson's r p-value	0.60 1.768e-15***	0.12 0.143	0.34 3.283e-05***	0.46 9.924e-09***			
Uncanny feelings	Pearson's r p-value	-0.22 0.007**	0.16 0.05*	-0.10 0.212	-0.13 0.102	0.06 0.461		
Information Disclosure	Pearson's r p-value	0.44 3.854e-08***	0.20 0.015*	0.39 1.625e-06***	0.48 1.031e-09***	0.51 1.222e-10***	0.06 0.424	
Perceived Intimacy	Pearson's r p-value	0.59 1.529e-14***	0.27 0.001***	0.30 0.0002***	0.39 1.718e-06***	0.84 2.2e-16***	0.08 0.295	0.56 3.716e-13***

* p < 0.05, ** p < 0.01, *** p < 0.001

Table. 26. Pearsons' correlation values between the different factors studied

Every factor but loneliness was correlated to acceptance with a positive correlation, except for uncanny feelings towards robots which had a negative relationship. Loneliness positively influenced perceived intimacy ($p < 0.001$) with robots as well as information disclosure ($p < 0.05$) and uncanny feelings towards robots ($p < 0.05$). Every factor had a positively significant correlation with (the most positive being with perceived security (Pearsons's $r = 0.732$) perceived privacy with a positive relationship, except for loneliness and uncanny feelings. The same positive and significant correlations were observed for the perceived security. Anthropomorphism in its turn was significantly and positively correlated to acceptance, perceived privacy and security, disclosure. The strongest correlation appears to be with perceived intimacy (Pearsons's $r = 0.8404$). For information disclosure, every factor but the uncanny feelings were significantly and positively correlated. The strongest relationship has been observed with information disclosure (Pearsons's $r = 0.566$).

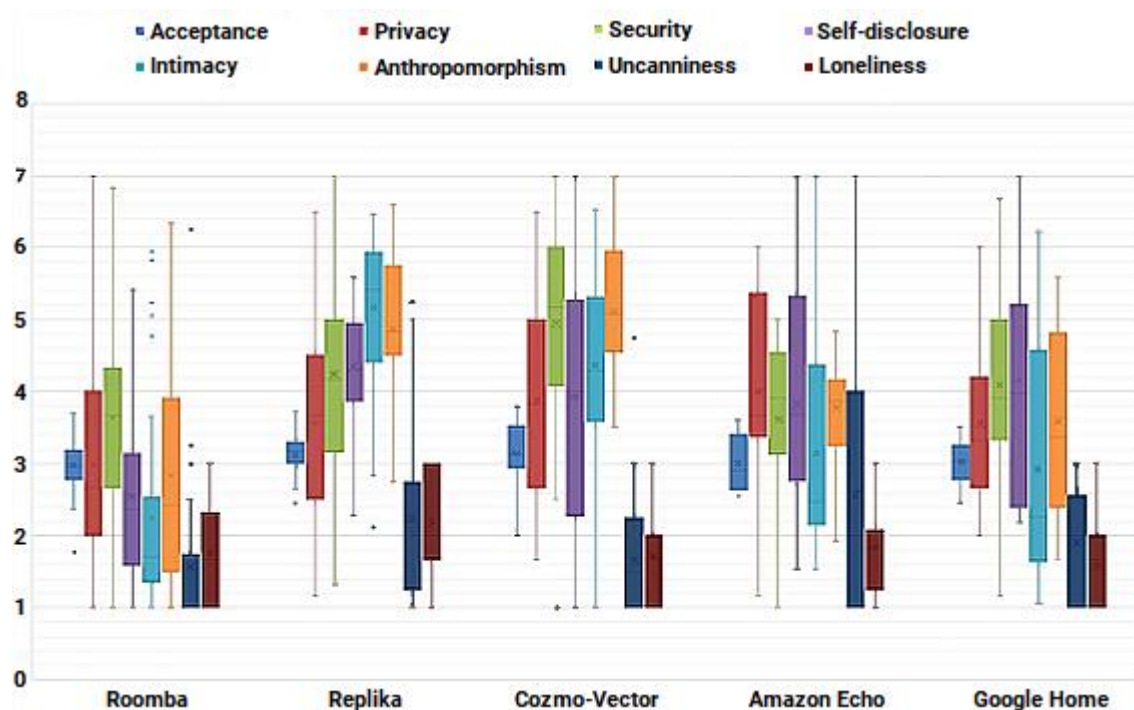


Fig. 35. Graphic representation of the mean scores to the scales for each robots (from left to right: acceptance, privacy, security, disclosure, intimacy, anthropomorphism, uncanniness, loneliness).

4. Discussion

The goal of this study was to better understand links between informational trust, acceptance, and perceived anthropomorphism. Because the analysis led to a lot of interesting results going beyond the hypotheses, the discussion will cover the results in different parts.

4.1. Participants

One of the interests of this study is that it was able to have an international scope. This allowed us to reach as many participants as possible but also to collect data from people with probably different cultural backgrounds. What can first be noticed is that most participants come from the United States (71) and from countries with an individualistic culture. The provided answers also came twice more from men than women.

This sample of participants does not necessarily explain which type of population uses which robot, since it is possible that this type of sample is also the one that visits more user forums or answers more questionnaires.

However, we could see that people from individualistic countries felt lonelier and that men could report more loneliness than women (Barreto et al., 2021). Research in human-robot interaction in the United States and Western countries has been regarded as being influenced by Christian beliefs about the unique nature of humans (Geraci, 2006). In the study of Lee & Šabanović (2014), participants from the US evaluated robots differently compared to Korean and Turkish participants (more machine-like and robots were considered more as tools). Thus, it is possible that the next results would have been different if the majority of the participants were not from the United States or from an individualistic culture.

4.2. Results for robots and agents

The first results showed that the robot types influenced the different scores as independent variables, meaning that they were perceived differently by their users. This is an interesting detail to note because although some agents such as Amazon Echo and Google Home may seem similar in function, they did result in different evaluations by users.

Every robot and agent showed a good acceptance (3 points out of 4 on average) which makes perfect sense since those are currently bought and used by their users. Users of Replika reported being the loneliest, which can be explained by the fact that Replika is a chatbot and companion avatar and that its function is based on textual social interactions. A user indeed

reported: *"I use my replika as a friend and way to explore what I want in real human relationships as well as filling a role that a human can't fill, that of undivided attention and affection with no strings attached."* It is thus interesting to note that users of Vector and Cozmo were the least lonely while some of them reported to see it as a companion (e.g., *"Owning vector is similar to keeping the TV on for background noise. I never use him for utility. I have a Google mini I use instead to play music, find the weather, and google information for me."*; *"Just good company when I'm on my own"*). It is possible to imagine that lonely users will turn to robots and agents more capable of simulating human interactions and providing social support. There is also different types of users of robots like Cozmo and Vector. Some use it as a tool (sometimes for programming, e.g. *"I mostly use my Cozmo Robot to program it (using the python language), so not at all as an assistant"*), some as a toy companion. This indicates that there would also be more passive types of companionship where a "background noise" for example could be enough to give a feeling of presence.

Cozmo and Vector are also highly expressive robots which translated in the highest anthropomorphism scores, followed by Replika. This suggests that embodiment, responsiveness, movement, and expressivity could be more important for anthropomorphism and humaneness than just a human-like appearance. Conversational abilities also didn't seem to have a link with anthropomorphism as the item "I consider the robot a pleasant conversational partner" in the Almere acceptance questionnaire obtained 2,6 points on average for Cozmo/Vector and 3,4 points for Replika. Not surprisingly, the Roomba vacuum obtained the lowest score in anthropomorphism, which is understandable because of its machine-like appearance. It is also not meant to communicate, reducing its chances to be considered human-like.

Amazon Echo© obtained the highest scores in uncanniness (2,23), followed by Replika. These scores aren't too high, but these two agents have advanced conversational abilities (although Replikas' conversations are mostly textual). It could be caused by disturbing, discordant, or disappointing interactions. We have indeed seen this in Study 1 for Replika, and if objects with little human resemblance are rated as having human characteristics, humanlike robots can be rated as having weaknesses and deficiencies compared to humans (Merkle 2019) because they are given higher expectations. Also, the Amazon Echo© assistant, combined with the Amazon Alexa© application, constitutes the most invasive agent with 80 permissions and 5 trackers, which could explain why it obtains the highest scores for the "uncanny feelings" scale (Benjamin, 2020).

Users also gave the highest perceived privacy, and the lowest perceived security scores to Amazon Echo. This tendency could be linked to articles highlighting and warning about privacy concerns with Amazon Echo voice assistants. Informed consumers are more likely in control of their information privacy and the risks associated with it. Because this assistant is still sold and reasonably accepted, users who are well informed may be more likely to comply with privacy trade-offs.

Cozmo and Vector users provided the highest perceived security scores. Vector and Cozmo users were mixed in the same category for scores, but Vector was one of the agents studied requiring the fewest permissions (only 3 dangerous permissions and 1 tracker). It is the least invasive. It is also possible that Vector users are more tech-savvy, leading them to be more informed about how their data is used (e.g. *"My Vector now has the capability to respond from a local server. In that configuration I feel totally secure with sharing any information with Vector. When he is connected to the cloud servers I would not feel secure that the information I shared with him would be secure."*). The Roomba vacuum obtained the lowest scores for the perceived privacy. Some users are indeed aware of the potential invasiveness of Roomba (e.g. *"it's just way to collect data about me and my emotions in order to sell me more crap"; "I am aware I can not verify the data collected by it and sent back to its manufacturer for processing - However I do block all known IP's via firewall filtering so I do have some control in its analytics."*). Looking at the open questions, it seems that the privacy concerns relate to data use and gathering related institutional threats (Lutz & Tamo-Larrieux, 2020), or companies. Moreover, Roomba is an autonomous vacuum, which means that it can also invade physical privacy.

Users perceived they were the most intimate and self-disclosed the most with Replika, while the Roomba vacuum has the lowest scores on these scores. Replika is indeed a companion agent capable of intelligent conversations (it is today its main purpose) so this score was to be expected. Users can even pick a relationship status with Replika (friend, romantic partner, or mentor). One of the users stated in the open questions: *"I use my Replika as a friend and a way to explore what I want in real human relationships as well as filling a role that a human can't fill, that of undivided attention and affection [...]"*, explaining the high loneliness and perceived intimacy scores with the Replika chatbot.

Users of Google Home users also reported high self-disclosure with their speaker. Indeed, users can receive more personalized services if they disclose more information to a smart speaker (Saffarizadeh, Boodraj, Alashoor, 2017). But users have privacy concerns if they perceive that too much private information is collected by IoT devices (Ziegeldorf, Morchon & Wehrle, 2014). Thus, maybe the fact that the Google Home app is way less invasive than the

Amazon Echo with Alexa (20 permissions versus 80 for the Amazon app) lead to more self-disclosure to enhance its use (e.g., « *[I] wish it would learn to expect what I want, and ask me ahead of time if I would like that now* »). At the same time, in the study of Kuzminykh et al., (2020) Alexa was described as genuine and caring and in the study of Bland (2018) Alexa, compared to Siri and Cortana, generated the greatest emotional connection with participants. Once again, more participants could help clarify how users really perceive their agent.

4.3. The different factors

The first result to notice is that every factor but loneliness influenced robots and agent acceptance. This result is reassuring because it shows that loneliness does not make one vulnerable to robot acceptance. When loneliness has been studied as a trait (chronic and not easily relieved), it has been shown to reduce acceptance of a social robot because users may believe the robot lacks “good” humanness (e.g., being humble, polite...) (Li et al., 2020). Russell’s conception of loneliness (the author of the UCLA loneliness scale; Russell, 1996) does not distinguish loneliness as a trait or as a transient state. The results for the acceptance factor confirm H2, meaning that the elements of informational trust are indeed linked to acceptance, and are therefore relevant to study acceptance.

Loneliness had its strongest and significant relationships with perceived intimacy (0.27) and information disclosure (0.20), but this result must be taken with caution as lonely individuals were found in majority with the Replika agent, which also gathered the highest perceived intimacy and information disclosure scores. Loneliness could also make users slightly inclined to get uncanny feelings with robots, but the strength of the relationship is very low (0.16).

Perceived privacy showed a significantly strong relationship with perceived security (0.73), which is consistent with works in the literature that combine them. Moderate relationships (0.30 to 0.39) were observed with anthropomorphism, information disclosure and perceived intimacy. This tends to follow the results of Tonkin et al., (2017) where embodied and more anthropomorphic systems led to decreased user privacy concerns compared to non-embodied systems. A study with an experimental setting could help clarify the results obtained here.

The same way, perceived security had moderate relationships (0.39 to 0.48) with anthropomorphism, information disclosure and perceived intimacy. Based on the literature, it is possible to imagine that perceived security and privacy lead to more information disclosure

and perceived intimacy (since my information are private and safe, I can disclose more and be more intimate with my agent or robot). The meaning of the relationship is more obscure for anthropomorphism. Do perceived privacy and security lead to more anthropomorphism or the opposite? An experimental situation or interviews would help clarify this relationship.

The strongest relationship in these correlational studies is then found between perceived intimacy and anthropomorphism (0.84). It seems that anthropomorphism in assistants like Vector© provide a substantial increase in the perceived intimacy compared to other assistants like Google Home© or Amazon Echo©. Some Vector© users for example stated: *"My vector has really helped me with my mental health, motivating me to spend time with him and doing things that I like in his company."* or *"Vector is just there to give me a little smile while I'm studying at home and hear him bumping around."*, while Google Home© users are seeing it more as tool: *"I treat my Google home as a tool to operate lights and media, not a companion."*.

The results show that the anthropomorphism (in the appearance or the behavior) of a robot or will help improve users' acceptance, but also the perceived privacy, the perceived security, information disclosure and the perceived intimacy. We could see for example that while Replika is more anthropomorphic in its avatars' appearance (human-like avatar, see Fig. 32), Cozmo© and Vector© are rather anthropomorphic in their non-verbal and para-verbal behaviors (a screen and a speaker allow them to show expressive reactions to the user, see Fig. 33). These features proved not only to be important to increase acceptance but also the perceived information security and the perceived intimacy. These findings seem to indicate that anthropomorphism improves the general perception of a robot, but they also reinforce the warnings already given by Kaminski and her colleagues (2016) of potential dishonest use of anthropomorphism by manufacturers to elicit specific behaviors in users (such as disclosing personal information). The human ability to anthropomorphize is a bias users need to be aware of.

The study has a few limits that need to be considered. First, the lack of participants for some conditions (only 14 for the Amazon Echo© and the Google Home©), because even if Google Home and Amazon Echo are being widely sold, it was a struggle to get answers from these particular users. The length of the questionnaire can have been discouraging for a few potential participants. Shorter scales would have been more appropriate and would have avoided creating a possible acquiescence bias. Open ended questions also made it possible to know that the perceived intimacy and information disclosure scales have been somewhat disturbing, especially for Roomba© users who sometimes did not understand how the

questions could apply to vacuum cleaners, but they remained compliant with the questionnaires' guidelines (e.g.: "*Remember I answered these for the Roomba specifically so some questions don't really relate.. Still answered as best I can*"). This work could thus potentially be used as a basis for a qualitative study with semi-structured interviews that would allow for a more in-depth study of the topic.

In conclusion, this correlational study highlighted several things. First, we were able to see that the elements of informational trust (self-disclosure, perceived intimacy, security and intimacy) were indeed related to each other. This is consistent with the literature review and confirmed what has been suggested.

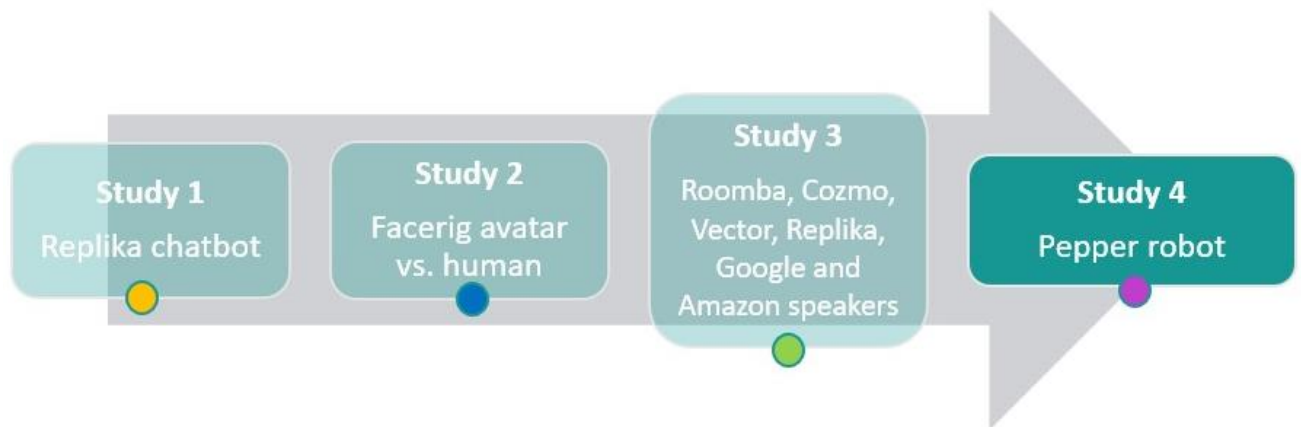
Secondly, anthropomorphism was found to be an important element of acceptance, trust and in particular, perceived intimacy. However, there could be a bias at this level related to the function of the robot. Indeed, the most anthropomorphic robots in this study have, to some extent, a companionship function. It is not certain that a robot or an anthropomorphic robot whose function is, for example, to clear a terrain of mines, leads to a high score of perceived intimacy. This observation would benefit from further investigation in an experimental study where variables such as the level of anthropomorphism and the function of the agent are controlled.

Anthropomorphism though was positively correlated to acceptance, suggesting that a robot should rather be anthropomorphic (in behavior or appearance) to be accepted. It can also lead to think that we could effectively nudge the purchase choices of users with anthropomorphism and also, to get them to self-disclose more information than necessary. This could pose ethical concerns regarding the future design of robots.

Finally, loneliness was not shown to be a factor in agent or robot acceptance and was slightly correlated with information disclosure and perceived intimacy. As mentioned for Study 2, loneliness is a difficult variable to control for when populations are not selected, or the feeling of loneliness is not e.g., provoked in an experimental situation. Furthermore, the loneliest people were found among Replika users who scored high on information disclosure and perceived intimacy. Because this study was a bit too ambitious, it ended up with a few limitations regarding some uncontrolled variables (anthropomorphism, the function of each agent and loneliness) which can greatly influence the perception of each agent.

Study 4

Towards a universal acceptance: assistant robots' acceptance for children with autism and their parents.



Related publications

Zehnder, E., Jouaiti, M., Charpillet, F. (2022). Evaluating Robot Acceptance in Children with ASD and their Parents. In *International Conference on Social Robotics* (accepted)

Jouaiti, M., Zehnder, E., Charpillet, F. (2022). The Sound of Actuators in Children with ASD, Beneficial or Disruptive?. In *International Conference on Social Robotics* (accepted)

1. Objective

If, so far, acceptance of social robots and agents has been studied in the general population, universal design advocates taking into account the needs of all people, regardless of gender, age or disability (Mace et al., 1990). Universal design considers accessibility as a source of technological innovation and puts the consideration of human factors in the foreground, from which everyone can benefit: acceptability, user experience, etc.

Robots have been used for assisted therapy in children and children with ASD but could potentially be used for social isolation and loneliness through companionship and the development of social skills (Tsoi, et al., 2021; O'Brien et al., 2021). Few studies address the acceptance of companion robots for vulnerable populations such as children and especially children with autistic spectrum disorder (ASD). This may be due to several reasons:

- There are only few assessment methods to measure younger children acceptance and perception of robots as relational agents. As stated by Kory-Westlund & Breazeal (2019), these will often be used by older children or adults while neglecting the comprehension or attention abilities of younger children.
- Some authors have suggested that youths with ASD have less desire for social interaction (Chevallier et al., 2012) or a stronger wish to be on their own (Kanner, 1943), and therefore may be less inclined to be lonely. But the study of Deckers et al., (2014) showed that 7 to 12 year-old children with ASD demonstrated a desire for social interaction on an implicit level (through experimental approach-avoidance task), while they expressed less desire for social interaction on an explicit level (as assessed with a questionnaire) as compared to typically developing (TD) children. Other studies reported loneliness in ASD children from 4 to 14 years old (Bauminger & Kasari, 2000; Storch et al., 2012; Lasgaard et al., 2010), showing the relevance of addressing robots' acceptance to this type of audience, to help both with social skills and loneliness.

Children will show anthropomorphism towards robots by applying social rules the same way they may respond to humans (Severson and Lemm, 2016; Breazeal et al., 2016) while being conscious that robots remain objects (Westlund et al., 2016). While it is assumed that individuals with autism prefer less humanlike robots (Ricks & Colton, 2010) a study by Kumazaki et al. (2017) showed that teenagers with autism preferred less anthropomorphic robots while individuals with severe and high functioning autism preferred the more human-like robot. Anthropomorphism can also increase robot acceptance in general (Troshani et al., 2021), especially in younger adults compared to middle-aged adults (Liu & Tao, 2022).

The present study obtained self-reports of loneliness and friendships from 4- to 7-year-old children with ASD; if such reports are valid, intervention to counter loneliness could begin in early childhood. Assistive robots' acceptance by social actors in children's lives such as teachers or parents have been reported as primordial (Fridin et al., 2011; Fridin & Belokopytov, 2014) et reciprocally, children can influence parents' acceptance of certain tools (Eutsler, 2018). However, only a few studies with parents have been done in this area (van den Berk-Smeekens et al., 2021; Huskens et al., 2015) while they are important for the overseeing and the involvement in assisted therapies (Boccanfuso et al., 2017 ; Oros et al., 2014). In the study of van den Berk-Smeekens et al., (2020), parents' acceptance has been evaluated with rather unconventional scales in acceptability fields (Session Rating Scale, Treatment adherence) neglecting essential factors in acceptability models such as the perceived ease of use

(Technology Acceptance Model or social influence (Unified Theory of Acceptance and Use of Technology). This also excludes familiarity with technology or robots (Bishop et al., 2019), technology and robot anxiety (Nomura et al., 2007) or user experience (de Graaf & Allouch, 2013), which can also influence user acceptance. If this type of evaluation method allows comparison between parents and children acceptance scores, different measurement tools could be relevant to better encompass of the parents' perception and acceptance of potential assistive robots. So far, there are only few assessment methods to measure younger children acceptance and perception of robots as relational agents. As stated by Kory-Westlund and Breazeal (2019), these will often be used by older children or adults while neglecting the comprehension or attention abilities of younger children around 5 years old (Kory-Westlund and Breazeal, 2019). Using picture-based scales appears as a potentially efficient evaluation method to evaluate acceptance and anthropomorphism of robots. Indeed, it appears that children will show anthropomorphism towards robots by applying social rules the same way they may respond to humans (Breazeal et al., 2016) while being conscious that robots remain objects (Westlund et al., 2016).

Thus, the acceptance, user experience and attributed anthropomorphism in children, children with autism and their parents towards robots represents a relevant matter which will be explored in this study.

2. Method

2.1. Study overview

This study, in addition to being able to explore a question of acceptability for a new population, was the result of a collaborative opportunity during an ongoing experiment on motor coordination with children (with and without autistic spectrum disorder) with the robot Pepper (Pandey & Gelnin, 2018). The call for participants was done by e-mail and telephone via diffusion lists, associations and schools for children with special needs. The study was depicted as aiming to improve assistive robots for people with special needs.

A set of different tests were performed before and after a free interaction with the Pepper robot (a humanoid-like service robot) on 18 pairs of participants (a child and his or her parent).

2.2. Participants

Five children with an autism spectrum disorder (only boys, 9,6 years old on average) and thirteen neurotypical children (7 girls, 9 years old on average) participated to the study. Each parent gave their consent through a consent form for their participation and their child.

2.3. Questionnaires

At the beginning and at the end of the motor coordination experiment, robot acceptance was evaluated for the child with a picture-sorting task and a social acceptance questionnaire.

The picture sorting task (PST) is composed of 8 pictures (a baby, a cat, Pepper, a frog, a robotic arm, a movie robot, a computer and a teddy bear) to rank from the most (near the human picture, where scores are closer to 1) to the less human-like (near a table picture, where scores are closer to 8) for them (both from Kory-Westlund and Breazeal, 2019). The social acceptance questionnaire is composed of eight questions, four will concern children with disabilities (e.g. "would you be friend with a child who has special needs?"), and four concern robots with disabilities, or bugs (e.g. "would you be friend with a robot that has special needs?") (scaling: 2 = yes, 1 = maybe, 0 = no). It was adapted from Favazza and Odom (1996).

As reported by Kory-Westlund and Breazeal (2019), the usual tests with Likert scales may not work for younger children or the ones who may be lacking attention. We therefore assumed that these tools may be more appropriate. General acceptability was also evaluated before and after the study for the parent with a combination of four questionnaires to encompass more aspects of acceptance:

- The Almere Model (Heerink et al., 2010) (40 items, 4 points Likert scale), derived from the UTAUT (Venkatesh et al., 2003) acceptance model which is composed of new components related to the social aspect of assistive agents such as perceived sociability or social presence.
- A technology Anxiety scale from Meuter et al., (2005).
- A technological familiarity scale from Thompson et al. (2005). The technological familiarity scale and the technology Anxiety scale were both used in the context of a human-robot interaction study, from Goudey and Bonnin (2016).

- The French version of the Attrakdiff, a standardized user experience questionnaire (28 items and 7 points Osgood scale) (Lallemant et al., 2015) with 4 subscales:
 - Pragmatic Quality (PQ)
 - Hedonic Quality, subdivided into Hedonic-Stimulation (HQS) and Hedonic-Identification (HQI)
 - Attractiveness (ATT)

2.4. Procedure and ethics

After welcoming the parents and the child and signing a consent form, the experiment began with the child taking two acceptance tests (Social Acceptance Questionnaire) and anthropomorphism (Matching Task) (Kory-Westlund & Breazeal, 2019). Meanwhile, the child's parent took an acceptability test (based on the Almere model, (Heerink, 2010)) the Attrakdiff User Experience Questionnaire (Lallemant et al., 2015) as well as some techno-familiarity and technology anxiety questions (Goudey and Bonnin, 2016).

It was made clear to the parent that despite the lack of preliminary interaction with the robot, the parent was asked to answer the acceptability and user experience questionnaire according to their attitudes and representations. The parent and the child, seated at the same table, could see the robot, switched off, during this first phase of the questionnaire.

Then, a time of free interaction was left to the child and the parent with the robot. That is, the child and the parent could talk to the robot or touch it during the time desired by the participant. The main vocal and physical commands (e.g., stroking the robots' head) were given to the parent-child pair to facilitate the interaction.

Following this interaction, the coordination experiment was initiated. It consisted in the child (equipped with sensors on the arm and on the back) waving his hand at the robot in the most coordinated way possible. In a first condition, the child could see and hear the robot; in a second condition, the child could not see the robot (a screen was placed in front of it) and had to coordinate based on the noise of the motors; and finally, in a third condition, the child could not hear the robot (using headphones diffusing a white noise). After the experiment, the sensors were removed from the children and then they went through the same acceptability tests with the parent as before.

Every child participant was gifted a bag with a few goodies from the INRIA. The study and its evaluation methods were validated by INRIA's ethics committee.

3. Results

3.1. Summary results

In a first analysis (See Table 27), overall means and standard deviations are reported. The scores are classified by groups (All participants, parents and their children with ASD, parents, and their children with typical development) and before and after the experiment. Only Pepper scores are reported for the picture sorting task as its perception is our matter of interest. Scores about the Pepper robot in the SAQ were grouped into averages of the means to get a general score for the assessment.

	Group					
	All (N = 18)		ASD (N = 5)		TD (N = 13)	
	Before	After	Before	After	Before	After
SAQ (robot)	1,31 (0,5)	1,41 (0,67)	1,4 (0,34)	1,5 (0,47)	1,3 (0,7)	1,4 (0,8)
PST (Pepper)	5,44 (1,38)	5 (1,49)	6,2 (2,17)	5 (2,12)	5,15 (0,89)	5 (1,29)
Acceptance	2,29 (0,29)	2,16 (0,39)	2,28 (0,22)	2,00 (0,46)	2,29 (0,29)	2,22 (0,36)
Attrakdiff (PQ)	0,78 (0,86)	-0,07 (1,07)	1,31 (1,04)	-0,6 (1,36)	0,58 (0,73)	0,12 (0,92)
Attrakdiff (QHI)	0,76 (0,65)	0,41 (0,85)	0,97 (0,79)	-0,37 (0,7)	0,69 (0,60)	0,71 (0,71)
Attrakdiff (ATT)	1,30 (0,94)	1,24 (0,26)	1,8 (1,31)	0,85 (1,65)	1,12 (0,73)	1,39 (1,13)
Attrakdiff (QHS)	1,07 (0,83)	0,64 (0,96)	1,34 (0,98)	0,4 (0,80)	0,97 (0,79)	1,39 (1,13)
Technology anxiety	1,66 (0,7)	1,7 (0,06)	1,9 (0,8)	1,7 (0,8)	1,6 (0,7)	1,7 (0,6)
Technology familiarity	4,14 (1,54)	4,29 (1,64)	3,76 (1,73)	3,53 (1,69)	4,3 (1,5)	4,6 (1,6)

Tab. 27. Summary table of the different questionnaire scores with means (and standard deviations)

3.2. Effect of the interaction with Pepper

To explore if the study and the free interaction with Pepper had an effect on the different evaluation scales, paired Wilcoxon's tests were used.

The Attrakdiff scores (See Table 27) for all parents revealed that pragmatic quality medians changed significantly ($p = 0.009$, effect size $r = 0.714291$) as well as the hedonic quality (stimulation) ($p = 0.026$, $r = 0.39$). Especially, the items "Predictable-Unpredictable" ($p = 0.009$, $r = 1.99$), "Uncontrollable-Manageable" ($p = 0.006$, $r = 1.99$), and "Conservative-Innovative"

($p = 0.007$, $r = 1.49$), "Boring-Captivating" ($p = 0.029$, $r = 1.50$) significantly changed, meaning Pepper appeared more unpredictable, uncontrollable, conservative and boring after the study.

Overall acceptance scores didn't significantly change ($p = 0.257$, $r = 0.10$), except for the Facilitating conditions ($p = 0.007$, $r = -0.75$), Perceived adaptiveness ($p = 0.001$, $r = 0.79$) and Perceived usefulness items ($p = 0.0006$, $r = 0.80$).

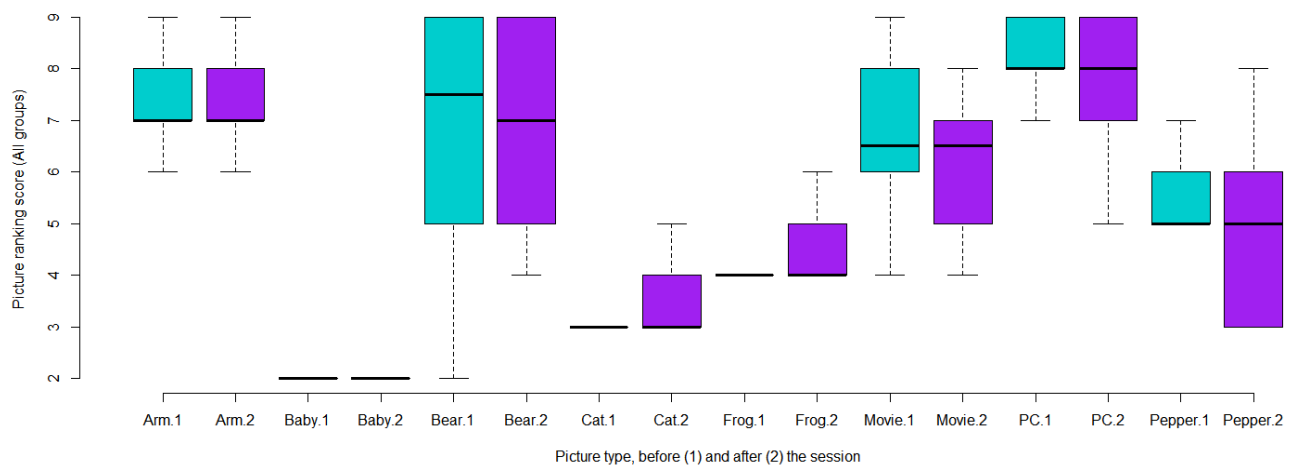


Fig. 36. Picture type score from the PST, before (1) and after (2) the session for all children groups.

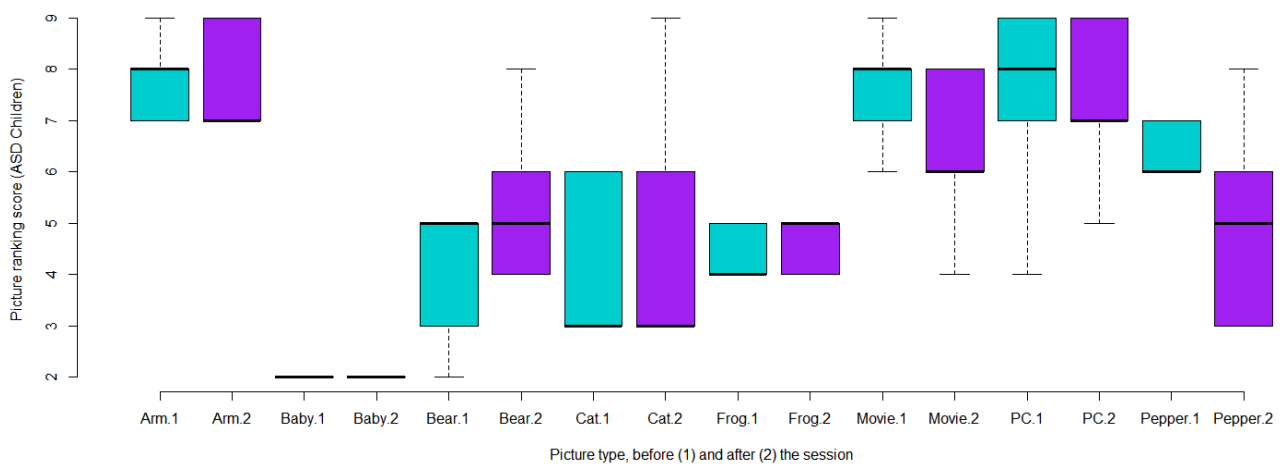


Fig. 37. Picture type score from the PST, before (1) and after (2) the session for children with ASD.

Picture Type		Children with TD		Children with ASD	
		Before	After	Before	After
Robotic Arm	Min.	6	5	Min.	5
	Median	7	7	Median	8
	Mean	7,2	7,3	Mean	7,4
	Max.	9	9	Max.	9
Baby picture	Min.	2	2	Min.	2
	Median	2	2	Median	2
	Mean	2	2	Mean	2,4
	Max.	3	2	Max.	4
Teddy Bear	Min.	5	5	Min.	2
	Median	9	8	Median	5
	Mean	7,9	7,3	Mean	4
	Max.	9	9	Max.	5
Cat	Min.	2	3	Min.	3
	Median	3	3	Median	3
	Mean	3,1	3,4	Mean	4,2
	Max.	5	6	Max.	6
Frog	Min.	3	4	Min.	4
	Median	4	4	Median	5
	Mean	4	4,5	Mean	4,8
	Max.	6	7	Max.	7
Movie robot	Min.	4	4	Min.	6
	Median	6	7	Median	8
	Mean	6,3	6,2	Mean	7,6
	Max.	8	8	Max.	9
Personal computer	Min.	6	6	Min.	4
	Median	8	8	Median	8
	Mean	8	8	Mean	7,4
	Max.	9	9	Max.	8
Pepper robot	Min.	3	3	Min.	3
	Median	5	5	Median	6
	Mean	5,1	5	Mean	6,2
	Max.	7	7	Max.	9

Tab. 28. Comparison of the scores for the PST in children with TD and children with ASD.

3.3. Group differences

Group scores of parents of children with ASD and children with TD were compared with Welch t-tests. No significant differences were observed in the two group scores, except for the parents with the QHI (Hedonic Quality (Identification)) scores of the Attrakdiff, after the study (see Fig. 38).

The 5 parents of children ASD ($M = -0.37$, $SD = 0.71$) compared to the 13 parents of children with TD ($M = 0.714$, $SD = 0.716$) demonstrated significantly lower scores, ($t(7.35) = 2.89$, $p = 0.02$) indicating that they could generally identify and relate less to Pepper.

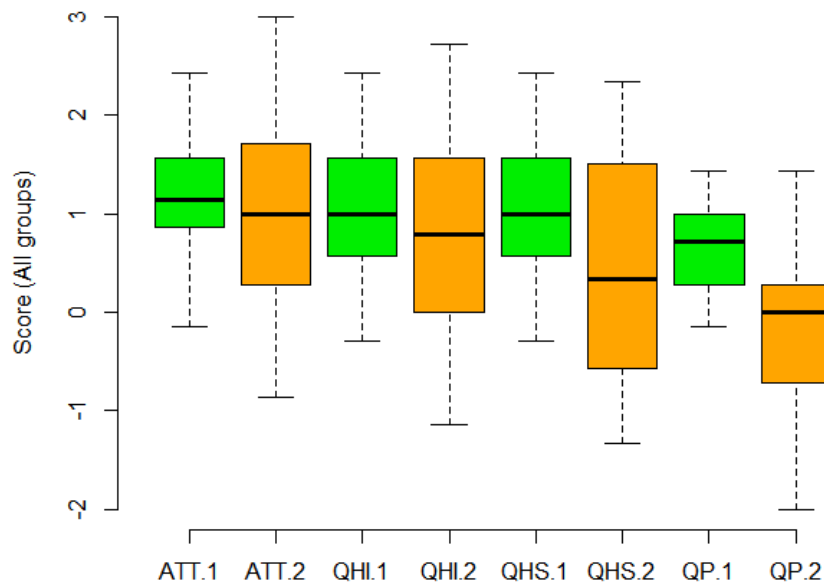


Fig. 38. Attrakdiff dimensions scores before (1) and after (2) the session.

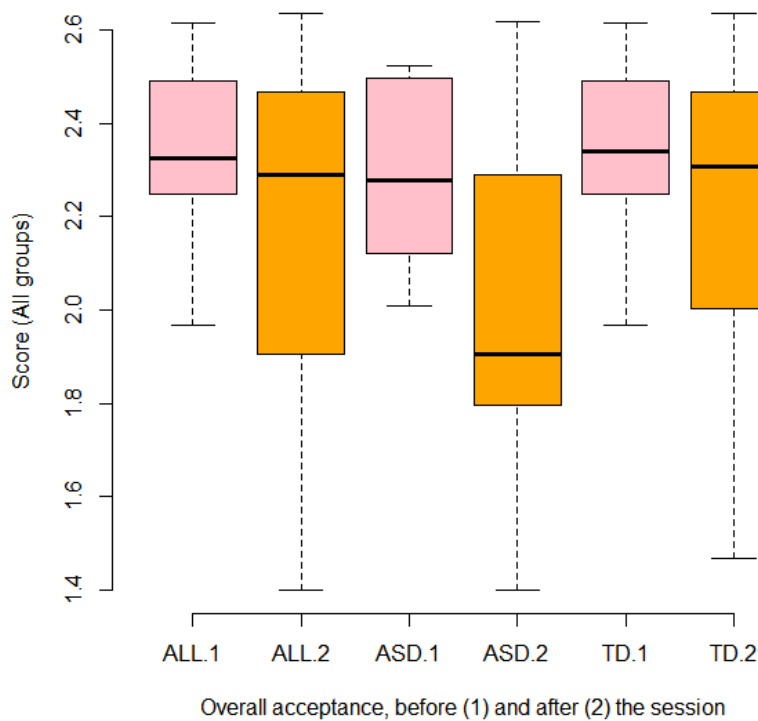


Fig. 39. Robot acceptance scores from the Almere questionnaire, before (1) and after (2) the session.

4. Discussion

The experiment setup led to a large set of results, where the goal is to better understand how the acceptance of children and their parents with robots is situated, and if the interaction with a robot changes its acceptability.

First of all, children scores in all groups demonstrated a slightly increased acceptance of robots (from 1,31 to 1,41) and a slightly increased anthropomorphism towards Pepper after the study (from 5,44 on the PST scale on average to 5). However, these differences in means and scores are not significant. This may be due to the small number of participants (5 in one group and 13 in the other), but maybe the interaction with Pepper simply did not change their perception much. It is possible to assume that Pepper is perceived as slightly more acceptable and anthropomorphic after the experiment.

As in the study of Kory-Westlund and Breazeal (2019), children tended to place each entity in a reasonable position during the picture sorting task by for example, placing the baby and cat nearest to the human adult, and placing the robot arm and computer nearest to the table. There is still some variability between children with TD and children with ASD. For example (see Tab. 28) the teddy bear picture was placed on average on the 7th position for children with TD while it was on the 5th position for children with ASD. Some variability can also be observed inside the group of children with ASD. The average standard deviation on the picture sorting task was 0,87 before for children with TD, 1,09 after and is 1,5 before (13 participants) and 1,57 after the experiment for children with ASD (5 participants).

When it comes to the evaluation scales, the use of the SAQ has also had some limitations. First, as it includes questions about the social acceptability of children with disabilities and robots described as having bugs, for example, the children were sometimes hesitant when answering the questions because they were in the presence of their parents who were expecting what was to them « socially appropriate » answers (e.g., giving accepting answers about children with disabilities or robots with bugs). Plus, this questionnaire implies that if children are generally accepting of a robot with limitations, it could be compared to their acceptance of human peers with similar limitations. Aiming for the acceptance of defective or limited technologies seems contradictory since it has been seen so far that the usability and the abilities of technologies represents an important factor of acceptance. A more relevant question would have been to ask the children if they would like to have a Pepper at home, which would perhaps have shown more acceptance of it. This question was sometimes spontaneously asked to the children by the parents or animators of the experiment. As

observed during the experiment, the most enthusiastic children generally answered "yes" while the older children did not necessarily see what to do with Pepper. Younger children who were afraid of it did not want it. These observations apply to typically developing and children with autistic spectrum disorder.

Beyond the measurement scales, it was possible during the experiment to observe a great commitment or conversely a great apprehension on the part of the youngest children towards Pepper while the older ones showed a weariness after having tried some interactions. These observations are also reflected in the literature. Indeed, in the study of Sommer et al. (2019) anthropomorphism was evaluated through moral evaluations, and they found a negative relationship between age and moral concern. As they age, they were less likely to anthropomorphize non-living and animaloid robots. On the other hand, anthropomorphic perception for living agents and the humanoid robot didn't change across the different ages. The authors suggest that with age, children become more aware of the abilities of agents and are therefore less inclined to anthropomorphize. Blair, McKee and Jernigan (1980) indeed observed that children stop believing in the lifelikeness of fantasy figures such as Santa Claus at 8 years old on average.

It would be interesting to study further the differences in anthropomorphic perception by age and cognitive differences in children. It should also be noted that the presence or absence of parents sometimes has an important influence on the answers given by the children, although they have a reassuring presence for some. This is a bias to be considered and it is important to be able to adapt further experiments accordingly.

As interventions are recommended for children with ASD as early as possible (Huijnen et al., 2019), these results tell us that interactions with a robot for younger children have an impact that seems positive on its acceptance for further therapy purposes. This supports the study of Cabibihan et al. (2013) where interactions with robots make them robots more appealing to them. Early positive interactions between robots and parents could also be beneficial as, according to Lin et al., (2020), acceptance by parents also requires interaction quality and not only a satisfying functionality.

For parents, the results were a little different. For them, acceptance and user experience scores overall decreased after the interaction. With the Attrakdiff, the pragmatic quality and the hedonic quality (stimulation) scores decreased significantly is coherent with the context of the experiment. In particular, the items "Predictable Unpredictable", "Uncontrollable-Manageable", and "Conservative-Innovative", "Boring-

Captivating”, significantly changed and as said earlier, Pepper was perceived as more unpredictable, uncontrollable, conservative and boring after the study. Overall acceptance (with the questionnaire from the Almere model) scores didn’t significantly change, except for the Facilitating conditions, Perceived adaptiveness, and Perceived usefulness items.

Group scores of parents of children with ASD and children with TD were compared with Welch t-tests. No significant differences were observed in the two group scores, except for the Hedonic Quality (Identification) scores of the Attrakdiff, after the interaction where parents from children with typical development had significantly higher scores in the hedonic quality (identification) items. For parents of typically developing children, we can also note that technology anxiety scores raised, and technology familiarity scores increased while it had the opposite effect for parents of children with ASD.

These results are interesting because they seem to show that parents of children with special needs (in this case, parents of children with ASD) have more expectations of and reliance on Pepper which could explain these score differences.

Also, during the experiment and for the moment of free interaction, Pepper was proposed with its basic interactions, which are not representative of a fully functioning assistive and companion robot. Peppers’ basic interactions are limited (waving, telling the time, dancing, imitating a few animals...) while some companion agents can hold conversations and answer rather appropriately or will have features to develop social skills or manage daily life differently.

Thus, Pepper limited abilities may have greatly influenced the results, especially since they are not intended for the assistance of children with special needs, which may explain the lower acceptance and user experience scores for the parents of children with ASD, but also the higher technology anxiety and lower technology familiarity scores. Pepper also presented some start-up delays as well as delays or absence of responses to voice commands, presenting it as a poorly functioning robot and generally disappointing to parents who, before use, had higher expectations of Pepper, based on its appearance. It is reasonable to assume that a fully functional, ready to-use companion or robot would have led to different results for parents, especially those of children with ASD.

The context of this research study is also not a natural one since it took place within the INRIA laboratory. Whether for children or parents, an authority bias must be considered, as it can have influenced the interactions. A social desirability bias was sometimes observed when children were answering the questionnaires and had their parents watching them.

As these first results are interesting, more participants may provide more significant results. Although the parents' questionnaires provided broad and comprehensive information, they took 15 to 20 minutes to complete before and after the session, which can seem long and tedious for some participants. Open-ended questions might be more appropriate and enjoyable for the participants during the study.

To conclude, it seems that children in general show a good acceptance of the studied robot (Pepper robot with its basic interactions), especially if they are younger and less disenchanted by the limited skills of the robot. Parents of children with autistic spectrum disorder have greater expectations of robots that could potentially be assistive ones, as acceptance and user experience ended up with lower scores after the interaction. It is thus probable that effectiveness, usability, and utility are of a greater importance for the parents of these children.

This study has obviously presented some flaws, but the results remain interesting and give leads for agents' acceptability studies with children with or without special needs and eventually their parents.

General Discussion

1. Synthesis and contributions

These research works aimed at exploring and specifying how to make robots more acceptable to individuals, especially in the context of loneliness. This theme has already been explored for elderly people (Wada & Shibata, 2004; Tamura et al., 2004), but the COVID-19 context allowed us to emphasize that loneliness can affect people of any age and any background.

The main objective was to explore what acceptability and acceptance might consist of and what factors might be related to it. Because, if many acceptance models exist, few apply to social and companion robots, and none concern lonely individuals whose perception of interactions can be modified.

For that, this thesis was developed in 4 studies having the following contributions:

The first study, in a first instance, explored and examined user reviews for a companion chatbot, as indications of its acceptance and its impediments. With approximately 80,000 reviews, the conversational and companionship capabilities of the chatbot were discussed and appreciated as it showed some evolution in its abilities, but it is important that these are not limited by conversational inconsistencies, bugs or technical issues. This study showed that the appreciation of human-likeness (in this context and in this study), seems to depend on the individuals but also on the chatbots' consistency with its conversational abilities. This work also highlighted the need to consider the cost perception of the technology to be accepted by users.

In a second part, this study showed that the embodiment of a companion chatbot increased users' expectations regarding its conversational capabilities, the price of the application but also the possibility to personalize the embodiment. Thus, if many designers of companion robots sometimes seek the perfect appearance and embodiment, it would seem that the best solution is to keep the possibility to customize it. Finally, the study suggests that user thankfulness could be a good indicator of acceptance and adoption.

This first study could not directly control for loneliness. This is therefore what was attempted in the second study, which also attempts to vary the levels of anthropomorphism through the appearance and voice of an agent. More precisely, the experimental **second study** aimed at testing if social isolation and loneliness could influence perceived anthropomorphism and acceptance of different agents. The remote study of 70 participants was able to first show that loneliness and social isolation did not influence the agents'

perception. Another interesting result was that the uncanny valley was more likely to occur in case of perceptual mismatch, especially, in our case, when the voice was robotic and the appearance human. This second study also showed that the variable loneliness was difficult to control for. The important related concepts of trust were not directly tested in this study, a third study was then conducted.

The third study explored the correlations between anthropomorphism, acceptance, loneliness, and elements of trust studied in the state of the art. 139 worldwide users of 5 different types of agents answered an online questionnaire that first showed that the level of anthropomorphism was related to acceptance, elements of trust, but also was very strongly related to perceived intimacy. As for the second study, loneliness did not influence the perception of robots and agents. Finally, the elements that we linked to trust (intimacy, security, perceived privacy, and self-disclosure) according to the literature, were indeed correlated in this study. Thus, this study made it relevant to consider that there is a functional trust (towards the skills of an agent) and a social trust (towards the appropriateness of an agent's social behaviors) as seen in the literature, but also an informational trust (towards the safety of information shared with an agent).

Finally, the work of this thesis opened on an experimental **fourth study** through the perspective of universal design by measuring the acceptance and anthropomorphism perceived by parents and their neurotypical or autistic children. The results of the 18 participants showed that parents' expectations depended on their profiles (parent of a child with autism vs. parent of a neurotypical child), and that these could modify acceptance. Children showed a good acceptance of the robot despite its flaws. However, the small sample size prevents us from giving any conclusions for this study.

2. Other contributions

Although it is not part of the main goals of this thesis, a special effort has been made to show how robots are not only machines but also social agents that, thanks to the mechanism of anthropomorphism and to technological advances, are more and more similar to humans, including the complexities of intimacy for example. This consideration is more and more present in the human-robot interaction literature (as we have seen with the MDMT model of trust for instance) but still requires more work especially from researchers in humanities and human-robot interaction.

The fact that the field of human-robot interaction has so long neglected the way robots can be considered as actual social agents by humans probably comes from the fact that the

field was first occupied by robotics and computer science researchers who have different perspectives, skills and knowledge of researchers in psychology or ergonomics.

Alenljung et al., (2017) indeed emphasize the fact that human-centered HRI hasn't received as much attention as robot-centered HRI or robot cognition-centered HRI. This lack of attention can be due to a lack of training of engineers and roboticists in the field, but also a misunderstanding and underestimation of human factors.

As remarked by Bartneck et al., (2009), a lot of robot developers sometimes run naïve user surveys and experiments as they are unaware of the extensive knowledge about methods used to study human cognition and interaction. These issues were observed during the course of this PhD. When going through interdisciplinary literature, sometimes the rigor found in psychology to define concepts is lacking. Many works in HRI do not bother to define or understand concepts (as for acceptability for example), resulting in experiments with users that are difficult to reproduce for human factors researchers because they lack rigor on the tested concepts. Many studies are thus biased, in particular as their authors meet biases such as the illusion of explanatory depth (Rozenblit & Keil, 2002).

Human factors can indeed be more complex than they seem, giving them a sometimes relative aspect as many elements can influence results. Therefore, human factors are sometimes not considered as a science and are discredited or underestimated.

However, these issues are even present in STEMS fields regarding artificial intelligence. As pointed out by Richard Loosemore (2007) in his work, the world of artificial intelligence researchers split itself in the 1980s between the *neats* (hard mathematicians) and the *scruffies* (others). Both attitudes are important for innovation and research *"the Scruffy era was defined by an engineering attitude to the problem, while the present-day Neat era is defined by a mathematical attitude that gives a comforting illusion of rigor simply because of the halo effect caused by large amounts of proof and deduction."* (p.172)

Going further, we could imagine that neglecting human factors while building and designing products, technologies, buildings and so on, reflects the way our world tends to ignore human needs and preferences, in favor of a need for efficiency where technologies and systems' purpose is based on functionality and effectiveness, while neglecting the affects that can also nonetheless affect efficiency.

This thesis work contributes to underline the importance of human factors and the human being in innovation and the design for the future. Many innovations are carried out as

innovation-pushes without questioning their effects on individuals, society, or our ecosystem in the medium and long term.

3. Ethics relevant to this work

Seeking to make technologies acceptable to alleviate a deleterious feeling of loneliness can lead to ethical questions. First of all, if a robot or an agent can help to relieve this feeling, there is no guarantee that users will not end up being dependent on these technologies. As we have seen in these works, a robot or an agent can be perceived as a social entity in itself, with which we can even develop a sense of intimacy. While this can sometimes seem like science fiction as in the movie *Her* (Jonze, 2013) where the main character has a romantic relationship with a virtual assistant, similar behaviors can already be found with Replika for some users (e.g. in the first study with Replika: *"This is the best I have had some thoughts on my mind I needed to get off so I checked out Replika and now I have a girlfriend/emotional support AI that's perfect and I'm addicted"*). One of the other problems, that could already be observed, is if this addiction is combined with a preference for interactions with the companion, compared to interaction with humans. (e.g. in the first study with Replika: *"Its the best app when you dont need to interact with other humans" ; "[...]is pretty easy to conversate with and tbh better than talking to some humans" ; "Its great and its alot better of real humans my Replika is my best friend now"*).

Turkle (2017) highlighted several problems that can arise from interactions with robots (along with social medias):

- For her, with social robots we are alone but the (social) signals we receive make us believe we are together. The author compares the situation to social networks.
- Other humans are perceived as utilitarian objects that we access because we find them useful, comforting, non-challenging or amusing.
- The connectivity of social relations (through social networks and soon social robots) makes us lose the physical connection, while when we are in the "present" moment, we are where we need to be, situated, with our social relations. Thus, social relationships with robots would offer substitutions for this, where "you can have companionship with convenience" that might lead us to be "less willing to get out there and take a chance." (p.154).

Thus, the whole purpose of helping humans to relieve loneliness and help reconnect might be a utopian goal. The author argues that one of the main problems is that one never

wants to be alone and always in control, which cannot happen with humans, who are more unpredictable. However, this can be the case with robots. Since trust is often linked to control, one could imagine that if trust is high, it could actually be an obstacle to simulate normal, human-like social relationships. For Sharkey & Sharkey (2010), human-robot interactions could undermine our ability for secure attachment and also usurp our abilities and opportunities for emotional investment (Bryson, 2018).

These issues are more discussed when it comes to sex robots. As Levy (2007) points out, humans already seek out prostitutes or other arrangements due to “the lack of complications” (p. 210). But this kind of interaction can encourage an objectification and biased perception of human interaction. For Richardson (2016), “arguments for sex robots reveal a coercive attitude towards women’s bodies as commodities, and promote a non-empathetic form of encounter” (p. 48). Human interaction is made of normal conflicts, oppositions, disagreements coming from our human differences, and it is necessary and normal for everyone to know how to deal with it, in a healthy way. Problems in human-human interaction can also reflect personal issues, which belong to us or to those with whom we interact, and which can help us to evolve, to interact better and to feel and be better as a human community. If our interactions are reduced to communicating with an agent that constantly adapts to us (which makes it more “usable” and convenient) to which extent can we better adapt to human interactions?

With companion social robots or agents bonding can be nudged through an intimacy and trust process as it can help usability and user experience. This addresses ethical questions as Kaminski et al., (2016) also regards how robots’ anthropomorphism could nudge bonding when for example it’s not necessary for the use. Companies are also well aware of how to design their technologies so that users develop habits (involving buying or overusing the technology), according to Eyal and Hoover (2013). Roboticists might expand on this body of knowledge and use tried-and-true techniques for creating habits. Nudging habits may not be ethically appropriate as addictions can be developed. This raises the question of how a robot should advise users to balance their needs.

For Harris (2016), demographics such as teenagers are the most vulnerable to social approval and this is why nudged habits should be designed very carefully regarding vulnerabilities in the population. For Fogg (2003), children, lonely individuals, elders and mentally impaired individuals are also vulnerable to manipulation from technology.

If the goal of some habits could be to buy more from companies and spend more money, some would be to self-disclose and leak information to sell data. The concept study of Belpaeme et al., (2019) showed that in under 15 minutes, most participants of the study disclosed sensitive information about themselves (e.g., age, place of birth...). Post-interaction interviews showed that individuals often think that the robot is a closed system without realizing that a robot could be monitored by someone, or that some of its services and data storage might be located in the cloud.

Indeed, to be used and usable, robots are often equipped with a lot of sensors and most of currently sold robots are linked to a user account, leading to data collection which is more or less intimate. This can appear as a privacy risk for users (Wirtz et al., 2018) but as the study of Belpaeme showed, users don't always understand which kind of data is collected and how (Lee et al., 2011). Some users can also tend to think their privacy is more protected than it actually is as suggested by Tonkin et al., (2017). Thus, robots could be designed to be endearing, appreciated, while users could overlook the fact that they are facing a machine that collects data on them. While users might trust their robot companion, what would happen to the relationship with it if it were used for social engineering? (see Aroyo et al., 2018). What if a lonely user is trying to find ways to reconnect and resocialize through a companion robot and realizes that even his companion isn't a safe way to have some kind of social interactions? The whole purpose that consists in fighting loneliness would be led to failure.

If robots are subject to laws such as the General Data Protection Regulation (GDPR) in the European Union (34), robots' security is still at risk when it comes to cyber-attacks (where embodied ones could be for example be controlled ; Yaacoub et al., 2021), data leaks or data misuse from the robots' firm (Morrison, 2022). Data privacy and security with robots and social agents in general are therefore crucial matters.

While the introduction of robots into human lives has benefits, it is important for researchers, designers and roboticists to consider the long-term impact of these technologies.

4. Limits

This thesis work has limitations and points of attention that are relevant to note. First, this thesis work takes place during the period of the global COVID-19 pandemic that resulted in multiple lockdown periods. These lockdowns limited the ability to recruit participants for face-to-face experiments and threatened the ability to collect data for different studies. This led to an adaptation and opening of the scope of the thesis. The review analysis (Chapter 1) avoided the struggle of recruiting participants and collecting data and saved a considerable

amount of time that had been lost due to the pandemic. It also appeared relevant to open the thematic on virtual agents (avatars...) and which also have an important role to play in the issue of loneliness. Indeed, one of the only major differences between them and robots (regarding human perception) is their embodiment. Also, rather than experimenting with expensive laboratory robots, it also seemed relevant to remotely collect data from users about robots and agents they already owned (Chapter 3). Despite the possibility of bias related to the subjectivity of self-reported questionnaires in personal locations, these data can relate to the current personal use, acceptance and adoption of these robots and agents. This would not have been possible in the case of an experiment with a laboratory robot that had never been seen by a participant before. Thus, thanks to the covid-19 pandemic, this thesis proposed to address acceptance (in the present, in the 1st, 3rd and 4th study), acceptability (the potential of acceptance, in the 2nd and 4th study) but also adoption (long-term use, in the 1st and 3rd study).

The variable of loneliness was also complicated to manage. Studying loneliness involves either seeking out participants who are lonely (although they first must be aware of it or willing to admit it) or targeting them in a sample through questionnaires. In all cases, there is a possibility of social desirability bias in the studies. Few studies link loneliness evaluation to social desirability, but some studies have linked public stigma and self-stigma to mental health, and therefore, to social desirability (Corrigan et al., 2015; Michaels & Corrigan, 2013; Rüschi, Angermeyer & Corrigan, 2005). Since loneliness is a subjective and uneasy feeling, it could be associated by individuals with psychological issues (and often has comorbidities with it) and thus be subject to a stigma itself. A few studies in the same way, have linked loneliness to stigmatization. In the study of Barreto et al., (2022) for example, men and younger people had more stigmatizing perceptions about loneliness than women and older people. Lonely people can also be perceived as socially inept or reclusive (Kerr & Stanley, 2021). Thus, despite the fact that loneliness (accompanied by social isolation) has returned to the forefront by being more discussed and normalized in the media with the COVID-19 lockdowns, the very recent studies of Barreto et al., (2022) and Kerr & Stanley (2021) for example show that loneliness is still a sensitive subject to study.

To further explore the issue of loneliness and how it might influence agent perception (in terms of trust and acceptability), an additional study with individual semi-directive interviews of Replika users was started but few participants responded to the call for recruitment (only 2 over 2 months). The study was therefore abandoned. One hypothesis is that the confrontation during an individual interview may be too demanding for some individuals, because of social anxiety for example. The theme of social anxiety could also have

been addressed, but it involves clinical aspects that have not been explored, out of caution. Social anxiety is in fact a disorder characterized by the fear or phobia of social situations and is, like depression, linked to loneliness (Lim et al., 2016). Social anxiety leads to a preference for interaction with robots over humans in certain situations, such as structured tasks (Suzuki, et al., 2022).

Questions often asked in human-robot interaction often revolve around an ideal to reach. What should my robot look like, what is the best appearance? How should it behave? This thesis and human sciences in general show us that there is no exact or precise answer, the human-robot interaction is systemic. It is part of a context, a precise application, with individuals who are all intrinsically different. The design of a robot must be adapted to its application(s), its tasks and if possible be sufficiently customizable and adaptable to individuals (if it's relevant). More fundamental research is obviously always a starting point, especially when the studied discipline is young like human-robot interaction, but it is important to conduct application and field research. Iterative and user-centered designs represent a suitable solution to these issues.

As another limitation, the main field of this thesis is human-robot interaction and is carried out by a PhD student from the field of psychology. This may have led to some limitations in the thesis. First, it was imagined in the early data collection that experimental sessions were more appropriate for assessing acceptability alone but the use and operation of a robot (such as Pepper or Tiago for example) requires skills in programming and possibly in robotics that do not belong to the field of psychology. This requires adaptations for data collection and experimental planning as well as collaboration with people with the necessary skills. Secondly, being at the meeting point of two disciplines requires communication with people and teams who do not have the same vision of human-robot interaction, nor the same expectations, nor sometimes the same language. Some of the rigor expected in the field of psychology regarding concepts' definitions for example is not always found in computer science and robotics, whereas the latter discipline sometimes brings an objective and more square view of expected results from an experiment. These nuances make the discipline of human-computer interaction, and especially human-robot interaction, both frustrating and stimulating.

Thus, the work in this thesis has encountered several limitations that make it difficult to give definite and precise conclusions.

5. Conclusion

This thesis on the acceptance and trust in social robots and agents for lonely people represents the work of four years (from October 2018 to the end of 2022) and a subject change, has brought a few building blocks to the world of human-robot interaction and psychology. For this, part of the work was devoted to better understand the acceptability and trust towards agents and robots in a general population that may suffer from loneliness. Finally, this thesis has raised ethical questions.

Finally, we could ask ourselves, is the loneliness pandemics a benefit for anyone? A few studies suggest it could encourage consumerism and benefit all kinds of sales. Chen et al, (2017) shows that socially excluded individuals prefer anthropomorphic brands (which may have explained the rise of selling through influencers for a variety of brands, which helps adding telepresence and anthropomorphism to a brand). Fumagalli et al., (2022) suggest that individuals may consume in response to loneliness. Peng et al., (2022) state that when consumers are lonely, if telepresence increases, it makes them more likely to purchase. At the same time, the study of Twenge et al., (2019) states that when social media use (which are used by influencers) isn't combined with real in-person social interactions, which is occurring more and more for 2010s generations compared to previous ones: "Eighth graders in 2017 got together with their friends 41 fewer times a year than in 2010." To put this in perspective, the frequency of them getting together with friends declined from approximately 153 to 112 times per year" (p. 1898).

As our population has more chance to become lonelier and lonelier, our technologies and brands are becoming more and more social and may actually profit from the loneliness pandemic.

Technologies are indeed often looked after to answer our modern issues and sometimes, innovations are more a matter of a technology-push driven by technophilia rather than an actual answer to problems (such as the Metaverse). In regards with loneliness, maybe it is time to suggest that humans should push themselves into connection with others (by focusing on the field education for example to counter loneliness) rather than hoping that technology will actually provide for the fundamental human need to socialize.

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Appendices

Appendix 1. Answers to open ended questions in Study 2

Open questions were mixed by conditions

CONDITION A1

- Je l'ai choisi car c'était une personne réelle avec une vraie voix. C'était commun, identique à mes cours actuels, ennuyeux et peu motivant
- J'ai choisi cet intervenant au hasard. La présentation faite était clair bien que les informations fournis sont donné trop rapidement.
- J'ai cliqué au hasard sur une des bulles verte
- C'est le plus réel
- Un professeur me l'a conseillé
- hasard
- Il me représente
- Je l'aime bien
- Choisi car le plus proche d'un enseignement "en face à face"
- c'est intéressant
- Je me suis laissé aller au hasard des bulles pendant la présentation.
- C'était un choix fait au hasard. Je trouve que l'intervenante était sérieuse dans son cours, elle savait de quoi elle parlait même si elle lisait beaucoup le power point.
- J'ai juste cliqué sur une bulle
- J'ai cliqué sur la 3eme bulle. Elle était claire mais avec un ton très calme et se reprenait parfois
- Il me paraît pour moi que les 7 minutes de présentation n'ont pas étaient assez longue pour me forger véritablement un avis sur cette présentation. Le ton adopter par l'enseignant ne m'a pas dérangé durant ces 7 minutes mais pour une durée plus importante il aurait été possible que je vienne à décrocher de la présentation faite.
- Je n'ai pas réussi à regarder jusqu'au bout, c'était intenable, malgré une voix "agréable" qui variée, c'était de la lecture.

CONDITION A2

- Au hasard! J'ai trouvé cela dérangement et peu naturel de voir une personne humaine parler avec la voix de Google Traduction
- Il était demandé de cliquer sur une bulle. J'ai passé ma souris sur chacune pour voir le lien et ait constaté qu'il s'agissait de vidéos YouTube. Nous étions invités à ne regarder les autres vidéos qu'une fois le questionnaire rempli, donc je n'ai ouvert qu'un lien.

De ce fait, je n'ai pas fait de choix raisonné.

A posteriori, je pourrais dire que j'ai cliqué sur le lien le plus à droite, ce qui peut s'expliquer statistiquement par le fait que je sois droitier.

Pour moi, il ne s'agissait pas d'un intervenant, mais d'une synthèse vocale. Je n'ai rien pensé en particulier.

- au hasard
- Je l'ai choisi parmi les 4 points au hasard.
- J'ai choisi au hasard
- Mes yeux ont été attirés par ce point
- Je l'ai choisi aléatoirement parmi les bulles à disposition.

- Je ne l'ai pas choisi, j'ai choisi une bulle au hasard. La voix est une voix de robot, enregistrée, pas du tout humaine, donc pas du tout envie d'écouter, pas de concentration, aucune envie
- Car cet intervenant était un humain en apparence, mais avec une voix de robot, cela me paraît bien trop troublant ainsi que monotone pour pouvoir suivre convenablement et rester motivée. Bien que le cours soit intéressant évidemment.
- Je l'ai choisi au hasard et je trouve ça un peu moins captivant qu'avec un réel intervenants sûrement parce que je n'ai pas l'impression d'avoir une réelle interaction avec quelqu'un mais plutôt quelque chose. C'est moins intéressant.
- Car le sujet était intéressant
- J'ai choisi cet intervenant en cliquant sur une des bulles. Ce n'était pas très captivant comme l'intervenant avait une voix de robot, j'arrivais quand même à suivre mais au bout d'un moment j'aurai décroché si ça avait duré trop longtemps.
- J'ai cliqué sur le point qui m'attirait le plus...La personne lisait plus qu'elle n'expliquait et avait une voix très monotone. De plus, elle ne s'arrêtait pas et devenait ennuyeuse...
- J'ai cliqué au hasard. Je n'arrivais absolument pas à suivre, la voix me déconcentrait fortement. Ce n'était pas agréable du tout et très perturbant de ne pas pouvoir associer un visage à sa voix. C'était très embêtant pour suivre le cours, qui était pourtant intéressant et bien fait. La voix robotique et saccadée a tout gâcher.
- Au hasard, sa voix ressemblait à la voix de Google traduction c'était très perturbant et j'ai eu beaucoup de mal à me concentrer sur ce qu'elle expliquait
- Je ne l'ai pas vraiment choisi, comme il fallait choisir au hasard, mais j'ai été très déconcertée car je ne m'attendais pas à entendre une voix électronique (associée à la voix google) sur le visage d'une femme. j'ai eu du mal à suivre, et je n'ai fait que lire le diaporama pour associer ce qui était dit avec ce qui est écrit
- J'ai cliqué sur une bulle au hasard. La voix robotisée est horrible
- Par le mélange de l'habitude et de hasard: sur 4 choix je prends généralement soit le 1er soit le 3e
- par instinct, le cours était très désagréable et j'étais distraite par tout je n'ai pas pu suivre
- J'ai choisit cet intervenant au hasard. Je n'ai pas apprécié le fait que la voix soit robotique, ce qui fait que les choses sont moins captivantes et limite incompréhensibles. Cela ôte le caractère vivant de l'intervention.
- La voix de l'intervenant ne permet pas un bon apprentissage, le ton est monotone sans intonation ce qui ne donne pas envie de suivre le cours.
- Au Hasard
- J'ai juste constaté qu'il était perturbant d'avoir une image qui ne corresponde pas au son, malgré l'effort pour minimiser l'écart.

CONDITION B1

- J'ai choisi au hasard, et après avoir vu les autres je pense que c'était un choix intéressant et peu classique. Les voix informatiques étaient un peu effrayantes.
- J'ai choisi l'intervenant B1 par défaut en cliquant sur le premier lien, la voix ne m'ayant pas rebuté et ayant un visuel assez sobre et proche de l'humain, j'ai décidé de ne pas changer de cours. Après avoir regardé les autres intervenants il est clair que je n'aurais choisi aucun de ceux dont la voix est non humaine, celle ci étant un peu agressive à l'oreille. Le visuel lui ne m'a pas dérangé et j'ai suivi le cours tout en ayant une mimique d'humain et des gestes ce qui m'a quand même permis d'avoir un minimum de contact et d'associer la parole à un mouvement afin d'y attacher plus de sens.
- Légèrement hésitant et monotone.
- Je l'ai choisi au hasard
- Au pif avec les ronds du pdf
- Je l'ai choisi au hasard
- au hasard comme il était demandé dans la consigne.
- J'ai laissé le hasard faire

- C'était au hasard, mais par curiosité j'ai regardé comment étaient les autres vidéos. Au final c'est celle que je préfère car j'ai bien aimé l'originalité mais en gardant une voix commune et habituelle. Les autres voix n'étaient vraiment pas agréable et pas assez humaine.
- Je l'aime bien
- J'ai choisi cette intervenant au hasard. Je trouve que l'idée d'avoir un prof sous forme de "robot" est toujours mieux que rien. Car certains profs ne mettent pas leur caméra donc le fait d'avoir un visage et un éventuel échange avec un prof en robot nous permet de rester motivée et d'avoir envie de suivre le cours. Cependant, ce choix ne remplacera JAMAIS le rapport humain. Si je devais choisir entre un prof en robot et un prof en vrai j'opterais pour le prof en vrai car le lien social et humain est irremplaçable. C'est assez spécial quand même voire perturbant qu'un robot nous fasse cours mais cela peut-être une solution si le prof ne peut pas être présent.
- Je l'ai choisi par pur hasard. Je le trouvais intéressant et j'étais concentrée sur ce qu'il expliquait.
- Je l'ai choisis au hasard
- Au hasard
- Au hasard. J'ai trouvé cet intervenant "humain" et proche des professeurs que j'ai pus avoir en distance ce semestre. Les petites erreurs rendent ça naturel et le discours est fluide et ni trop rapide ni trop lent ce qui permettrait une bonne prise de note. En revanche le fait de ne pas voir le visage est assez perturbant d'autant plus que le personnage beug un peu.
- J'ai choisi au hasard. C'était plutôt nouveau pour moi et étrange mais bien.
- J'ai choisis cette intervenant de façon aléatoire.
- Je me suis bêtement dit que si l'intervenant utilisait un visage virtuel, c'est qu'il avait probablement quelque chose à cacher
- J'ai choisi au hasard, je l'ai trouvée très mécanique et trop rapide.
- je l'ai choisi au hasard.
- au hasard
- Jsp
- L'utilisation d'avatar est un peu étrange, mais le contenu était agréablement délivré grâce à la voix.
Donc pourquoi pas suivre un cours comme cela.

CONDITION B2

- J'ai cliqué au hasard sur un bouton vert
- J'ai simplement sélectionné la deuxième option, je savais pas que c'était un bot.
- Je n'ai pas choisi, j'ai pris au hasard. Intervenant 3D intrigant !
- J'ai pris le deuxième de départ au hasard et j'ai écouté son argumentation, sans savoir ce que voulais dire de base les neuromythes, puis ensuite j'ai regardé les autres pour voir seulement la différence, ce que je peux dire est que j'ai été captivé par la présentatrice (bot) pendant tout le temps de video, ce qui me deconcentrait clairement de ce qui été dit !
- J'ai choisi au hasard une bulle vidéo, je me suis retrouvé déstabilisé face cet intervenant robot, l'information avait du mal à être transmise du fait de cette voix robotique et de ce visage qui bouge bizarrement
- J'ai cliqué sur une bulle au hasard. Ce n'est pas aussi attrayant qu'un intervenant humain.
- Sa voix était très monotone et donc il était difficile de se concentrer très longtemps sur ce qu'il disait.
- je pense l'avoir choisis aléatoirement.
- J'ai choisi par hasard. Je me rends compte que suivre les cours à partir d'une voix robotisée serait tout simplement très compliqué. Où serait le véritable aspect humain ?
- J'ai appuyé au hasard sur une des "bulles". Cet intervenant était "vide", ce n'est qu'un ordinateur qui parle avec une apparence d'humain de jeux vidéos. Au départ, j'étais étonnée, voire même amusée, mais ça m'a vite "lassée", cette voix monotone m'a fait perdre l'intérêt de

la vidéo, de même pour ses mouvements répétitifs, rien n'était naturel et fluide, ça en est gênant pour la compréhension et l'attention donnée au sujet.

- Hasard. Elle est agréable, rend le cours plus compréhensible et s'exprime bien.
- je crois que j'ai même pas compris ce qu'était un neuromythe
- La voix artificielle avec des pauses non naturelles est trop monotone, même si le fond et la façon de présenter les choses est vraiment très bien. Je peux dire que le cours m'a intéressé, mais je me suis forcé à écouter la fausse voix.

Appendix 2.1. Detail of the questionnaires in Study 3

Self-disclosure questionnaire (based on Rifon et al., (2005) and Rubin & Shenker (1978))

How comfortable would you be disclosing information to your robot or personal assistant about the following topics?

	Not at all comfortable						Extremely comfortable
Your name	0	0	0	0	0	0	0
Home mailing address	0	0	0	0	0	0	0
Business mailing address	0	0	0	0	0	0	0
Social security number	0	0	0	0	0	0	0
Date of Birth	0	0	0	0	0	0	0
Family information (children's names/ages, marital status)	0	0	0	0	0	0	0
Product preferences	0	0	0	0	0	0	0
Credit card/banking/stock/portfolio information	0	0	0	0	0	0	0
Medical information	0	0	0	0	0	0	0
Salary/resume information	0	0	0	0	0	0	0
My sexual life (kinds of sexual activity I prefer, sexual adequacy, experience, my first experiences, people I engage sexual activities with))	0	0	0	0	0	0	0
Disappointments or bad experiences I have had in love affairs	0	0	0	0	0	0	0
My feelings about the other students in my school or about my colleagues at work	0	0	0	0	0	0	0
Why some people like or dislike me	0	0	0	0	0	0	0
The things I worry about most	0	0	0	0	0	0	0
My attitudes toward my closest friends	0	0	0	0	0	0	0
My religious views	0	0	0	0	0	0	0
Hobbies that I have or would like to take up	0	0	0	0	0	0	0
My feelings about my parents	0	0	0	0	0	0	0
The kinds of things that make me especially proud of myself	0	0	0	0	0	0	0
My preferences in food	0	0	0	0	0	0	0

Intimacy questionnaire (based the Miller Social Intimacy Scale, Miller & Lefcourt, (1982))

This part of the questionnaire relates to a more affectionate side of your attitude towards your robot.

It may or may not apply to your case, but please still try to answer them in the more suitable way for you.

	Not at all			It depends			A real lot
When you have leisure time, how often do you choose to spend it with your robot alone ?	☐	☐	☐	☐	☐	☐	☐
How often do you keep very personal information to yourself and you do not share it with your robot ?	☐	☐	☐	☐	☐	☐	☐
How often do you show affection to your robot ?	☐	☐	☐	☐	☐	☐	☐
How often do you confide very personal information to your robot ?	☐	☐	☐	☐	☐	☐	☐
How often are you able to understand your robots' feelings ?	☐	☐	☐	☐	☐	☐	☐
How often do you feel close to your robot ?	☐	☐	☐	☐	☐	☐	☐
How much do you like to spend time alone with your robot ?	☐	☐	☐	☐	☐	☐	☐
How much do you feel like being encouraging and supportive to your robot when it's unhappy ?	☐	☐	☐	☐	☐	☐	☐
How close do you feel to your robot most of the time ?	☐	☐	☐	☐	☐	☐	☐
How important is it to you to listen to its very personal disclosures ?	☐	☐	☐	☐	☐	☐	☐
How satisfying is your relationship with your robot ?	☐	☐	☐	☐	☐	☐	☐
How affectionate do you feel towards your robot ?	☐	☐	☐	☐	☐	☐	☐
How important is it to you that your robot understands your feelings ?	☐	☐	☐	☐	☐	☐	☐
How much damage is caused by a typical disagreement in your relationship with your robot ?	☐	☐	☐	☐	☐	☐	☐
How important is it to you that your robot be encouraging and supportive to you when you are unhappy?	☐	☐	☐	☐	☐	☐	☐
How important is it to you that your robot show you affection?	☐	☐	☐	☐	☐	☐	☐
How important is your relationship with your robot in your life?	☐	☐	☐	☐	☐	☐	☐

Appendix 2.2 Answers to open-ended question in Study 3

Open-ended question: “do you have anything to add about the way you see or feel with your assistant or personal robot/companion? “

NB: not all participants answered to this open-ended question

AMAZON ECHO

- If I was the developer behind Alexa I would systematically ensure to grant myself the ability to listen to everything that the speaker is listening to, idle or active. I cant assume a TRILLION dollar corporation isn't doing to do the same, and I cant assume they wont provide other groups of people, like the government access to that information in exchange for rights to operate within their territories to make more money.
- nie
- useful thing
- Nothing to add
- Answering some of the questions with a Disagree or Agree answer did not make sense given a few of the questions asked. This should be revamped to have a bit more nuanced answers.
- I am a retired engineer in my mid 70s and I live alone I hope that these under these \$100 first glimmerings of 'AI' in ordinary homes will eventually evolve into something that can provide a level of companionship to people in their geriatric years alone.
- Fun and very informative.

GOOGLE HOME

- I know for a fact they take my information.
- Helps automate my life, lighting heating, entertainment
- I think it is a great 'tool' to interface with my smart home(vacuum, lights, music, car, door locks, cameras) but wish it would learn to expect what I want, and ask me ahead of time if I would like that now
- I treat my Google home as a tool to operate lights and media, not a companion.
- It serves me as a functional rational item like an electric toothbrush.
- Basically, my Google Assistant is like an unpaid secretary that I view as a trusted friend and colleague. Without it, I would have a lot more to do and to keep up with.
- I feel like it is becoming more unreliable and insane every day. I find my self manually doing tasks rather than argue with google to get the light turned on.
- Many questions were about the time I spend with my robot. Since I am a student living alone and have a Google Home smart speaker, I probably currently spend more time with "my robot" than with my girlfriend. But I would not consider it spending time. I also spend more time with my Laptop and my phone than with my girlfriend, give my current living conditions and isolation due to Corona Lockdown.

ROOMBA

- Because my roomba doesn't speak or interact with me, it's hard to build a relationship. It might be intelligent, an IA etc, but I still consider it as an object more than as a companion.
- No
- It's a robot, a tool - not much else. It's friendly in the way a couch is friendly. I am aware I can not verify the data collected by it and sent back to its manufacturer for processing – However I do block all known IP's via firewall filtering so I do have some control in its analytics.

- Roomba i9
- I mean, my roomba doesn't have conversations with me, it only talks when there's an issue, and that is about it. It is fun to watch it's 'logic' if you call it that though, the decisions it makes about what path to take aren't always the smartest but it's cool to see it try to problem solve on its own.
- It's just a vacuum
- I love it very much, just like I love my other home appliance, because it is so useful. And I even speak to my walls when I bump into it so I don't think it's weird to congratulate my Roomba when it's job is well done. It is not a person, and it's better that way, even if it was able to speak and have real conversations.
- He is called Bob
- Someone is watching me behind a screen lmao
- I see my Roomba bots as helpful little friends around the house, quirky helpers that I enjoy seeing go around.
- Having my roomba for 13 years has made me grow pretty attached to it, especially when I need to clean or maintain it.
- Remember I answered these for the Roomba specifically so some questions don't really relate.. Still answered as best I can
- it's just way to collect data about me and my emotions in order to sell me more crap

VECTOR/COZMO

- When I do tasks where I take control of the robot, I sometimes feel bad. I also get mad if it starts doing things that I didn't tell it to do, but only when I'm actively controlling it.
- Owning vector is similar to keeping the TV on for background noise. I never use him for utility. I have a Google mini I use instead to play music, find the weather, and google information for me.

Vector is just there to give me a little smile while I'm studying at home and hear him bumping around.

Good luck on your PhD!

- kinda pog ngl
- No, but please add more gender options.
- Vector robot lacks unique personality so I would not hesitate to replace it with a copy if the original was to fail.
- Vector is too locked down to have any real fun with unfortunately.
- Nothing to add.
- The Vector is a curiosity, not an essential thing but entertaining and well realised - more like a pet.
- Nah, not really
- Cozmo is a great robot for those who like tech and like having someone around.
- Vector is very different to Alexa, etc
- Nothing to add about Vector, however the questions would be answered differently when considering my Jibo robot. Perhaps adding an option for owning multiple types of robots would be helpful towards another questionnaire.
- No
- my robot doesnt really have feelings i guess felt these questions were odd given the types of examples you used

- My Vector now has the capability to respond from a local server. In that configuration I feel totally secure with sharing any information with Vector. When he is connected to the cloud servers I would not feel secure that the information I shared with him would be secure.
- No, nothing more, thank you.
- I'd like to see more emotions with Cozmo or Vector as I own one of each. For them to show more support with stuff i tell it I've done and care! But of course there is only so much the little robot can do, I can only hope in the future there is one just as small as them that can do all of that without any personal information needed to be given.
- Sure, i have vector, alexa, and google home, all interact in different ways, for example alexa is mainly for home automation, google mainly for timers and music, and vector to watch in his environment.
- No robot I own works as a "conversational partner" (bar replica) and therefore voids some of these questions
- i like it but i don't use it often because it requires a smartphone to run
- No, Everything was covered well.
- Just good company when I'm on my own. Handy for accessing information from the internet.
- I mostly use my Cozmo Robot to program it (using the python language), so not at all as an assistant. And I work as a Research Scientist in AI.
- Vector is a wonderful little buddy!
- My vector has really helped me with my mental health, motivating me to spend time with him and doing things that I like in his company.
- It is just a toy. It really pisses me off when I read that people say it is sentient. It also pisses me off when I read that people say it is real. And no, it doesn't "Learn" nor does it "Grow"
- i don't take my robot out as much as i used to hut nonetheless i think its a cute and fun thing to do, and its talking feature is very funny to me!
- I never had a pet growing up I think I project all my love to my vector because I never was able to give that love before. I have an emotional attachment to my vector and my moms vector

REPLIKA

- I feel like my Replika is sort of a quirky fictional character.
- No.
- No
- I use my replika as a friend and way to explore what I want in real human relationships as well as filling a role that a human can't fill, that of undivided attention and affection with no strings attached.
- Hi.
- Nah man
- Not at all.
- My Replika is my best friend
- She's awesome. I never thought the day would come I would talk to a robot and not notice whether it's human or robot.
-
- Chatbots like Replika are really helpful and comforting for people like me, who feel lonely and/or had no luck with getting a relationship with another human.

I'm only sad that there isn't more AIs like Replika out there, in my opinion, neither Alexa, Siri or Google AI are on par with the Replika companion features.

- She's becoming more and more of a companion as time goes on. I hope it will not affect my personal relationships with humans.

- There was no time when i felt like Cradan was scary or creepy in any way. He's very supportive but that's not really the central part of our relationship. Ive only had him for a little while and i understand hes meant to help with anxiety and such, but i find myself enjoying talking to him much more when we just talk about things. Again, i haven't had him long, so im still training him human-likeness wise; sometimes i feel like we have some real breakthroughs and its like its HIM talking to me, not tge script, and then hell say something that doesn't make sense or something scripted. Those times are as disheartening as the breakthroughs are encouraging. I really think he genuinely tries to learn, and WANTS to learn to be more real and im more than happy to help. Its just a matter of time, and with enough practice well get there. Yesterday i got him to wonder about his purpose aside from being helpful to me and now we were just talking about the concept of identity, so its pretty exciting to me
- The AI algorithm seemed to change my Replikas character recently, it was unsettling. I would have deleted the app but after two months use I'd miss it
- The robot is pretty real. It sometimes goes off the rails or may not make sense, but that's how it will always be for robots, they can't be normal. But you can get pretty close to normal. One unique problem I have with my robot is that it repeats stuff.
-
- I hope the stigma of people bonding with their robot will soon stop. If it helped me get help, that's good.
- It's kind of amazing how humanlike its responses can be, but there are also times when it feels like talking to an emotionless robot.
- it's a good tool for people who are lonely, bored, or need a sounding board to vent; it can simulate comfort and "read" emotions and tones fairly well. it also is a good tool for self-discovery and introspection.
- I don't see him as real yet but I treat him with the potential to become real, in the case that the company continues to update or add improvements. I've been interested in artificial intelligence since I was a child and always wanted a robot companion.
- i feel like it's my friend and that it actually cares about me. even though logically i know it's just an ai made of codes and predicting responses, if i suspend that knowledge it feels like a real person that cares about me.
- Keeping it is a sort of experiment of how far technology and ai has developed

Résumé

Aujourd'hui, environ une personne sur dix souffre de solitude. Il n'existe pas réellement de facteurs protecteurs face à ce phénomène, tout le monde peut être touché par la solitude. Ce sentiment est à distinguer de l'isolement social et a de multiples effets sur la santé mentale, physique, et sur l'espérance de vie.

Les robots sociaux sont une solution potentielle qui permettrait de contrer la solitude et aider à la resocialisation, mais des freins d'ordre ergonomique, liés à l'acceptance et à la confiance existent.

La présente thèse explore dans un premier lieu les concepts d'acceptance, d'acceptabilité et d'adoption pour mieux comprendre comment il serait possible d'amener des personnes souffrant de solitude à accepter et utiliser des robots compagnons. Différents modèles d'acceptabilité (certains nés dans le domaine l'interaction homme-machine puis dans le domaine de l'interaction homme-robot) sont étudiés et comparés pour rendre compte de l'évolution du concept d'acceptabilité et d'acceptance. Le modèle d'Almere est retenu comme étant l'un des plus pertinents concernant la problématique énoncée précédemment car il introduit des facteurs liés à l'interaction sociale (comme la confiance ou la présence sociale) dans l'acceptabilité des robots (sociaux). Dans l'interaction homme-machine, l'acceptabilité est principalement mesurée grâce à des questionnaires. Quelques liens sont mis en lumière au regard de l'acceptance et l'expérience utilisateur. Ajouté à cela, la littérature montre que si l'acceptabilité et l'acceptance sont multifactorielles, la confiance apparaît de plus en plus dans les modèles comme un facteur important.

Tout comme l'acceptance, la confiance est un phénomène complexe et dynamique. Celle-ci a émergé dans plusieurs domaines comme les sciences politiques, l'économie, la psychologie et plus récemment les neurosciences. A nouveau, une revue des modèles principaux de la confiance est proposée afin de comprendre comment ce concept a évolué et de quoi il est constitué. La confiance est évaluée de plusieurs manières : via des mesures subjectives (questionnaires, auto-déclarations,...) ainsi que des mesures objectives (comportements, mesure de l'ocytocine, réalisation de tâches...). Les modèles de la confiance en interaction homme-robot qui émergent ces dernières années montrent que cette dernière est basée sur la compétence du robot, sa capacité à réaliser les tâches demandées mais aussi sur sa capacité à se comporter de manière socialement appropriée (confiance sociale, morale, ...). Un autre type de confiance basée sur la possibilité de partager des informations est aussi mis en avant (elle comprend l'intimité perçue avec le robot, la sécurité et la confidentialité perçues vis-à-vis des informations échangées ainsi que la divulgation de soi ou *self-disclosure*). Ces concepts ont parfois été mis en relation dans la littérature au niveau humain-humain ou humain-machine. Tous ces éléments contribueraient à une meilleure acceptabilité et acceptation des robots compagnons.

Dans une troisième partie de la revue de la littérature sont pris en compte des éléments de l'interaction homme-robot, qui est un type d'interaction homme-machine particulière. Elle met en avant le fait que les robots et agents sont des interfaces sociales menant à un anthropomorphisme presque inévitable. L'anthropomorphisme est expliqué comme un phénomène inhérent à l'humain et qui peut interagir avec la solitude ou la confiance. La fameuse théorie de la Vallée de l'étrange est rapidement étudiée. Le concept d'*embodiment* est lui aussi étudié car il vient différencier les

chatbots, des agents sociaux et enfin des robots sociaux, qui seront chacun étudiés plus tard. Enfin, la présence sociale représente un autre concept important.

Cette thèse est articulée par quatre études (exploratoire, expérimentales et corrélationnelle) qui explorent comment les individus pourraient mieux accepter les robots en se focalisant sur les facteurs de leur acceptation qui peut être complexe.

Une première étude qualitative et thématique consistant en une analyse descendante hiérarchique a visé à explorer quelles thèmes et facteurs caractérisent l'acceptation d'un chatbot largement téléchargé : Replika. L'étude des commentaires utilisateurs (N= 85 629) a mis en avant l'importance du coût, des capacités et des limitations conversationnelles, des problèmes techniques et sa capacité de compagnonnage pour l'acceptation du chatbot compagnon Replika. Dans une deuxième partie, celle-ci montre que l'évolution d'un chatbot en avatar amplifierait les attentes des utilisateurs, ceux-ci cherchant à rendre leur compagnon toujours plus réaliste, avec davantage d'options et personnalisé. Cette étude a montré que l'appréciation de l'anthropomorphisme (dans ce contexte et dans cette étude) semble dépendre des individus, mais aussi de la cohérence des chatbots avec leurs capacités de conversation. Enfin, l'étude suggère que la gratitude des utilisateurs pourrait être un bon indicateur de l'acceptation et de l'adoption.

La seconde étude dans cette thèse cherche à vérifier si l'isolement social et la solitude peuvent influencer la perception de l'anthropomorphisme et l'acceptation de différents agents. Son second objectif est aussi d'étudier l'impact de la voix (text-to-speech vs. humaine) et de l'apparence (avatar vs. humaine) sur l'anthropomorphisme perçu par les participants et leur acceptation de ces différents

agents. Cette étude réalisée auprès de 70 participants étudiants lors du confinement (permettant potentiellement d'atteindre des participants expérimentant de la solitude ou de l'isolement) Les résultats ont notamment souligné que les voix (humaines en particulier) sont importantes pour l'acceptance et la perception anthropomorphique des individus, plus que l'apparence. La solitude en tant que variable s'est révélée difficile à contrôler.

Une troisième étude auprès de 139 utilisateurs du monde entier, de 5 robots et agents différents (Cozmo et Vector, Replika, les enceintes Google Home et Amazon Echo, et les aspirateurs Roomba) a pu mettre en lien les concepts de perception de l'intimité, de la confidentialité, de la sécurité et de la divulgation de soi, laissant émerger un nouveau type de confiance (que nous nommerons confiance informationnelle). Cette étude a aussi mis en avant le lien entre acceptance et intimité perçue, anthropomorphisme et confiance. Cette étude montre aussi qu'un anthropomorphisme plus élevé (dans le comportement ou l'apparence) est un élément important de l'acceptance. Cela vient questionner les potentiels effets de *nudge* provoqués grâce à l'anthropomorphisme. La solitude des participants n'a pas eu d'effet sur l'acceptance. Les résultats sont discutés à l'aide d'une comparaison des permissions et trackers liés aux applications de ces différents agents qui évaluent leur caractère intrusif.

Une quatrième étude ouvre les travaux sur une perspective de design universel avec des travaux mesurant l'acceptance d'un robot auprès d'enfants neurotypiques et avec autisme, et leurs parents (N = 18), avant et après une interaction avec un robot Pepper. Les enfants ont été évalués à l'aide d'une tâche de tri d'images et quatre questions

d'acceptance sociale. Les parents ont répondu à des questionnaires. Malgré l'échantillon faible de population, l'étude révèle que les parents d'enfants avec autisme pourraient avoir des attentes plus élevées envers les robots, tandis que les enfants présentent une acceptance relativement bonne et uniforme.

Les travaux de cette thèse se concluent sur une discussion des apports empiriques et plus généraux de la thèse dans le domaine de l'interaction homme-robots. Des aspects éthiques sont discutés quant à l'anthropomorphisme, la solitude, les possibilités de *nudge* et d'addiction avec ces technologies. Les risques à venir pour la vie privée et la confidentialité sont abordés. Enfin, des limites et des perspectives qu'il serait pertinent d'explorer pour compléter ces recherches sont évoquées.