Social Touch in Human-agent Interactions in an Immersive Virtual Environment

Fabien Boucaud, Quentin Tafiani, Catherine Pelachaud, Indira Thouvenin

Social Touch in Human-Agent Interactions in an Immersive Virtual Environment

Fabien Boucaud[1], Quentin Tafiani[1], Catherine Pelachaud[1] and Indira Thouvenin[2]
[1]*Institut des Systèmes Intelligents et de Robotique, CNRS UMR 7222, Sorbonne Universités, UPMC Campus Jussieu, 75005 Paris, France*
[2]*Laboratoire Heudiasyc, CNRS UMR 7253, Sorbonne Universités, Université de Technologie de Compiègne, 60200 Compiègne, France*
{fabien.boucaud, indira.thouvenin}@utc.fr, tafiani.quentin@gmail.com, catherine.pelachaud@upmc.fr

Keywords: Virtual Reality, Immersive Environment, Human-Agent Interaction, Immersive Room, Embodied Conversational Agents, Social Touch, Empathic Communication.

Abstract: Works on artificial social agents, and especially embodied conversational agents, have endowed them with social-emotional capabilities. They are being given the abilities to take into account more and more modalities to express their thoughts, such as speech, gestures, facial expressions, etc. However, the sense of touch, although particularly interesting for social and emotional communication, is still a modality widely missing from interactions between humans and agents. We believe that integrating touch into those modalities of interaction between humans and agents would help enhancing their channels of empathic communication. In order to verify this idea, we present in this paper a system allowing tactile communication through haptic feedback on the hand and the arm of a human user. We then present a preliminary evaluation of the credibility of social touch in human-agent interaction in an immersive environment. The first results are promising and bring new leads to improve the way humans can interact through touch with virtual social agents.

1 INTRODUCTION

Anthropology has shown how touch has always been our main modality of interaction with tools (Leroi-Gourhan, 1964). This is still true today in the digital era, as we can see with the addition of more and more touch-based properties to our smartphones or computers (Cranny-Francis, 2011).

Artificial social agents such as the embodied conversational agents can express thoughts and emotions as well as interpret those of their interlocutors through more and more interaction modalities. Touch, however, is a sense still widely missing from social interactions between human and agents. For many cultural as well as technical reasons, researches on social functions of touch only started relatively recently (Cranny-Francis, 2011). Those recent studies show that touch is a sense with a lot of interesting communicative functions in the same way as other types of non-verbal communication like gestures or facial expressions (M. J. Hertenstein, J. M. Verkamp, A. M. Kerestes, and R. M. Holmes, 2006). Touch is considered especially useful for empathic communication, i.e. the communication of emotions.

With this paper, we intend to show a way to integrate social touch into human-agent interaction modalities in the context of virtual reality. It is our belief that this would enhance empathic communication channels between human and agents. We therefore present a system and a preliminary study allowing us to explore the idea that an exchange of social touches between human and agent, with the support of appropriate facial expressions and gestures, enables a credible empathic communication.

2 DEFINING SOCIAL TOUCH AND SOCIAL TOUCH TECHNOLOGIES

2.1 What is Social Touch?

Social touch designates all the uses of touch with social intentions. A salutation handshake, a tap of encouragement in the back, or any type of non-accidental interpersonal touch can be considered as an example of social touch.

Works of definition and classification of social touch (M. J. Hertenstein, D. Keltner, B. App, B. a. Bulleit, and A. R. Jaskolka, 2006) (M. J. Hertenstein, R. Holmes, M. McCullough, and D. Keltner, 2009) (Bianchi-Berthouze and Tajadura-Jiménez, 2014) are an essential source of information to elaborate the needs of technological systems able to produce credible social touch. These studies show how the many different types of touch can be defined through their physical properties and how each type of touch can be more particularly apt to express certain specific emotions. Those studies also show how touch is in itself a very multi-modal sense with characteristics as diverse as pressure, impact velocity, speed of the touch movement on the skin (in the event of a caress for example), total duration of the gesture,… But even then, Hertenstein et al. also show how these are not sufficient to correctly interpret the communicative intention of a touch. Touch is indeed based on the principles of equipotentiality and equifinality. That is to say that one unique type of touch, such as hitting someone, can be used to express anger as well as to express encouragement if it is used with a sport teammate for example: this is the concept of equipotentiality. On the other hand, two different types of touch, such as pushing and grasping someone, can still be used indifferently to express the same emotion of anger: this is the concept of equifinality. This means that other factors than the sole physical properties of a touch must be taken into account when socially interpreting any touch event. Among those other factors we can name: the situation in which the touch takes place (competitive setting, salutations, etc.), the relationship between the person touching and the one being touched, their respective cultures, the part of the body that is touched, etc.

2.2 Related Works on Social Touch Technologies

From the technical point of view, haptic technologies (technologies producing kinesthetic or tactile sensations) are very diverse, covering vibration technologies, force-feedback devices or thermal technologies and many more (M. Teyssier, G. Bailly, É. Lecolinet and C. Pelachaud, 2017). Pseudo-haptics, as defined by Gómez Jáuregui, Argelaguet Sanz, Olivier, Marchal, Multon and Lécuyer (2014), allow to give the illusion of a credible force-feedback by using appropriate visual cues to reinforce a simpler existing haptic feedback. However, there are still no technology able to completely reproduce real touch sensations on every level. When it comes to studies on social touch, devices such as the sleeve equipped with vibrators TASST made by Huisman, Darriba Frederiks, van Dijk, Heylen and Krose (2013) are often used.

In his works, Gijs Huisman (2017) differentiates social touch mediation technologies, which focus on transmitting touch from one human to another through a technological interface, from social touch simulation technologies, which generate a tactile behaviour on their own, without human input. While social touch simulation often use social touch mediation technologies to produce its haptic feedback, it also needs the "intelligence" to adapt its behaviour and decide what kind of tactile behaviour it should adopt, based on a decision model.

As to whether mediation and simulation of social touch have the same properties as natural social touch, Van Erp and Toet's studies (2013) prove three principles. Emotions can be transmitted through touch only, without any other cues. Interpersonal communication of emotion or social intention can still be achieved through a technologically mediated touch. Finally, systems are also capable of using technologically mediated touch to successfully transmit emotions, just like humans.

Although with nuanced results, it was shown how simulated social touch enhanced empathic communication when using augmented reality to materialize agents in the social context of a cooperative game (Huisman, Kolkmeier and Heylen, 2014).

Works by Yohanan (2012) on the "Haptic Creature", which has an animal-like appearance, show that humans are expecting the agent to react in a mimetic way when touched. However, there are still very few works that have studied the agent's reaction to being touched when it comes to humanoid agents.

Where most of the works we discussed here were focused on either the agent touching the human or the human touching the agent, our work focuses on using a virtual humanoid embodied conversational agent that will be able to both touch and be touched by the user. We will measure the credibility of the interaction throughout the whole interactive loop.

Figure 1: A touch-based human-agent interaction inside the immersive room TRANSLIFE.

3 TO TOUCH AND BE TOUCHED IN AN IMMERSIVE VIRTUAL ENVIRONMENT

3.1 How to Touch a Virtual Agent in an Immersive Environment

To achieve this a priori counter-intuitive idea of touching a virtual agent and having it be aware of the touch, we took inspiration in Nguyen, Wachsmuth and Kopp's works (2007) on the tactile perception of a virtual agent inside an immersive room. The immersive room system produces an immersive environment of virtual reality through the projection of the 3D environment on each of the three walls and the floor it is made up of. This, coupled with motion capture cameras and the use of stereoscopic 3D glasses, allows the user to experience the environment to the 1:1 scale (Cruz-Neira, Sandin and DeFanti, 1993). This very specific setup allows the user to experience a virtual environment while still being able to see and perceive his own body (unlike with most of the head-mounted displays for virtual reality). The user will be able to see himself touch the agent with his own hand and be touched on his own arm.

To make the agent able to perceive touch, Nguyen et al. idea is to cover the 3D model of the virtual agent with a virtual "skin" made up of "tactile cells", which are virtual receptors put on the surface of the body of the agent and taking the form of geometries varying in size and shape. When any element of the real world tracked in the immersive room is detected as colliding with any of the cells, through comparison of coordinates, we consider that there is touch and we can record its different properties, such as location on the body. This allows to make the agent aware of when it is being touched.

Basing ourselves on these ideas we gave colliders to the 3D model of our virtual agent to reproduce the principle of Nguyen et al.'s skin receptors. These colliders can be seen in Figure 2. Upon collision with the virtual representation of the hand, we record the cell that was touched but also properties such as the duration of the touch, the initial velocity of the hand when the touch occurred, etc. This is done every time a tactile cell is activated and we can build a sequence of touches that will represent the whole touch gesture.

Figure 2: The virtual environment with the agent and its tactile cells (in green).

Without physical embodiment though, our hand will still go through the visual representation of the agent without resistance. It is thus very difficult to measure physical properties such as pressure or to perform types of touch such as holding the arm.

3.2 How to Be Touched by a Virtual Agent in an Immersive Environment

To make touching and being touched by our virtual agent a credible experience, we can't satisfy ourselves with only seeing our hand colliding with and go through the body of the agent. Our interactions with reality are based on our habits of perceiving the world through our senses. When we see our hand coming into contact with something, we are always expecting to feel touch. If that sensation was missing when touching the agent, there would be perceptive dissonance, which would produce discomfort and a loss of credibility of the interaction. In order to give the user a substitute sensory feedback able to compensate perceptively the immaterial nature of the virtual body, we turned ourselves towards the design and creation of a sleeve and a glove able to perform haptic feedbacks. Those two devices are required to simulate the touch of the agent on the human (sleeve) and to offer a suitable perceptive substitution when the human touches the agent (glove).

4 DESIGNING HAPTIC INTERFACES

In order to implement haptic feedback for the user, we designed an interface composed of two devices: a glove equipped with four vibrators (similar to the ones we can find in a smartphone in terms of size and power) on each corner of the palm of the hand, and a sleeve using the same vibrators in the shape of a matrix of two columns and four lines of those vibrators. The arm and the hand are privileged places for social touch, where it is generally well received even between strangers (Suvilehtoa, Glereana, Dunbarb, Haria and Nummenmaa, 2015).

We chose to use vibrations for its lightweight, making it easy to wear on the body, as well as for the richness of the scientific literature on how we can use them to produce interesting haptic sensations (Huisman et al., 2013). Despite their inherent limitations when it comes to reproducing human touch sensation, we used the principles of the tactile brush algorithm (Israr and Poupyrev, 2011) on the sleeve and achieved the simulation of four different types of touch by manipulating duration and intensity levels of the vibrations. Those four types of touch were based on Hertenstein et al. (2006) (2009) categorization of the types of touch and were chosen for their ability to transmit different emotions. Those types of touch are hitting, tapping, stroking and what we will call a neutral touch. We defined the physical properties of those touches as follow:

- A hit is a short touch (400 ms) without any movement and with a high intensity.
- A tap is a very short touch (200 ms) without any movement and with a moderate intensity.
- A stroke is a longer touch (4*200 ms) with a movement on the skin and with a lower intensity.
- A neutral touch is a longer touch (1000ms) without any movement and with a lower intensity.

As natural human touch has much more physical properties than the few we can take into account with vibrations, some types of touch can’t be reproduced with those devices, such as any type of touch using pressure. Nevertheless, we believe that those four types of touch can be simulated in a satisfactory way by vibrations and suffice to produce an understandable haptic feedback for the user.

To prevent another perceptive dissonance, the gesture visually performed by the agent also had to be correctly synchronized with the vibrations. The prototype of the sleeve built for our system can be seen in Figure 3 and makes use of the Arduino technology.

We will now present the preliminary study conducted to make a first evaluation of the system.

Figure 3: The sleeve prototype.

5 PRELIMINARY STUDY

With this first experiment, we aim to produce a preliminary study on the credibility of simulated social-touch based interactions between human and agent in our immersive room TRANSLIFE. This will also serve as an evaluation of the system we built and presented in the previous sections.

5.1 Experimental Protocol

This preliminary experiment is split in two distinct phases in which the participant will have to touch and be touched by a virtual agent. A between subject design was chosen in order to prevent fatigue (the experiment being already quite long) as well as any bias based on the participant learning from the phases. Participants are thus divided in three groups depending on the emotion they have to transmit and the emotion being transmitted to them by the agent.

Before the beginning of the experiment, in order to reduce the novelty effect, the participant is put in a test environment which allows him to familiarize himself with the virtual environment, the haptic feedbacks and a different virtual agent than the one used in the rest of the experiment.

The actual environment (see Figure 2) is then launched and the participant is asked to get the attention of the agent, who is first turned away from the participant, by placing himself on the white marking and touching the agent. The agent then turns around and proceeds to introduce itself as Camille and explains the experiment.

Phase 1. The participant will first express an emotion by touching the agent with the vibratory glove, and the agent will answer to the touch and the emotion transmitted with an adequate facial expression. Practically, the participant touches the agent four times and is left free to use any touch type he considers appropriate, while being warned that only his hand is recognized by the system.

During this phase, emotional scenarios will first be read to the participant in order to indicate the emotion that must be transmitted and its intensity to the participant. There are two sessions of four touches in which the same emotion is being transmitted but each session is preceded by a different scenario indicating a different intensity of the emotion. Our goal in using two distinct emotional intensities is to observe and determine if the participant uses different kinds of touch. Three emotions were chosen to be transmitted, they are sympathy (C1), anger (C2) and sadness (C3). Those emotions benefit from being very different from each other while being a priori easily understandable for the participants. Emotional scenarios are based on works by Bänziger, Pirker and Scherer (2006) and by Scherer, Banse, Wallbott and Goldbeck (1991). As an example, the following low emotional intensity scenario was used to indicate sympathy: "You meet a friend of yours, Camille, that you hadn't seen for some time. You express what you are feeling to her." High emotional intensity scenarios involve more emphatic adjectives and expressions.

Phase 2. Still inside the room, the virtual agent will then touch the participant where the vibratory sleeve is worn, while performing facial expression and gesture adequate to the emotion being expressed. The emotion being expressed is different from the one expressed in the previous phase to prevent any kind of learning bias (future works should beware order bias though).

There are also two sessions of four touches in this phase, and it is the same emotion that is being expressed in both phases but this time it is the type of touch that changes between the sessions. The agent uses stroking and tapping to express sympathy while tapping and hitting are used for anger, and stroking and neutral touch are used for sadness.

As said before, physical properties of touch are not sufficient for the correct interpretation of social touch. We chose to add other non-verbal cues, facial expressions and gestures corresponding to the emotions being transmitted, so that we can evaluate if this setting is already sufficient to the interpretation of touch.

In-between each session of the experiment and at the end, the participant is asked to answer some questions from the questionnaire. At the very end, after having answered the questionnaire, the participant is debriefed about the experiment.

5.2 Setup and Questionnaire

In this setup, we are using a wizard-of-oz type of procedure where the reactions of the agent are prepared in advance and activated by the person conducting the experiment.

The agent is monitored and animated through the use of the GRETA software platform (De Sevin, Niewiadomski, Bevacqua, Pez, Mancini, Pelachaud, 2010), which allows us to manage the social behaviour of such agents both in terms of verbal and non-verbal cues.

As for the questionnaire, it is inspired by works by Demeure, Niewiadomski and Pelachaud (2011). In the first phase, participants are asked to describe the properties of the types of touch they chose to use, so that we can confront the answers to the information recorded by the system as well as to the results from the literature. The participants are also asked to evaluate the degree to which they considered the reaction of the agent to their touch as credible and why. We understand credibility here as the degree to which the participant feels the agent behaved itself in an adequate human-like way.

In the second phase, participants are asked to describe the tactile sensation they felt when the agent touched them and to name it. Finally, participants were asked to determine to what degree they felt like the agent was expressing sadness, anger or sympathy, or any other kind of emotion they believed they had felt, and to evaluate to which degree they considered the behaviour of the agent as credible and why.

5.3 Participants

The experiment, which lasted one hour on average, was conducted with twelve participants, among which there were eight women and four men. Nine of those participants had no prior experience of virtual reality. Ten considered themselves as having a good touch receptivity (they thought they received touch well) and two didn't know. All the participants were between 18 and 39 years old and were of occidental culture. Mean age value was 23,25 and standard deviation was approximately 5,7897.

6 RESULTS

Subjective data was gathered with 5-items Likert scales. Since we had very few participants (twelve split in three groups of four), conducting future new experiments with more participants and improved procedures should allow to confirm or infirm the following elements.

6.1 Touching and Being Touched

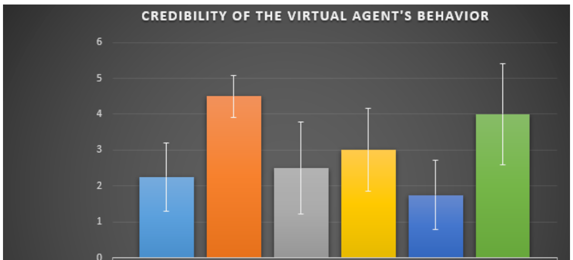
All of the participants that had to transmit sadness through touch expressed a big difficulty to decide how to touch the agent for this emotion.

Unexpectedly, and even though they had been clearly informed that only the glove was tracked and taken account for their touch on the agent, all the participants used a type of touch that we considered as inadequate to virtual reality at least once. In the case of sympathy and sadness most of the participants tried to hug the virtual agent.

Seven out of the eight participants concerned recognized correctly, by name, the vibration pattern that corresponded to a stroking, and more than half of the participants concerned could identify the patterns that simulated both the hit and the tap. However, no participant identified the "neutral touch", which could be explained by the fact that "neutral touch" might not be a natural term.

6.2 Overall Credibility of the Touch Interaction and the Agent's Behaviour

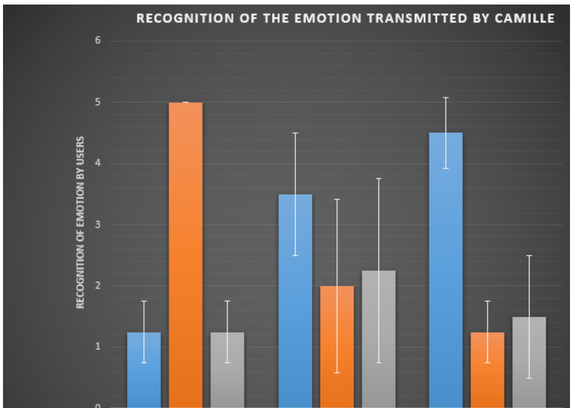
The results shown in Figure 4 (User stand for when the participant touched the agent and Agent stands for when the agent touched the participant) indicate that the agent appeared as more credible when it touched the participants to express anger (red column) and sympathy (green column), with the participants rating its credibility around or above 4 on average. The agent was however much less credible when it reacted to being touched or when it tried to express sadness. In their answers to the questionnaire, participants have said that facial reactions were hardly noticeable when they touched the agent, which can partly explain the low credibility of the agent when it was being touched.



	Average Credibility
User_Sympathy	2,25
Agent_Anger	4,5
User_Anger	2,5
Agent_Sadness	3
User_Sadness	1,75
Agent_Sympathy	4

Figure 4: Credibility of the virtual agent's behaviour according to participants.

The results shown in Figure 5 indicate that the emotion transmitted by the agent was correctly recognized as anger in group C1 and as sympathy in group C3 by almost all the participants, but that the group that was confronted to sadness had a lot more trouble to correctly identify the emotion. We can add that half of the participants from group C2 have said that the agent was trying to comfort them or to be compassionate instead of expressing sadness.



	Agent_Anger	Agent_Sadness	Agent_Sympathy
Average Sympathy	1,25	3,5	4,5
Average Anger	5	2	1,25
Average Sadness	1,25	2,25	1,5

Figure 5: Recognition rate of the emotion transmitted by the agent.

6.3 Discussion

Despite their overall obviously low significance considering the number of participants, we believe the answers support the idea that social touch is a viable modality to enhance empathic communication channels between human and agent. It notably shows how agents using touch to express emotions can be considered as credible by humans. Results are less encouraging when it comes to the credibility of the reaction of the agent to touch. This means that the agent was not perceived as having noticed the touch performed on itself by the participants, or that its reaction was not felt human-like. However, we believe that this is something that can be improved by enhancing the quality of the other reaction cues of the agent (speech, gestures and especially facial expressions) and by the implementation of a real computational model of emotion that would allow the agent to have a full and autonomous interaction.

Another interesting result is that sadness was poorly recognized and felt hard to transmit through touch. When asked about it, participants said that when they feel sad they are more expecting to be touched by someone else (in order to be comforted or shown empathy) than they are prone to go touch someone. It thus appears that an emotion such as being *sorry-for* someone would be more appropriate in a social touch context than sadness in itself.

It is also noteworthy that even though results were very encouraging about the recognition rate of the types of touch simulated with the sleeve, all the participants have expressed that they didn't feel like vibrations were an appropriate feedback for imitating the natural touch sensations.

Despite this, participants have unexpectedly not hesitated to use types of touch that we had thought inadequate in the context of virtual reality, such as hugging or pushing, all of those being types of touch requiring some kind of physical resistance from the object being touched. While participants absolutely realized that only their hand was detected and received haptic feedback, they still tried to use the types of touch that seemed the most natural to them to express the emotion they had to express.

When asked what kind of perceptive substitution they would have preferred, participants described force-feedback devices. Such devices could indeed give a more realistic sensation of touching something with a physical presence.

Among the other possibilities that can be explored, one of the participant remarked that the vibratory sensation might have seemed less surprising and more credible if there had been some sort of mediation of the touch and the vibratory feedback through some kind of physical tool, such as a HTC Vive controller or any other command device of this kind, instead of the glove. It seemed to the participant that such a proxy would have made the vibrations feel less dissonant, since it would have used a tool that doesn't look like it aims at perfectly imitating the sensation of natural touch.

This idea seemed particularly interesting to us considering that social touch is overall a rarely used social interaction modality in our daily-lives (at least outside ritualistic usages and more intimate relationships), but is, on the other hand, our main modality of interaction with technical objects and tools. André Leroi-Gourhan (1964) has shown how by becoming bipeds and thus freeing their hands, our main touching organs, the first humans have been able to develop themselves technically and cognitively through the handling of external tools. Using some kind of proxy to mediate our touch in a virtual environment could therefore be a relevant and interesting way to produce a credible social touch sensation even with a sensory feedback very different from the actual sensation of touch. In the context of virtual reality, such a mediation coupled with pseudo-haptics could greatly enhance the quality of the perceptive substitution.

The question remains as to what kind of mediation tool could be relevant in the context of virtual reality. How using such a proxy would influence the behavior of the human towards the agent also needs to be studied with more attention, as it could potentially put distance between them.

7 CONCLUSIONS

To sum things up, our goal was to estimate in what measure credible social interactions based on touch can be implemented between human and embodied conversational agent in a virtual immersive environment. With the system and the preliminary experiment presented in this paper, we hope to have shown that a credible empathic communication between human and agent can indeed be performed with the use of simulated social touch based on vibrations. In particular, we have shown how patterns of vibrations can be recognized as specific types of touch and how emotions transmitted through a combination of touch and facial expressions can also be identified by humans in an immersive virtual environment. Leads on how to improve both the system proposed here and the evaluation protocol have been identified and should allow to pursue new studies on touch-based human-agent social interactions in immersive virtual environments.

However, our agent doesn't meet, yet, all the requirements mentioned in the literature (Huisman, Bruijnes, Kolkmeier, Jung, Darriba Frederiks et al, 2014) that would make it qualify as an autonomous social agent. If it has the ability to perceive and to perform touch, it still lacks the intelligence to interpret the touches and to adapt its behavior accordingly. With an adequate computational model of emotion, a maintained exchange of social touches between human and agent could happen.

ACKNOWLEDGEMENTS

This work was realized thanks to the ANR's funding in the context of the Social Touch project (ANR-17-CE33-0006). We also thank the FEDER and the Hauts de France for their funding of the immersive room TRANSLIFE at UMR CNRS Heudiasyc Lab.

REFERENCES

T. Bänziger, H. Pirker, and K. Scherer. 2006. "GEMEP-Geneva Multimodal Emotion Portrayals: A corpus for the study of multimodal emotional expressions". In *Proceedings of LREC*.

N. Bianchi-Berthouze, and A. Tajadura-Jiménez. 2014. "It's not just what we touch but also how we touch it". In Paper presented at the TouchME workshop, *CHI Conference on Human Factors in Computing Systems*.

Anne Cranny-Francis. 2011 Semefulness: a social semiotics of touch, *Social Semiotics*, 21:4, 463-481, DOI: 10.1080/10350330.2011.591993

Carolina Cruz-Neira, Daniel J. Sandin and Thomas A. DeFanti. "Surround-Screen Projection-based Virtual Reality: The Design and Implementation of the CAVE", SIGGRAPH'93: *Proceedings of the 20th Annual Conference on Computer Graphics and Interactive Techniques*, pp. 135–142, DOI:10.1145/166117.166134

V. Demeure, R. Niewiadomski and C. Pelachaud. 2011. "How is Believability of Virtual Agent Related to Warmth, Competence, Personifiation and Embodiment?". In *Presence* (pp. 431-448).

Jan B. F. van Erp, and Alexander Toet. 2013. "How to Touch Humans Guidelines for Social Agents and Robots that can Touch". In *Human Association Conference on Affective Computing and Intelligent Interaction.*

D.A. Gómez Jáuregui, F. Argelaguet Sanz, A.H. Olivier, M. Marchal, F. Multon, A. Lécuyer, 2014. "Toward "Pseudo-Haptic Avatars": Modifying the Visual Animation of Self-Avatar Can Simulate the Perception of Weight Lifting", *IEEE Transactions on Visualization and Computer Graphics* (Proceedings of IEEE VR 2014), pp.654-661.

M. J. Hertenstein, J. M. Verkamp, A. M. Kerestes, and R. M. Holmes. 2006. "The communicative functions of touch in humans, nonhuman primates and rats: A review and synthesis of the empirical research". In *Genetic, Social, and General Psychology Monographs*.

M. J. Hertenstein, D. Keltner, B. App, B. a. Bulleit, and A. R. Jaskolka. 2006. "Touch communicates distinct emotions". In *Emotion.*

G. Huisman. 2017. "Social Touch Technology: A Survey of Haptic Technology for Social Touch". In *IEEE Transactions on Haptic.,*10(3), pp. 391-408. DOI:10.1109/TOH.2017.2650221

Gijs Huisman, Merijn Bruijnes, Jan Kolkmeier, Merel Jung, Adu´en Darriba Frederiks, et al.. 2014. "Touching Virtual Agents: Embodiment and Mind." Yves Rybarczyk; Tiago Cardoso; Jo˜ao Rosas; Luis M. Camarinha-Matos. 9th International Summer Workshop on Multimodal Interfaces (eNTERFACE), Jul 2013, Lisbon, Portugal. Springer, *IFIP Advances in Information and Communication Technology*, AICT-425, pp.114-138, Innovative and Creative Developments in Multimodal Interaction Systems.

Huisman, Gijs and Darriba Frederiks, Aduen and van Dijk, Betsy and Heylen, Dirk and Krose, Ben, 2013 "The TaSST: Tactile Sleeve for Social Touch". IEEE World Haptics Conference 2013, 14-18 April, Daejeon, Korea.

G. Huisman, J. Kolkmeier, D. Heylen. 2014. "With Us or Against Us: Simulated Social Touch by Virtual Agents in a Cooperative or Competitive Setting". In *International Conference on Intelligent Virtual Agents*.

Ali Israr and Ivan Poupyrev. 2011. "Tactile Brush: Drawing on Skin with a Tactile Display". Disney Research Pittsburgh.

Leroi-Gourhan, André. 1964. *Le geste et la parole*. Paris, A. Michel. Tome I: Technique et langage. 325 p.

N. Nguyen, I. Wachsmuth, and S. Kopp. 2007. "Touch perception and emotional appraisal for a virtual agent". In *Proceedings Workshop Emotion and Computing*.

K. R. Scherer, R. Banse, H. G. Wallbott, T. Goldbeck. 1991. "Vocal cues in emotion encoding and decoding". In *Motivation and Emotion*.

E. de Sevin, R. Niewiadomski, E. Bevacqua, AM. Pez, M. Mancini, C. Pelachaud. 2010. « Greta, une plateforme d'agent conversationnel expressif et interactif ». In *Technique et Science Informatique.*

J. T. Suvilehtoa, E. Glereana, R. I. M. Dunbarb, R. Haria, and L. Nummenmaa. 2015. "Topography of social touching depends on emotional bonds between humans". In *National Academy of Sciences*.

M. Teyssier, G. Bailly, É. Lecolinet, C. Pelachaud. 2017. « Revue et Perspectives du Toucher Social en IHM ». In *AFIHM. 29ème conférence francophone sur l'Interaction Homme-Machine*.

Yohanan, S., 2012. "The Haptic Creature: Social Human-Robot Interaction through Affective Touch," Ph.D. Thesis, University of British Columbia.