Beyond backchannels: co-construction of dyadic stance by reciprocal reinforcement of smiles between virtual agents.

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Abstract

When two persons participate in a discussion, they not only exchange the concepts and ideas they are discussing, they also express attitudes, feelings and commitments regarding their partner: they express *interpersonal stances*. Endowed with backchannel model, several virtual agents are able to react to their partners' behaviour through their non-verbal behaviour. In this paper, we go beyond this approach, proposing and testing a model that enables agents to express a *dyadic stance*, marker of effective communication: agents will naturally co-construct a shared *dyadic stance* if and only if their *interpersonal stance* is *reciprocally* positive. We focus on smile, which conveys *interpersonal stance* and is a particularly efficient signal for co-regulation of communication. With this model, a virtual agent, only capable to control its own individual parameters, can, in fact, modulate and control the dyadic stance appearing when it interacts with its partner. The evaluation of the model through a user perceptive study has enabled us to validate that the dyadic stance is significantly perceived as more positive (mutual understanding, attention, agreement, interest, pleasantness) when reinforcement of smile is reciprocal.

Keywords: dyadic interaction; interactive behaviours; dynamical systems; dyadic stance; smile; virtual agent;

Introduction

When we consider verbal communication, interlocutors not only exchange the concepts and ideas which constitute the subject of their discussion, they also express feelings, judgements or commitments regarding this subject. This "attitude which, for some time, is expressed and sustained interactively in communication, in a unimodal or multi-modal manner" corresponds to the *stance*: Chindamo, Allwood, and Ahlsén (2012) review the existing definitions and descriptions of stance; they show how these definitions have evolved from a focus on individual expression of stance to a more interactive and social description. *Individual stance* refers to two types of stance: epistemic and interpersonal stance (Kielsing, 2009). The *epistemic stance* is the expression of the relationship of a person to his/her own talk (for instance "certain"). The *interpersonal stances* convey the relationship of a person to the interlocutor (for example "warm" or "polite"). Moreover, during an interaction, "stances are constructed across turns rather than being the product of a single turn" (Chindamo et al., 2012). When interactants with individual epistemic and interpersonal stances are put in presence, *dyadic stances* can be inferred (Prepin, Ochs, & Pelachaud, 2012) from diachronic *alignment* between interactants. The effort of interlocutors to linguistically and non-verbally align through time is a marker of stance: it convey stance of mutual understanding, attention, agreement, interest and pleasantness (Louwerse, Dale, Bard, & Jeuniaux, 2012).

The description of stance has not only evolved toward a distinction between *individual* and *co-constructed* stance. It has also evolved from a uniquely linguistic description (DuBois, 2007; Kielsing, 2009) to a description implying interactants' Non-Verbal Behaviours (NVBs) (Scherer, 2005; Prepin et al., 2012). The non-verbal behaviours participate in maintaining contact between interactants and facilitate verbal exchange: they are an integral part of the communication process (Paradowski, 2011). NVBs actively convey stances through paralinguistic features (such as tone of voice, duration, loudness or prosody), facial expressions, and postures (Chindamo et al., 2012).

Models of interactive agents have mainly explored the automatic generation of virtual agent's behaviour aligned on the interlocutor's behaviour. Buschmeier, S., and Kopp (2010) combine a model of lexical alignment with a model generating behaviours based on linguistic information. Bailenson and Yee (2005) model the NVBs alignment of a speaking virtual agent to a listening human. They propose a *Digital Chameleon* (in reference to the *Chameleon effect* described by Chartrand and Bargh (1999)). Bevacqua, Hyniewska, and Pelachaud (2010) model the NVBs alignment of a listening agent to a speaking human: they propose a model of *backchannels*, *i.e.* NVBs aligned in time and nature, to facilitate human users to tell a story.

All these models focus on the adaptation of the virtual agent to its interlocutor, but do not take into account the reciprocal adaptation of this interlocutor: behaviours are computed in *reaction to* partner's behaviour, but not in *interaction with* partner's behaviour; the dynamical coupling associated to the mutual engagement of interactants is not modelled, and critical parameters of interaction such as synchrony and alignment which appear as side effects of this coupling (Paolo, Rohde, & Iizuka, 2008; Prepin & Pelachaud, 2011, 2012a), are missed. In this paper, we aim at going further by proposing a model enabling virtual agents to co-construct their behaviours: agents will be enabled to adapt to each other behaviour *on the fly* (that is in the time scale of the coupling (Prepin & Pelachaud, 2011)) and to perform a resulting behaviour which is a dynamically built mix of each other behaviour; agents will also be enabled to modulate how much their own behaviour is influenced by the behaviour of the other, and doing so, they can control the stance of the dyad.

In the present paper, we propose and test a model that enables virtual agents to co-construct a *dyadic stance* by taking advantage of the interactive loop existing between agents and the resulting conjugated effects of reciprocal alignments. Each virtual agent, only capable to control its own individual parameters, can, in fact, modulate and control the dyadic stance appearing when it interacts with its partner. We focus on smile behaviours for three reasons: (P1) a smile is one of the simplest and most easily recognized facial expressions (Ekman & Friesen, 1982); (P2) recent works (Ochs, Niewiadmoski, & Pelachaud, 2010) have shown that people are able to distinguish different types of smile when they are expressed by a virtual character; (P3) in multimodal communication, smile alignment appears in the form of synchronous smile expressions of interactants (Louwerse et al., 2012). These three properties of smile enable us to focus on the dynamical mechanisms of smiles alignment to model the co-construction of dyadic stances. For this purpose, based on the first property of smile (P1), we model the sensitivity to partner's smile as a motor resonance phenomenon. Considering the second property of smile (P2), we implement this model on a dyad of smiling virtual agents. Based on the third property of smile (P3), we enable the virtual agents' smiles occurring synchronously to reinforce each other depending on the two agents' individual stances.

Model description

In order to create virtual agents able to co-construct a *dyadic stance* by taking advantage of the interactive loop they form with their partner, we focus on the agents capacity to mutually reinforce their smiles (see Introduction). The agents will be able to change the influence of their partner's smile on their own smile: the more their own actions are influenced by the perception of their partner's actions, the easier will be the coupling and the mutual reinforcement of the two agents smile; virtual agents will be able to control the *dyadic stance* they co-produce with their interlocutor.

Smiles descriptions

In the proposed model, we focus on virtual agent's smiles. On one hand, smile is one of the simplest and most easily recognised facial expression (Ekman & Friesen, 1982), and on the other hand it is one of the few behaviours often performed contingently by partners during interaction (Louwerse et al., 2012). The two muscles zygomatic major, on either side of the face, have to be activated to create a smile, and are sufficient for an observer to recognize a facial expression as being a smile. However, subtle differences in dynamics and in muscular activations make smiles convey different messages (such as amusement and politeness). Ochs et al. (2010) have studied the characteristics of polite, amused, and embarrassed smiles of virtual agent's. Their results are summarized in Table 1. The amused smiles are mainly characterized by large amplitude, open mouth, symmetry, and relaxed lips. Most of them also contain the activation of the cheek raising, and a long global duration. The polite smiles are mainly characterized by small amplitude, a closed mouth, symmetry, relaxed lips, and an absence of cheek raising. The embarrassed smiles often have small amplitude, a closed mouth, and tensed lips. They are also characterized by the absence of cheek raising and an asymmetry in the smile.

Characteristics of smile	Amused smile	Polite smile	Embarrassed smile
Cheek raising	**+**	−	−
Open mouth	**+**	−	−
Lips tension	−	−	**+**
Symmetry	+	+	**−**
Amplitude	**+**	−	−

Table 1: Smiles characteristics depending on their type (table filled based on the results described in (Ochs et al., 2010)): + indicates significantly higher and - significantly lower values of the characteristic for a given type of smile than the others,

Perception-Action mapping

In order to enable virtual agents to modify their facial expressions "on the fly" (that is dynamically and in real-time), as proposed in (Prepin & Pelachaud, 2012b), facial expressions are updated frame by frame depending on both the speech expressed and the continuously incoming reactions of its partner. When an agent is performing an action (e.g. the display of a facial expression), it can have feedbacks concerning this action and can modify it "on the fly".

Several researches have shown that there is a natural/structural tendency to imitate the other and to better perceive the other when imitating back (Muir, 2005; Nadel, Prepin, & Okanda, 2005). We model this property combining a mapping between the *perceptive space* and the *motor space*, and the self-activation of the *motor space*. Both the *perceptive space* and the *motor space* are defined by Action Units (AUs) in the Facial Action Coding System (Ekman & Friesen, 1982) necessary to define smiles.

The self-activation of the motor space, with a weight $\alpha < 1$ (see Figure.1), both simulates a short term memorisation of actions and facilitates the subsequent activation of similar actions (Schöner & Thelen, 2006). The nearer α is to 1, the longer the memorisation. We choose here $\alpha = 0.95$ to ensure that this memorisation is "short term", i.e. that after $1sec.$ (25 time steps), if there is no other stimulation, the activation of the AU is decreased by two thirds: $AU_i(t_0+25) < 1/3 \cdot AU_i(t_0)$.

The mapping between perceptive and motor spaces corresponds to the links between perceived characteristics of smiles and generated characteristics of smiles. The mapping is based on the results on smiles reported in previous section. More precisely, the nodes in the perceptive and motor spaces correspond to the characteristics of the different types of smile[1].

This mapping is represented in Figure 1 by links of different widths between the *perceptive* (AU_{per}) and *motor* (AU_{prod})spaces. The dashed links ending with a circle represent *inhibitory* links.

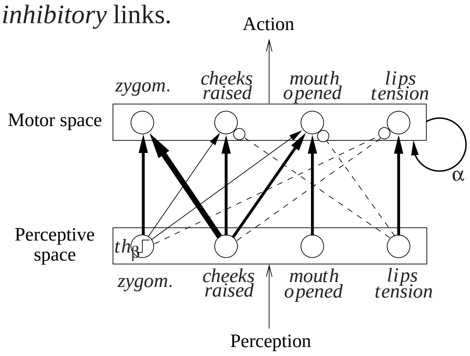

Figure 1: Perceptive Space and Motor Space mapping.

The excitatory/inhibitory nature of links and their weight have been inferred from Table 1. We detail the modelled effects for each smile characteristic:

- *Zygomatics*: *zygomatics* appear in every smile and only their high amplitude indicates *amused smile* (Table 1); we assume that their perception will influence their production only if the perceived amplitude is over a threshold th_β.
- *Lips tension*: *amused* and *embarrassed* smiles are incompatible (they have opposite characteristics, see Table 1); we assume that the specific AU of an embarrassed smile (i.e. lips tension) will *inhibit* and will *be inhibited by* the specific AUs of amused smile (i.e. cheeks raised and zygomatics over th_β).
- *Cheek raising*: *cheeks raising* is an exclusive marker of amused smile (Table 1); we assume that its perception highly excites all the specific characteristics of amused smile (zygomatic above th_β, cheeks raise and mouth opening).
- *Mouth Opened*: opening of mouth is not a specific characteristic of smiles. We assume that its perception only influence the opening of mouth production.

We stay at the level of a purely reactive model, only using muscular activations of produced and perceived signals. More cognitive modelling could infer emotions and intentions from these muscular activations.

Interpersonal stance influence

Virtual agent's *interpersonal stance* (i.e. its stance regarding its interlocutor) influences the visuo-motor mapping (Fig.2). For instance, a virtual agent with a cooperative attitude will be more sensitive to the interlocutor's perceived smile. Note that we do not model any cognitive model or strategy concerning the expression of stance, we just model how the *interpersonal stance* of the virtual agent modifies the way the agent is sensitive to its partner's behaviours: the agent will modify how much it is interactive, engaged and finally cooperative with its partner[2].

We assume here that *interpersonal stance* is represented as a single variable σ, in $[0,1]$, which multiplies all the influences between perceptive and motor spaces (see Fig.2). In the evaluation study, σ only takes two values: $\sigma = 0$ when the virtual agent is not cooperative, *i.e.* when its smiles are not reinforced by its partner's smiles; and $\sigma = 0.45$ when the virtual agent is cooperative, *i.e.* when its smiles are reinforced by its partner's smiles. Note here that if σ was higher than 0.45, even without any communicative intention stimulating smiles, the reciprocal influence between agents would be too high to let smiles decrease.

Virtual agents dyad

The last step in the design of our model is to put two virtual agents in presence, a speaker and a listener (Fig.2). For sake of simplicity and to focus on the dyadic effect of the smile expressions, the virtual listener has no access to the meaning of what the speaker says. The listener only perceives the speaker's non-verbal behaviour. On the other side, the speaker's speech directly influences its own actions in the *motor space* (see Fig.2).

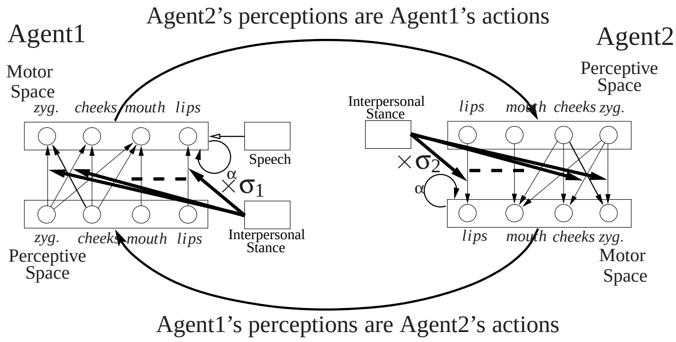

Figure 2: Scheme of the interactive loop within the dyad.

We implement our model of virtual agents dyadic stance generation in the *Leto/Prometheus* Neural Network (NN) simulator (Gaussier & Zrehen, 1994), interfaced with the virtual agent platform SEMAINE (Schröder, 2010). The NN simulator enables to design the architecture neuron by neuron and to control architecture dynamics in real-time (here frame by frame). The agent platform computes the communicative intention of the virtual character depending on its speech, and directly influences its actions in the *motor space* accordingly (see Fig.2). For instance, the utterance "I'm happy today" is automatically said with an amused smile.

[1]Note that we have not considered the symmetry of the smile since this characteristic is difficult to perceive by a user when watching a face to face interaction between virtual agents

[2]Other interpersonal stances may influence the mapping between perceptive space and motor space, such as warm or polite. However, a model of the effect of the different stances on the perceptive and motor space is out of the scope of this paper.

In the context of face to face interaction, if both virtual agents have a cooperative interpersonal stance, they reciprocally reinforce their smiles (see Fig.3, (Prepin & Pelachaud, 2012b)): a *snowball effect* on shared behaviours (when coupling occurs) and a decay/alignment of not-shared behaviours (when coupling is disrupted).

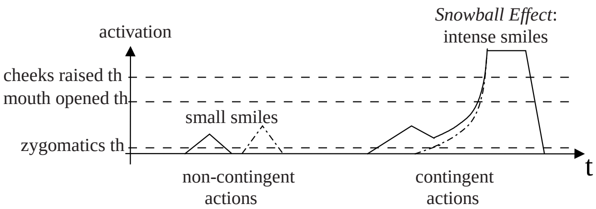

Figure 3: Dyadic dynamics of smiles. Solid and dotted lines are respectively for Agent1 and Agent2's intensity of smile.

The figure 4 shows the result of such an interaction on one agent: the virtual agent's smile is emphasized.

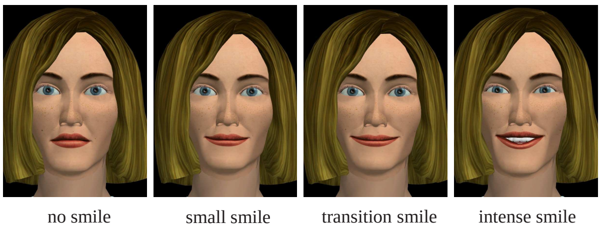

Figure 4: Snowball effect when smile reinforcement is reciprocal.

Finally, the proposed model enables one to simulate an interaction between two virtual agents with different smiling behaviour depending on the agents' interpersonal stance. The resulting interactions reflect different dyadic stances. In addition to cheeks raise and release of lips tension, the main side effect of mutual positive interpersonal stance is the snowball effect on smiles, i.e. the increase of smiles intensity and duration.

Indeed, considering that NVBs alignment and dynamical coupling are marker of the quality of the interaction (see Introduction), these side-effects (such as "snowball effect") are the cues that should give an impression of fruitful interaction. In order to validate that our model enables one to simulate interactions between virtual agents that convey different dyadic stances depending on the mutual reinforcement of their smiles, we have performed an evaluation presented in the next section.

Evaluation of the model

To test that the proposed model enables one to simulate the co-construction of different stances, we have performed a user perceptive study. Our objective through this evaluation is to show that the smiles mutual reinforcement between two interacting virtual characters conveys specific stances. We have focused on the following dyadic stances: *mutual understanding* (the virtual characters seem to understand each other), *mutual attention* (the virtual characters seem to pay attention to each other), *mutual agreement* (the virtual characters seem to be agreed with each other), *mutual interest* (the virtual characters seem to be interested to the discussion), *mutual pleasantness* (the virtual characters seem to spend a pleasant time to interact). These stances have been chosen since research (Louwerse et al., 2012) has shown that the mutual understanding, attention, agreement, interest and pleasantness are cues of the quality of an interaction between a speaker and a listener.

Hypothesis. The hypothesis we want to validate through the evaluation is the following:

> *The positive dyadic stance is significantly increased when reinforcement of smile is reciprocal.*

More precisely, the evaluation aims to show that the mutual reinforcement of the smiles of the two interlocutors (i.e. the speaker *and* the listener) increases the impression of *mutual understanding, attention, agreement, interest, pleasantness* compared to an interaction in which *only the listener's smiles* are reinforced by the speaker's smiles (and not in the other way round).

A validation of this hypothesis will enable us to validate the proposed model which simulates virtual characters' dyadic stances through smiles mutual reinforcement and emerging snowball effect.

Procedure. In order to verify the hypothesis, we have performed the evaluation on the web. The evaluation was in French. Four video clips showing two virtual characters discussing were presented to participants. For each video clip, we asked the participants to answer 5 questions using a Likert scale of 5 points (from "strongly disagree" to "strongly agree"). The questions concerned their perception of the mutual understanding, attention, agreement, interest and pleasantness of the two virtual characters. An example of a question is "When you watch the two virtual characters discussing, according to you, do they understand each other?" (translated from French).

Video Clips. To evaluate the perception of the interaction between virtual characters in one way versus reciprocal conditions of smiles reinforcement, we have recorded the two conditions of interaction:

- *reciprocal condition*: both the speaker and the listener mutually reinforce their smiles depending on the smiles expressed by each other, "snowball effect" is enabled.
- *control condition*: only the listener reinforces its smiles according to the speaker's expressed smiles.

In the video clips, the virtual characters discuss using an unintelligible verbal language (corresponding to an acoustic deformation of French texts). By this way, we avoid an influence of what the virtual characters said on the user's perception. We have considered 6 different texts corresponding to the situation in which the virtual character tells a joke to its interlocutor. Given the text and the associated communicative intention, the virtual character expresses a polite smile at the beginning and an amused smile in the middle of the text. For each text, we have recorded video clips in the 2 conditions described above with a virtual character saying this text with an acoustic deformation and another virtual character, in front, listening. In total, 12 video clips have been recorded. In order to visualize clearly the faces of the two virtual characters while keeping the impression that the virtual characters are face to face, we have used a film-making technique called *split-screen* (Fig.5). Before starting the evaluation on the web, to ensure that the instruction, the questions, and the video clips are understandable, the platform of test has been pre-tested with 7 participants.

Figure 5: Screen shot of a video clip of the two virtual characters interacting

Participants. Sixty-six individuals have participated in this evaluation on the web (34 females) with a mean age of 34 (SD=13). They were recruited via French mailing lists on line. The participants were predominantly from France (N=63). Each participant was shown and rated 4 video clips (two video clips selected randomly for each of the 2 conditions). The order of the presented video clips were counterbalanced to avoid any effect on the results.
Results (Fig.6). We have collected 264 video clips' ratings. Independent t-Test was conducted to compare the participants' ratings of the video clips in each condition. The analysis revealed statically significant effects of the condition on the participants' ratings of the *mutual understanding* ($p < 0.001$), the *mutual attention* ($p < 0.01$), the *mutual agreement* ($p < 0.001$), the *mutual interest* ($p < 0.001$), and the *mutual pleasantness* ($p < 0.001$).

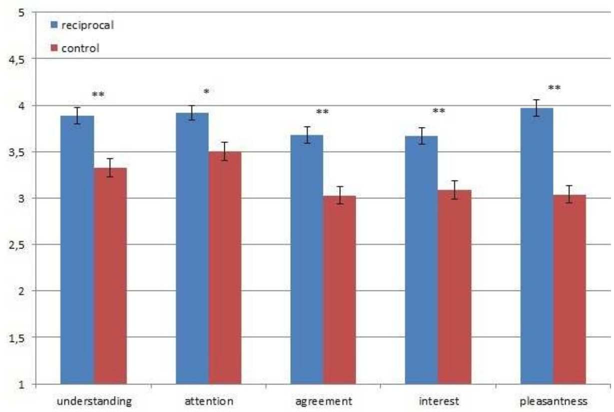

Figure 6: Means and standard errors of the dyadic stances' ratings for the two conditions. The significant differences between the condition are indicated by ** for ($p < 0.001$), and * for ($p < 0.01$)

Discussion of the results. The mutual understanding, attention, interest, agreement and pleasantness are perceived significantly higher when the speaker and the listener mutually reinforce their smiles according to the other's smiles (reciprocal condition) than when only the listener reinforces its smiles depending on the speaker's expressed smiles (control condition). The impression of mutual understanding, attention, agreement, interest and pleasantness directly depends on the reciprocity of the interaction. These results are consistent with psychology studies which claim that the interaction effort must be shared and reciprocal to enable effective communication (Nadel et al., 2005; Paolo et al., 2008; Auvray, Lenay, & Stewart, 2009; Fuchs & DeJaegher, 2009). Finally, the results validate the hypothesis described above: *The positive dyadic stance is significantly increased when reinforcement of smile is reciprocal and "snowball effect" is enabled*.

Conclusion

In the present paper, we have proposed a model enabling virtual agents to co-create different *dyadic stances*. We have described this model entwining each agent's ability to control its cooperation to the interaction and the dyadic effects emerging from the resulting agents coupling.
Agents are able to produce a continuum of smiling behaviours. They can modulate their own smiles depending directly on their perceptions of their partner's smiles. They can control the level of this modulation and doing so control their *interpersonal stance*: a highly cooperative agent reinforces its smiles when its interlocutor smiles. Finally when a speaking agent (which produces smiles in relation to its speech) and a listening agent are put together, their behaviours modulate each other reciprocally and dynamically form a new behaviour. Performing a user perceptive study, we have shown that this dyadic behaviour is the expression of the two agents *dyadic stance*: the specific dyadic dynamics which appear depending on each agent *interpersonal stance* convey information on agents' mutual understanding, attention, agreement, interest and pleasantness. The evaluation highlights that the virtual agent's backchannels (one way reactions) are less effective than reciprocal reactivity to convey some dyadic stances such as mutual understanding, attention, agreement, interest and pleasantness: The agents' reactions must be reciprocal, as proposed in our model, to enable side effects of dynamical coupling such as emphasise of smiles, increase in intensity and duration.
Future works. One of the aspect of the virtual agents modelling we have proposed is the fact that each agent of the dyad, has a different dynamic depending on the other agent stance: the agent's own smile dynamic (for instance the smile slope) changes according to whether or not the other agent has co-operative *interpersonal stance*. As a consequence, each agent, knowing its own *interpersonal stance* and detecting its own smile slope variation, could infer the other agent's *interpersonal stance*. Finally each agent can use this signal for modulating its own stance, its model of the other, or the way it interacts.

One of the next steps is to apply such a model to human-virtual agent interaction. For this purpose, we are currently integrating in the SEMAINE platform a system to detect in real-time user's smiles[3]. In this condition of direct interaction between user and virtual agent, the user perception of the dyadic stances could be different since the user is directly engaged in the interaction (compared to the studied conditions in which users have a third person point of view when they watch virtual characters interacting).

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References

Auvray, M., Lenay, C., & Stewart, J. (2009). Perceptual interactions in a minimalist virtual environment. *New ideas in psychology*, *27*, 32–47.

Bailenson, J., & Yee, N. (2005). Digital chameleons: automatic assimilation of nonverbal gestures in immersive virtual environments. *Psychological Science*, *16*(10), 814–9.

Bevacqua, E., Hyniewska, S., & Pelachaud, C. (2010, October). Positive influence of smile backchannels in ecas. In *International workshop on interacting with ecas as virtual characters (aamas 2010).* Toronto, Canada.

Buschmeier, H., S., K. B., & Kopp. (2010). Adaptive expressiveness: virtual conversational agents that can align to their interaction partner. In *Proceedings of the 9th international conference on autonomous agents and multiagent systems* (pp. 91–98). Richland, SC: IFAAMAS.

Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: the perception-behavior link and social interaction. *Journal of Personality and Social Psychology*, *76*(6), 893–910.

Chindamo, M., Allwood, J., & Ahlsén, E. (2012). Some suggestions for the study of stance in communication. In *2012 ase/ieee international conference on social computing* (pp. 617–622). IEEE Computer Society.

DuBois, J. W. (2007). The stance triangle. In R. Engelbretson (Ed.), *Stancetaking in discourse* (pp. 139–182). Amsterdam/Philadelphia: John Benjamins Publishing Company.

Ekman, P., & Friesen, W. V. (1982). Felt, False, And Miserable Smiles. *Journal of Nonverbal Behavior*, *6*, 238–252.

Fuchs, T., & DeJaegher, H. (2009). Enactive intersubjectivity: Participatory sense-making and mutual incorporation. *Phenomenology and the Cognitive Sciences*, *8*(4), 465–486.

Gaussier, P., & Zrehen, S. (1994). Avoiding the world model trap: An acting robot does not need to be so smart! *Journal of Robotics and Computer-Integrated Manufacturing*, *11*(4), 279–286.

Kielsing, S. F. (2009). Stance: Sociolinguistic perspectives. In A. Jaffe (Ed.), (pp. 171–194). Oxford: Oxford University Press.

[3]http://www.iis.fraunhofer.de/en/bf/bsy/produkte/shore.html

Louwerse, M., Dale, R., Bard, E. G., & Jeuniaux, P. (2012). Behavior Matching in Multimodal Communication is Synchronized. *Cognitive Science*, *36*(8), 1404–26.

Muir, D. (2005). Emotional development. In J. Nadel & D. Muir (Eds.), (pp. 207–233). Oxford, UK: Oxford University Press.

Nadel, J., Prepin, K., & Okanda, M. (2005). Experiencing contingency and agency: first step toward self-understanding? In P. Hauf (Ed.), *Making minds ii: Special issue of interaction studies 6:3 2005* (pp. 447–462). John Benjamins publishing company.

Ochs, M., Niewiadmoski, R., & Pelachaud, C. (2010). How a virtual agent should smile? morphological and dynamic characteristics of virtual agent's smiles. In *Intelligent virtual agent (iva).*

Paolo, E. A. D., Rohde, M., & Iizuka, H. (2008). Sensitivity to social contingency or stability of interaction? modelling the dynamics of perceptual crossing. *New ideas in psychology*, *26*, 278–294.

Paradowski, M. B. (2011). The Embodied Language: Why Language Should Not Be Conceived of in Abstraction from the Brain and Body, and the Consequences for Robotics. *SSRN eLibrary*.

Prepin, K., Ochs, M., & Pelachaud, C. (2012). Mutual stance building in dyad of virtual agents: Smile alignement and synchronisation. In *Proceedings of international workshop on exploring stances in interactions, ase/ieee international conference on social computing* (pp. 938–943).

Prepin, K., & Pelachaud, C. (2011). Effect of time delays on agents' interaction dynamics. In Tumer, Yolum, Sonenberg, & Stone (Eds.), *The tenth international conference on autonomous agents and multi agents systems, aamas2011* (pp. 1–8). IFAAMAS.

Prepin, K., & Pelachaud, C. (2012a). Basics of intersubjectivity dynamics: Model of synchrony emergence when dialog partners understand each other. In J. Filipe & A. Fred (Eds.), *Icaart 2011, revised selected papers, series: Communications in computer and information science (ccis)* (Vol. 271, pp. 302–318). Springer-Verlag.

Prepin, K., & Pelachaud, C. (2012b). Live generation of interactive non-verbal behaviours. In Conitzer, Winikoff, Padgham, & van der Hoek (Eds.), *11th international conference on autonomous agents and multiagent systems, aamas 2012* (pp. 1–2). IFAAMAS.

Scherer, K. (2005, December). What are emotions? and how can they be measured? *Social Science Information*, *44*(4), 695–729.

Schöner, G., & Thelen, E. (2006). Using dynamic field theory to rethink infant habituation. *Psychological Review*, *113*(2), 273–299.

Schröder, M. (2010). The semaine api: Towards a standards-based framework for building emotion-oriented systems. *Advances in Human-Computer Interaction*, *2010*, 21.