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SPENCER:

Social situation-aware perception and action for cognitive robots

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DELIVERABLE 4.1

Behavior evaluation through user studies early report

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Contents

Abstract

The FP7 project SPENCER is concerned with the development and the deployment of an autonomous guiding robot. This robot is envisioned to guide passengers in a crowded (airport) environment from A to B. The SPENCER project will extend the state-of-the-art in socially normative human-robot interaction (HRI) by determining socially normative motion behaviours (in terms of spatial motion and head motion) that will significantly impact the users' acceptance of the robot in crowded environments and the ease of use in group interaction [1].

This deliverable summarizes the user studies conducted in year 1 of the SPENCER project. The basis of these user studies is a literature overview, of which we summarize the most relevant findings. We provide an overview of the concept of social norms. As a part of this, we discuss social psychological and HRI literature on norms such as personal space. Given that the SPENCER robot will encounter people with different cultural backgrounds, it is not unlikely these people have different understandings of what is appropriate robot behaviour. Therefore, we provide an overview of research into (human-robot) cross-cultural research. The capstone of the literature review is an overview of the state-of-the-art in HRI social norms, and the identification of gaps that we intend to address in the coming years. Following the literature overview, we introduce two user studies we have conducted as part of the SPENCER project and we discuss a contextual analysis we intend to conduct at the end-user site.

1 Introduction

The SPENCER robot will guide transfer passengers at an airport from their arrival gate to their gate of departure. Given that flying is not an everyday activity, such a transfer can be stressful. An ethnographic study by the SPENCER industrial partner KLM showed that even experienced flyers mostly associate negative emotions with the process of "transferring". In order to help transfer passengers during their transfer, a robot will guide passengers to their next gate.

When human guides guide passengers around an airport, questions like "How fast should I walk?", "Am I walking on the right side of the corridor?", and "Should I overtake these people in front of me?" usually do not arise. People unconsciously negotiate their way even in crowded public space. However, these spatial behaviours are not as straightforward for a robot [22]. In order to program a robot to navigate as successfully as a human, we have to define how a robot should behave given certain situations [54]. Our main question is:

"Which social normative (motion) behaviours does a robot require to guide multicultural passengers from A to B at an international airport?"

To address this question, we are particularly interested in finding out what specific patterns, or rules, people apply when navigating semi-public spaces. Therefore, in the following we discuss important spatial behaviours like distancing (proxemics), speed, and normative pedestrian behaviours in social situations - for instance overtaking and walking direction.

A more fundamental, underlying question of our work is if social robots require different normative behaviours compared to humans. In Section 2 we will provide a summary of our findings, which includes an overview of (social) norms and examples of research into those norms. We will answer the following questions:

1. How do social norms affect our lives?
2. Do people treat robots as they treat humans?
3. Are there reasons to assume cultural differences with relation to existent norms?
4. Are there examples of social norms for robots?

We conclude Section 2 with an overview of the gaps we intend to address in the coming two years.

Section 3 contains the extended abstracts of two experiments. Full papers are included at the end of this deliverable. Section 3.1 summarizes a lab experiment in which we added artificial noise to two robots that differed in height. We show the importance of functional noise [24, 38]. Section 3.2 deals with cross-cultural human-robot interaction, and summarizes the preliminary results of a survey distributed to three countries (China, Argentina and the United States) [25, 23]. Both these studies are initial steps to answering our research questions in the Spencer project.

Section 4 provides information about another study that we are planning to conduct in a next step: a contextual analysis at an airport that will provide us with a better understanding of how passengers behave in terms of finding their way around. Thereafter, we present a conclusion of the deliverable in Section 5.

2 Related work

Parts of this section have been published as:
Joosse, M.P., Lohse, M., & Evers, V. (2014) Lost in Proxemics: Spatial Behavior for Cross-Cultural HRI. Proceedings of the 2014 ACM/IEEE Conference on Human-Robot Interaction Workshop in Culture Aware Robotics, 3 March 2014.

2.1 How do social norms affect our lives?

Webster [40] defines a norm as *"a principle of right action binding upon the members of a group and serving to guide, control, or regulate proper and acceptable behavior"*. A social norm is a specific type of norm. While scholars from different fields of research employ different definitions for social norms (see for example [13], [39], [77], [50]), one widely-used definition by Cialdini & Trost [10] seems appropriate for this research project: *"rules and standards that are understood by members of a group and that guide and/or constrain social behavior without the force of laws"*. Prentice [47] provides a similar definition, but focuses somewhat more on the situational-dependent nature of norms: *"[] defined as socially shared and enforced attitudes specifying what to do and what not to do in a given situation"*. Related to social norms are personal and legal norms, habits and customs. Both personal norms and habits are norms held by individuals, with the difference between the two being that the violation of a personal norm leads to some sort of personal sanction, the latter does not. A legal norm is a norm that is codified, thus called a law. As a working definition, influenced by [10] and [47] we define a social norm as *a rule, standard, or convention, understood by members of a*

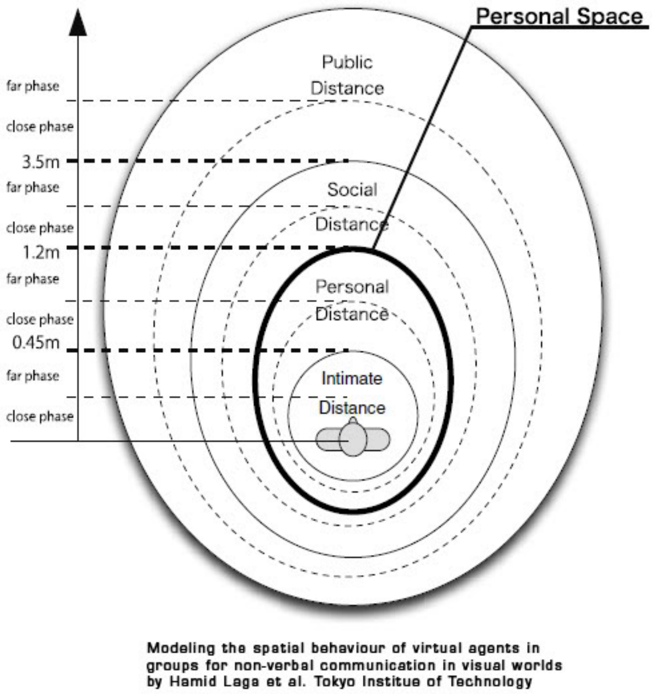

Figure 1: Proxemics zones as defined by Hall [17]. Image source [33]

group which guides and/or constrains social behavior without the force of laws in a certain context. From our working definition, we can conclude that a norm has to meet three prerequisites in order to be considered to be a social norm:

1. The norm is unwritten
2. The norm exists in a specific social context
3. The norm is culturally dependent, therefore it can vary between cultures.

Examples of research into human adherence to social norms include series of experiments by Cialdini et al. [9], Aarts & Dijksterhuis [2] and Keizer et al. [27]. The norms researched were social norms like littering, being silent in a library and adherence to prohibition signs. While above research provides insightful results, these are not automatically relevant or applicable for the SPENCER project. A robot does not litter, and the speech volume of the robot can be programmed. We are looking into human spatial behaviour: the norms and rituals people adhere to and expect from a robot in comparable situations. There are two norms that we believe are especially relevant for the SPENCER robot: adherence to others' personal space and positioning with respect to others in space. In the next sections we describe how these two norms affect HRI.

2.1.1 Adherence to others' personal space

Adherence to others' personal space is one aspect of the research on "proxemics". Edward T. Hall [17] introduced the term proxemics and defined it as *"the interrelated observations and theories of humans' use of space as a specialized elaboration of culture"*. The proxemics theory postulates that ones' body is surrounded by four eclipse-shaped bubbles: the intimate, personal, social and public spaces. Interaction partners mostly position themselves in the second- and third zone. For each of these zones, Hall defined approximate distances, as can be seen in Figure 1 and Table 1. In line with previous HRI work we will primarily focus on the identification of the personal space zone, in order to find out when a robot approaches too close for comfort.

There are several effects of personal space invasion. When one's personal space zone is invaded by "intruders" in semi-public spaces this is considered as a disturbance, an invasion of one's personal territory. Reactions to the invasion of personal space include avoidance behaviours to compensate for this invasion. The distance between two people is increased, for instance by avoiding eye contact (gaze), or physical flight behaviours, like leaning away or walking away entirely. Mediating factors influencing the size of one's personal space bubble include (but are not limited to) gender, age, personality, socioeconomic status, sociability, interpersonal likeability / attraction and gaze [19].

A detailed overview can be found in Hayduk [19]. The size of the proxemics zones is culturally dependent, as is explained in Section 3.2. This is relevant for the SPENCER project as the SPENCER robot is envisioned to interact with a culturally diverse audience. Therefore, HRI research is needed into cross-cultural HRI proxemics.

The norm of adherence to personal space has received a lot of attention with respect to other factors though. Different scholars in HRI, most notably Michael Walters et al., researched whether or not the size of the personal space bubble would be equal when approached by a robot. Additional studies looked into which factors influence succesful robot-human approaches. The work on HRI-related social norms relevant for SPENCER is summarized in Table 2. This research found that the baseline personal space distance for humans is around 57 centimeters and varies slightly depending on factors such as the appearance of the robot and the preference of the participant [58]. It has also been found that a full-frontal approach direction is not always considered to be the most appropriate [11]. However, most of the previous work focused on approaching single persons. For the SPENCER project this provides a basis upon which we can design our future user studies when we are going to approach small groups of people.

Proxemics zone	Range	Situation
Intimate zone	0.00 - 0.45m	Lover or close friend
Personal zone	0.45 - 1.20m	Conversation between friends
Social zone	1.20 to 3.60m	Conversation between non-friends
Public zone	3.60m +	Public speech

Table 1: Proxemics zones as defined by Hall [17]

What?	Reported in
Approaching	
Personal space (zone)	
Identification of approach distance	[21, 60]
Influence of age factor	[59, 44]
Influence of gaze behaviour	[42, 55]
Influence of robot voice	[61]
Influence of approach angle	[31]
Negative effects of violation of personal space zone	[51, 26]
Approach angle while seated	[54, 11]
Effect of robot height	[8, 24, 58]
Temporal stability	[31]
Spatial (F) Formations	
Formation assumed around a robot	[21]
Formation influenced by a robot	[32]
Social robot conventions while driving	[46, 48]

Table 2: Summary of HRI experiments related to physical robot behaviour

2.1.2 Positioning with respect to others (F-Formations)

People organize themselves not only in terms of interpersonal distance but also in terms of spatial arrangements. To capture this phenomenon, Kendon [28] introduced the concept of F-Formations. The space in which people direct their attention and manipulate objects can be called a transactional segment [28]. When two or more people interact, these segments overlap, thus, creating a joint transactional space: the O-space. Around the O-space, people arrange themselves in the P-space, in a certain F-Formation. Behind the P-space is the R-space which is everything not in the O- or P-space. These spaces have also been referred to as transactional region, agent region and buffer region [36].

Figure 2 shows an example formation with the O-, P-, and R-spaces. These three people are standing in a circular formation, however, also other formations are frequently observed; for instance, L-shape, vis-a-vis and circular formations. This is highly relevant for SPENCER because the robot has to approach groups of people. The formation and composition (size, male/female distribution, cultural background) of the group has an influence on which direction and distance of approach is considered to be the most appropriate. In Section 3.2 we describe a survey that we conducted to gain insights into what would be considered being the most appropriate approach direction and distance.

2.1.3 Guiding people

Guiding people is believed to be a major application area for (social) robots. While the context may differ (e.g. an airport or a museum [52]) there are people being guided, and therefore there are similarities. One of these similarities might lie in the speed of the robot. Research by Garrell & Sanfeliu [14] showed that people's interest in following a robot decreased when the speed of the robot decreased to 0.4 m/s. A speed of 0.8 m/s seemed to be more appropriate. This is still not as fast as the average walking speed observed by researchers as Bohannon [6], so it could be the case

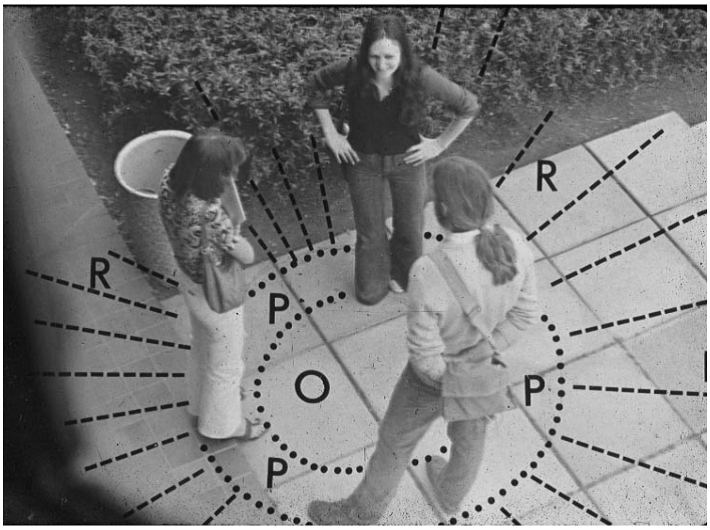

Figure 2: Typical circular F-formation [28].

the SPENCER robot could still comfortably guide passengers at a higher speed. Thus, incoherences in previous findings need to be addressed in order to determine the optimal speed for the SPENCER robot (see Section 2.4).

Next to speed, a guiding robot should communicate where it is going in one way or the other [30], not only for the passengers being guided but also for people being present around the robot. Humans use head movement and non-verbal cues (facial expressions) to communicate such intentions. Modalities such as gaze and sound could also be used in HRI as our previous work has indicated [24, 38]. However, these aspects will need to be researched more in depth with respect to guiding behaviours (see Section 2.4).

2.2 Do people treat robots as they treat humans?

When interacting with robot technology, or computer technology in general, people attribute certain human characteristics to both its appearance and behaviour. The term *anthropomorphism* describes the tendency to imbue the real or imagined behaviour of non-human agents with humanlike characteristics, motivations, intentions, or emotions [12]. In robot design, for instance, people have been found to automatically perceive anthropomorphic cues, for instance in that they prefer a more sociable robot head for a more social task [16].

Just as people anthropomorphize a robot's appearance, people sometimes e.g. scold at their computer in an attempt to make it work. This phenomenon can be explained by means of the Media Equation theory, also known as the CASA - Computers As Social Actors - paradigm. The Media Equation holds that people tend to treat computers and other media as if they were either real people or real places [49]. Supporting evidence has been found in the field of Human-Computer Interaction (HCI), e.g. participants attributed introverted or extroverted personality to a computer that read aloud book descriptions by ways of a TTS engine [43]. Similar evidence has been found in HRI literature: Lee et al. [35] programmed an AIBO robot to behave either introvert or extrovert and found that participants were able to distinguish between both personalities. This implies that the CASA paradigm might be equally valid for HRI as it is in HCI. However, HRI research has also revealed limitations of the Media Equation. Bartneck et al. [4] replicated Stanley Milgram's famous prison experiment [41] with a robot in place of the human. Unlike Milgram's experiment where 40% of the participants went up to the highest voltage setting to punish a person in another room, 100% of participants did so when asked to punish a robot [4]. While this could be considered to be an extreme example, it nicely points out that despite the fact that we might treat robots similar to humans to a certain extend, it is still necessary to study how norms in HRI differ.

Numerous HRI publications refer - either implicitly or explicitly - to the importance of conforming to social norms, the most popular of all norms appearing to be personal space (see Section 2.1.1). Qian et al. [48] conducted a survey in order to identify important, socially acceptable, safety criteria for robots. Out of eight possible social conventions, four were reported as being the most important, according to the participants of the survey. These conventions are (1) adhere to personal space, (2) maintain visibility when approaching, (3) drive at the correct side of a hallway, and (4) give priority to humans should a robot and human appear to be on a collision course. All of these are included in the research questions that we will present in the conclusion of this section.

2.3 Are there reasons to assume that cultural differences with relation to norms (for robots) exist?

Human interaction is not governed by one specific set of social norms but the norms differ across cultures. Unfamiliarity with cultural differences can lead to misinterpretation, misunderstanding and even unintentional insult [56]. Culture is an ambiguous concept, therefore, we will first look at different definitions of culture. Originally, the term culture stems from the Latin word colore, and it *"[] usually referred to something that is derived from, or created by the intervention of humans - culture is cultivated"* [18]. Triandis [57] divided culture into a subjective and material culture. Material culture consists of elements, for instance food, houses and tools. Subjective culture, on the other hand refers to the characteristic way in which a specific group perceives its environment [57]. When referring to culture, this review refers to subjective culture.

Brauer & Chaurand [7] compared 46 uncivil behaviours across eight countries, which varied along Hofstede's individualism-collectivism axis. For each of the behaviours, participants were asked to rate how uncivil they thought the behaviour was, how common it was in their country and how likely they would be to react negatively to that behaviour. Results indicated that if the behaviour was perceived as more deviant, participants would be more likely to react to it. In a similar study by Gelfand et al. [15], participants (N=6823) from over 33 countries were asked to rate the appropriateness of twelve behaviours in fifteen everyday situations, and, whether or not there were clear rules for appropriate behaviours in these situations. It was found that there was a high within-nation agreement about the level of constraint in everyday situations, and a high level of variability between-nations. The nation as unit of analysis appears to have proven to be a useful unit of analysis.

In the field of HRI, cross-cultural research has not yet focused on social norms. Cross-cultural HRI research up to date has primarily focused on general attitudes toward robots [5], and whether or not the mental model people have of robots is culturally-dependent [29]. Wang et al. [62] found people to be more willing to follow a robot's advice when the robot would provide advice in a culturally appropriate way. However, for the SPENCER project it is important that we investigate whether proxemic expectations of users toward the robot depend on culture. Research by social psychologists like Sussman & Rosenfeld [53] and Little [37] provides support for this hypothesis in human interaction. In Section 3.2 we provide some empirical evidence for this hypothesis with respect to HRI.

2.4 Identifying research questions

The SPENCER robot has to execute four primary movement tasks: Approach Me, Walk With Me, Talk To Me, and Leave Me. The "me" in this is the participant, or in case of the SPENCER project the group of participants. Based upon our literature review we have gained an overview of what has and what has not yet been tested in relation to these tasks. We sum this up in the following with the goal to identify open questions that we have already answered in the studies presented below and/or will address in our future research.

HRI trials have focused on approaching and engaging single persons in the lab (e.g., [11, 21, 24, 31, 42, 45, 55]). The SPENCER robot will have to interact with multiple passengers. Even though it might be possible to direct the robot's focus of attention on a spokesperson, approaching a small group could lead to different proxemics preferences (and thus expectations) since members of the group influence each other. A gap in the state of the art is therefore the approach (initial contact) and engagement of small groups of people.

We have briefly discussed F-formations and associated different interaction spaces. From this, we know that a robot can influence the formation of the group by adjusting its position when part of the group [32]. What we do not know is how a robot should approach a group of people and get their attention when they are standing in a specific F-formation. This gap is not only relevant for a guiding robot but basically for any attention-seeking robot.

Also little is known about an appropriate robot speed when guiding people. As guiding passengers is the *raison d'etre* of the SPENCER robot, we intend to conduct an experiment to understand how quickly the robot should move in certain situations. One specific situation that is important in the SPENCER context is how the robot can cause groups of passengers to walk quicker when being guided.

Approaching a group has been discussed in the literature (see Table 2). While there are preferences for approach direction and -distance, it has not yet been investigated how a robot should leave a group.

From this we identified several research questions related to the four primary movement tasks:

Approach me / Talk to me

1. How close and from what angle should a robot approach a group of passengers in order to engage them in interaction?
   See Section 3.2.

2. How does normative robot behaviour in terms of how close and from what angle to approach differ between situations with individuals compared to groups?

Walk with me

3. How should a robot's motion behaviour be designed to compensate for its lack in (facial) expressiveness of non-verbal cues?
   See Section 3.1.

4. a) What is the most appropriate robot speed when guiding a group of passengers?
   b) How can a robot make a group of passengers speed up / hurry?

5. How should a robot keep passengers engaged while guiding them over a longer distance (>100 meter)?

6. Do people expect a robot to give priority of way to elderly people at an airport?

Leave me

7. How should a robot leave a small group of transfer passengers in a culturally appropriate way?

3 Summary of experiments conducted in year 1

This section summarizes two studies we have conducted in year 1. An overview of symbols used to report the various statistical tests can be found in Section 6.

3.1 Sound over matter: the effects of functional noise, robot size and approach velocity in human-robot encounters

This section has been published as:
Joosse, M.P., Lohse, M., & Evers, V. (2014) Sound over matter: the effects of functional noise, robot size and approach velocity in human-robot encounters. Proceedings of the 2014 ACM/IEEE Conference on Human-Robot Interaction, pp. 184-185

We conducted a 2x2 between-groups experiment (N=40), manipulating the approach velocity of the robot and the use of functional noise (increasing in volume when the robot accelerated and decreasing in volume when the robot decelerated). See also Figure 3. Our hypothesis was that *"a robot using functional noise to convey its intention to the user will be more positively perceived than a robot which does not use intentional functional noise"*. In our previous work we introduced functional noise as a modality for robots to communicate intent [38]. In this follow-up experiment, we replicated the first study with a robot which was taller in order to find out if the same results would apply to a tall vs. a short robot.

Participants liked the robot more in the functional noise conditions, compared to the constant noise conditions, $F(1,39)=3.844$, $p<0.05$. A main effect was found for functional noise on perceived helpfulness: participants rated the functional noise conditions (M=3.35, sd=1.089), as being sig-

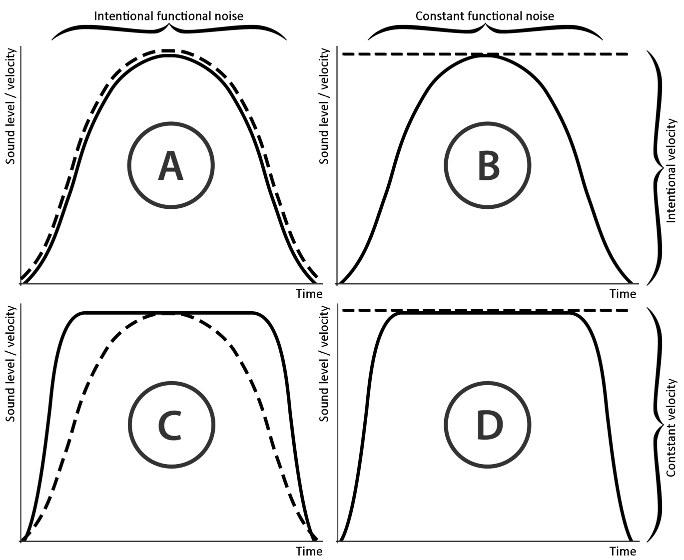

Figure 3: A 2x2 between-groups experiment was conducted, manipulating functional noise and velocity.

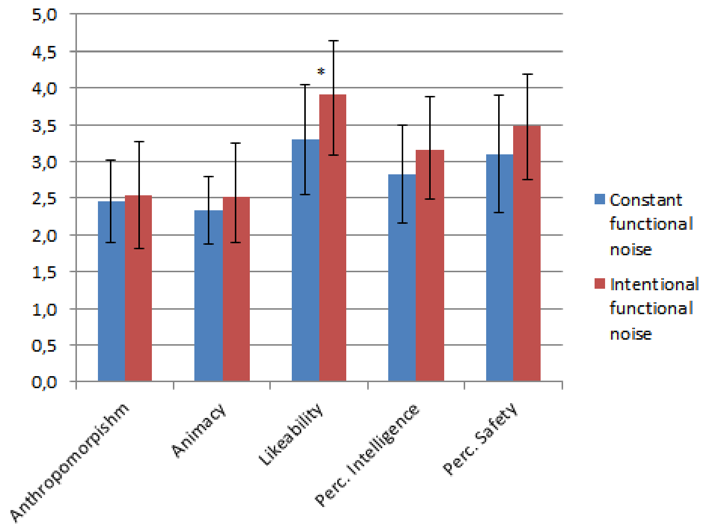

Figure 4: Mean ratings for the combined sample Godspeed scales.

nificantly more helpful than the constant noise conditions (M=2.70, sd=1.081), *U*=135.5, $p<0.05$. When we combined this dataset with the one in [38], we found a significant main effect of functional noise on helpfulness. Participants found an intentional noise pattern (M=3.35, sd=1.122) significantly more helpful a constant functional noise pattern (M=2.73, sd=.987), *U*=546.00, *Z*=-2.546, $p<0.05$. Furthermore, we found significant (2-tailed) main effects for functional noise on all Godspeed scales [3]: anthropomorphism (F(1,73)=7.685, $p<0.01$), animacy (F(1,75)=7.474, $p<0.01$), likeability (F(1,75)=9.336, $p<0.01$), perceived intelligence (*U*=520.00, *Z*=0.10, $p<0.01$) and perceived safety (*U*=607.50, *Z*=0.059, $p<0.05$). For the above scales the intentional noise conditions were rated more positively than the constant noise conditions (Figure 4). No significant effects were found between size of the robots.

In conclusion, we found that a robot approaching with intentional noise (increasing in volume when the robot accelerated and decreasing in volume when the robot decelerated) was regarded more positively. Our study shows that functional noise could be a powerful tool to convey a robot's intentions when approaching a user.

3.2 The Sweet Spot for Human Robot Interaction: Cultural Differences in how an Engagement-Seeking Robot should Approach a Small Family

This section has been published as:
Joosse, M.P., Poppe, R.W., Lohse, M., & Evers, V. (2014) The Sweet Spot for Human Robot Interaction: Cultural Differences in how an Engagement-Seeking Robot should Approach a Small Family. Submitted to the 5th ACM Conference on Collaboration Across Boundaries: Culture, Distance & Technology (CABS) (in review)

The sociologist Hall [17] coined the term proxemics to indicate the studies of human's use of space. Social psychological research found these interpersonal distances to be culturally dependent [20, 37, 53] as previously explained in Section 2.1.1. We set out to extend the state of the art on human-robot proxemics by investigating whether preferences for how a robot should approach a small group is culturally dependent. We present our first study in this, a set of measures and preliminary results of an online survey (N=181) distributed to people in China, the U.S. and Argentina. We chose these countries because related research indicated these three national countries would have significant different practices and values and that there would therefore have different proxemic expectations. A more detailed explanation is provided in the paper, which is included in the Appendix.

We conducted a 3 (nationality) x 3 (position in the group) x 6 (distance from the group) online study. A survey-based questionnaire was distributed through a crowdsourcing platform (crowdflower.com) to a targeted population. Participants were shown images of small families of 3D people and a robot (See Figure 5). These groups were composed of three people: a man, a woman and a child. Participants were asked to indicate on a 7-point Likert scale how appropriate they believed the position of the robot was after the robot had approached. The position and the distance of the robot were manipulated within-subjects, the nationality of the participants was a between-subjects variable.

Our results show that participants prefer a robot which stays out of people's intimate space zone just like a human would be expected to do. The cultural differences found were partly in line with previous socio-psychological research: Chinese participants believed that closer approaches were appropriate compared to the participants from the U.S. and Argentina. For the Spencer project, this implies that we actually have to take the culture of the passengers into account.

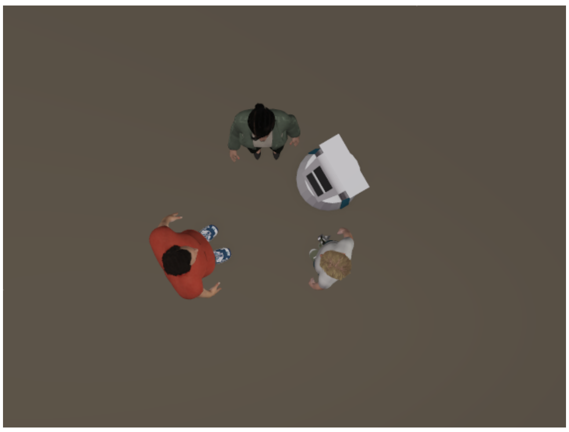

Figure 5: Example top-down still as shown to participants.

4 Contextual Analysis (to be conducted as a next step)

As part of the input for future robot development, we plan to conduct a contextual analysis at an airport. This section will describe what we will observe and what information we plan to determine from the analysis.

We use the term contextual analysis here to describe a scientific method to discover how people behave in a given context (here the airport) and in relevant situations within this context. Generally spoken, the main goal of the contextual analysis is to analyse human behaviour at the airport in order to identify normative behaviours that the SPENCER robot should employ in the same context.

The primary goal of the contextual analysis is to understand the behaviour of passengers (specifically transfer passengers) at an airport. This includes (observable) rituals and habits that guide their walking behaviour, and their needs when transferring. The results of the contextual analysis will be used as an inspiration for possible spatial behaviours of the SPENCER robot. The secondary goal is to better understand the transfer process, and the obstacles passengers encounter. This will provide input (if necessary) for modification of the use case scenarios as defined in the SPENCER Description of Work [1]. In preparation of this contextual analysis we have conducted pilot observations at two transportation hubs: a major Dutch railway station and the public area of Schiphol airport.

Table 3 provides an overview of the contextual analysis to be conducted. The observations are either participatory or non-participatory. In a participatory observation a person who knows about the study interacts with the participants (as opposed to a non-participatory observation). If the situations should be influenced as little as possible, non-participatory observations are preferred. Furthermore, the observations can be open or hidden. In an open observation the participants know that and why they are observed. In a hidden observation, people do not know about it. Again, if the goal is to interfere as little as possible in the situation, hidden observations are preferred.

The data will be analysed primarily by a so-called grounded theory method. The grounded theory method is a qualitative research method, that seeks to develop theory based upon data which is systematically gathered and analysed [34, p. 283-285]. Grounded theory is an iterative method, which consists of four phases, these being:

- Open coding
- Development of concepts
- Grouping concepts into categories
- Formation of a theory

These theories will be used to inspire behaviours of the SPENCER robot, which will be tested in future user studies in order to find out which human behaviours are deemed socially acceptable when executed by a robot.

#	Description of situations	Specific research questions	Method	Type of type	Place(s) for recording	Amount of data / required time
1	Follow passengers walking around without guidance	What happens when a group of passengers go from a gate to either SSTD [a] or Schengen barrier in terms of: - Spatial behaviours (speed, overtaking, spatial formation) - Communication with staff and/or information sources - Distractions (which distractions)	Observation (non-participatory, open)	video (moving around with the cameras) Observation (pen/paper)	From gate to SSTD/Schengen barrier	360 min
2	Staff approaching passengers	How does staff approach a small group of passengers	Observation (non-participatory, open)	Video (moving around with the cameras)	Gate area; in-etween gate-terminal	45 min.
3	Groups navigating through T-junction area	- How do (groups of) passengers pass through another pedestrian flow? - What are positive- and negative examples of small groups that navigate through a crowded space	Observation (non-participatory, open)	Video (static) from above	T-junction	90 min.
4	Passengers at SSTD	How does a "transaction" of a small group with a SSTD work, in terms of work flow and spatial behaviour (e.g. does group split up)?	Observation (non-participatory, open)	Video (static)	SSTD area	30 min.
5	General passengers at Schengen barrier	How does a small group deal with the Schengen barrier?	Observation (non-participatory, hidden)	Observation (pen/paper) Video (static)	Schengen barrier	30 min.
6	Passengers around (static) information sources	How do people make use of static sources of information (information monitors, information desks)	Observation (pen/paper) Video (static)	Schengen barrier	30 min.	

Table 3: Contextual analysis observation plan

[a] Self-service transfer desk

5 Conclusion

In this deliverable, we have summarized our research activities in the past year. We have conducted a literature review from which we defined seven research questions which we think would be especially relevant for the SPENCER project. To summarize, these research questions were as follows:

1. How close and from what angle should a robot approach a group of passengers in order to engage them in interaction?
2. How does normative robot behaviour in terms of how close and from what angle to approach differ between situations with individuals compared to groups?
3. How should a robot's motion behaviour be designed to compensate for its lack in (facial) expressiveness of non-verbal cues?
4. a) What is the most appropriate robot speed when guiding a group of passengers?
   b) How can a robot make a group of passengers speed up / hurry?
5. How should a robot keep passengers engaged while guiding them over a longer distance (>100 meter)?
6. Do people expect a robot to give priority of way to elderly people at an airport?
7. How should a robot leave a small group of transfer passengers in a culturally appropriate way?

We have addressed questions 1 and 3 by an online survey and lab experiment, respectively. As reported in Section 3.1, we conducted lab trials with artifical generated functional noise, which improved the overall evaluation of the robot. Because this first experiment lacked ecological validity due to several reasons (e.g., the experiment was conducted in the lab with only one user being approached) we will extend this research in the next years. The online survey (reported in Section 3.2) that we conducted with Argentinian, Chinese and U.S. participants showed that preferences with respect to a robot's proxemic behavior are actually different between U.S. and Chinese participants. This is in line with social-psychological research, and implies that for the SPENCER project we should take the culture factor into account when designing robot behaviour. In the next two years we intend to provide answers to the five remaining research questions we have identified. As stated in Section 4 in a very next step we will conduct a contextual analysis at an airport. In this contextual analysis we hope to gain a better understanding of passengers' walking behavior in a specific crowded environment.

In this year we have learned a lot already with respect to robot behavior. We look forward to conducting user studies, and we hope that the results we provide valuable input for the other project partners.

6 Symbols used in this deliverable

The following symbol are used in this deliverable:

Symbol	**Denotes**
N	Sample size
M	Mean, or average
sd	The standard deviation of a sample of data
T	Test statistic for the T-test
U	Test statistic for the Mann-Whitney test
F	F-ratio: the test statistic used in an ANOVA
p	Probability
Z	A data pont expressed in standard dev iation units

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Short Duration Robot Interaction at an Airport: Challenges from a Socio-Psychological Point of View

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1 Introduction

This extended abstract concerns the FP7-project Spencer[1]. As part of the Spencer project, a demonstrator robot will be developed which provide services to passengers at a major European airport. Example services include (1) guiding transfer passengers from their arrival gate to the so-called Schengen barrier, and (2) assisting in the transfer process by printing boarding passes. The goal of the robot is to make sure that passengers will make their connecting flight, with our own focus being on the human-robot interaction. In the following, we describe a sample use case of the project scenario. Based on this we identify possible challenges that are of interest with respect to interactive robots in public spaces.

2 Use case

The Spencer project aims to develop and deploy a demonstrator service robot which can provide assistance to transferring passengers at a major airport in Europe. The industrial partner has about 25.000 transfer passengers daily. A large portion of these passengers transfer from (intercontinental) non-Schengen flights to (European) Schengen flights, requiring passengers to go through a passport control before arriving at their next departure gate. This process costs time, and is one of the major sources why passenger miss their connecting flights.

The Spencer robot is envisioned to collect a group of transfer passengers with a minimal connection time at the gate (for example they could make their connection if they hurry and go to the fast-track Schengen lane). The Spencer robot will guide them towards the fast-track Schengen lane, after which they can proceed to their departure gate. An average group of transfer passengers constitutes between 20-40 people, who do not necessarily know each other; their only common denominator is their next flight.

Scientific challenges for the Spencer project include (among others) socially intelligent navigation and the detection of groups of people and relations within these groups. The scientific challenge we are focusing on, is the *evaluation and design of (spatial) robot behaviors that are experienced as (socially) normative.*

[1] http://www.spencer.eu

3 HRI challenges for the Spencer robot

The use case as described above contains both technical and scientific challenges. In this section, we will focus on what we believe as being the most important challenges for the interaction between passengers and a robot.

3.1 Normative behavior: it is about intention recognition

Independent of the ways by which the robot conveys its intentions, the robot should be perceived as behaving in a normative way. Thus, the behavior of the robot should conform to the social norms expected by the *current* passengers. Examples of these normative behaviors could include adjusting the speed to the group, and giving way to people approaching from the right. While the implementation of these issues could be considered technical ones, we believe the identification of the norms is a socio-psychological problem.

We believe that because - for most people - flying is not considered to be an everyday activity; many people consider it to be hectic, and are sometime unsure of what (not) to do or where to go. This makes it especially important that the messages a robot transmit, for instance those which convey its movement, are clear and predictable.

At airports identifying normative behavior is particularly complicated in part because the robot will have to deal with people with different cultural backgrounds. These might even form part of one group that has to be guided at the same time. Also the fact that we have to deal with groups as such is a challenge for behavior planning and other technical requirements such as robust spoken language processing and person tracking.

Thus, there are two distinct different normative behaviors we consider in this extended abstract. One the one hand we argue that the movement of the robot should be legible and conveying towards the passengers. On the other hand, the robot has to behave in a normative way in the sense that it abides with the (un)written conventions of pedestrian traffic.

3.2 Communication Modalities

To address the issue of legible and conveying movement, one can think of different modalities which could be useful to communicate intent. Whereas humans can use non-verbal communications to exchange social signals when approaching one another [2], robots are not (yet) capable of this. We propose to evaluate two different communication modalities for the robot, each having pro's and con's in the context of an airport.

Speech or sound in general, could be one of these modalities. Due to the multicultural mix of passengers these messages would ideally be universal. A solution can be to implement a text-to-speech engine in the robot, or a noise-like level as described in [1]. Since an airport is a noisy environment, the robot has to repeat the messages.

A graphical interface could also be used to convey movement intentions, for instance a screen, indicating the robot's speed or acceleration. This would be limited in that it can only supply information to those who can see the screen; people who are moving behind, or next to, the robot.

Both modalities could be used to communicate intent to passengers. We intend to test both modalities synchronous and asynchronous in order for the robot to communicate as effective as possible.

3.3 Research approach

The Media Equation states that people treat computers, and related media, as if they were people [3]. Based upon this work of Nass and colleagues, our approach is to first identify what people do, implement similar behaviors on a robot, and evaluate whether human norms hold for human-robot interaction.

We do not expect that human normative behavior will unequivocally carry over to normative robot behavior, however, we will use it as a starting point.

Based upon a literature review and a contextual analysis (systematic observation of what really happens), we will design and implement normative behaviors for a robot. These behaviors will first be tested in lab studies, followed by experiments at the site of the industrial partner; the airport in order to get an idea of the experiences of the passengers.

To get insight in the experiences of passengers at the airport, we can employ several methods for user studies. Examples include self-reported questionnaires, coding of video data and analysis of one's galvanic skin response.

For our experiments, we will primarily collect video data, as well as subjective questionnaires or -interviews. Objective video data makes it easy to capture certain behavioral responses from multiple people in a short time. However, legal and organizational issues (such as privacy and security) could hinder this method when used outside the lab. Interviews and questionnaires should be able to capture the required data in only a few questions, given that passengers will be likely be in a hurry. These languages should be unambiguous for passengers with different cultures; this raises the question if the language should be native, or universal (read: English). Different languages would require multiple iterations of translation and back translation to ensure the questions truly ask the same.

In light of the issues described above we may have to rethink our data collection methods. This also holds for the data the robot collects for its own perception. Prior to evaluation in a real-world setting, behavior will be evaluated in a more controlled setting. This could be in a lab setting as for example in [1, 4], but also by other ways, for instance by using videos of a robot interacting with people [5].

4 Conclusion

In this extended abstract we have described challenges from a socio-psychological point of view when a robot interacts with users at an airport. We argue the it is especially important to convey the robot's intentions toward users in an appropriate manner with respect to social norms while taking into account constraining environmental factors (such as noise levels). In part due to their safety-critical nature, airports in general cause specific challenges with regards to data collection practices.

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Sound over Matter: The Effects of Functional Noise, Robot Size and Approach Velocity in Human-Robot Encounters

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ABSTRACT
In our previous work we introduced functional noise as a modality for robots to communicate intent [6]. In this follow-up experiment, we replicated the first study with a robot which was taller in order to find out if the same results would apply to a tall vs. a short robot. Our results show a similar trend: a robot using functional noise is perceived more positively compared with a robot that does not.

Categories and Subject Descriptors
H.m [**Information systems**]: Miscellaneous

General Terms
Experimentation

Keywords
Social robot, functional noise, robot height, approach experiment, artificial noise

1. INTRODUCTION AND BACKGROUND
The first impression counts [1], and has already formed when approaching someone. Research has shown that when approaching each other, people exchange social signals using non-verbal communication [7]. Also their appearance is a signal that provides information to the other person [5]. While robot designers can control some of these latter signals by ways of morphological design, robots fall short in employing subtle (non-verbal) signals, such as short glances or gestures, due to technical limitations. Thus, we - as interaction designers - have to find ways to compensate for this lack to ensure that users understand and can predict the robot's behaviors.

Therefore we propose to add functional noise to robots to convey their intentions. Functional noise is added artificial noise to inform people. For instance to an electric car some engine noise may be artificially added so that people can hear it coming. We carried out a first study [6] in which we investigated the effect of fictional noise that communicates how fast the robot is going. This experiment provided us with results of how functional noise and approach velocity influence people's perception of robots.

In the current study we aim to address the biggest limitation in the first study: the height of the robot was only 78 cm [6]. This may explain the lack of effect of approach patterns on users' attitudes and behavior. Previous work on height in HRI found no significant result (120 cm vs. 140 cm) [8]. Or, when differences were found, both height and appearance were manipulated [3]. In order to address this limitation, we conducted an experiment in which we replicated the previous experiment [6] with a taller robot, having a height of 163 cm instead of 78 cm.

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2. METHOD
We conducted a 2x2 between-groups experiment, manipulating two independent variables: robot (acceleration and deceleration) velocity and functional noise, see also Figure 1. Our hypothesis is that "*a robot using functional noise to convey its intention to the user will be more positively perceived than a robot which does not use intentional functional noise*". A 163cm Giraff robot was used. On the screen of the robot, we displayed a pair of eyes, made up from static colored dots. The robot was programmed to accelerate and decelerate either slowly over time (0.1 m/s^2) and to drive "smoothly" or to accelerate and decelerate as fast as possible (1.35 m/s^2) and to drive in an "abrupt" way. The maximum speed of the robot was set to 0.69 m/s, and the robot would approach the participant by driving 4.9 meters in a straight line.

We created two different functional noises; a noise with "*constant noise* level" and a noise that increased in volume at the beginning of the approach and decreased in volume at the end, the latter called "*intentional noise*". The manipulations resulted in four different experimental conditions.

A 32-item post-experiment questionnaire was used as dependent variable, measuring among others helpfulness (see [6]) and the Godspeed scales [2]. All five Godspeed scales had medium to high internal reliability. The Godspeed scales anthropomorphism (α=.740), animacy (α=.656), likeability (α=.898), perceived intelligence (α=.804) and perceived safety (α=.778).

The sample consisted of 40 participants (25 males, 15 females) with a mean age of 21.25 years (sd=2.30). Participants were equally distributed over the experiment conditions. The participants, mainly students, were recruited from the premises of the University of Twente. After being provided with a short explanation about the experiment, participants filled out a consent form. The robot approached the participants once, after which they filled out the post-experiment questionnaire.

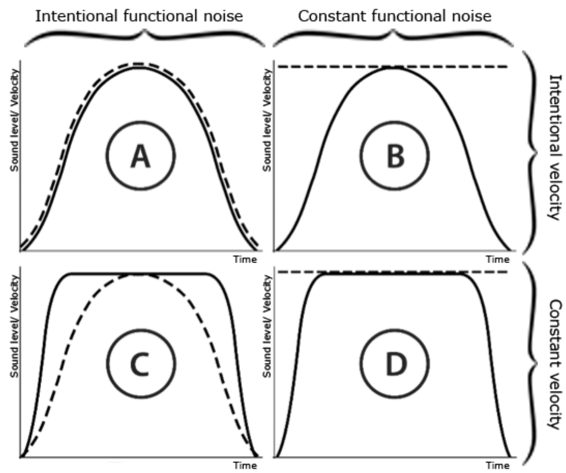

Figure 1. A 2x2 between-groups experiment was conducted, manipulating functional noise and velocity.

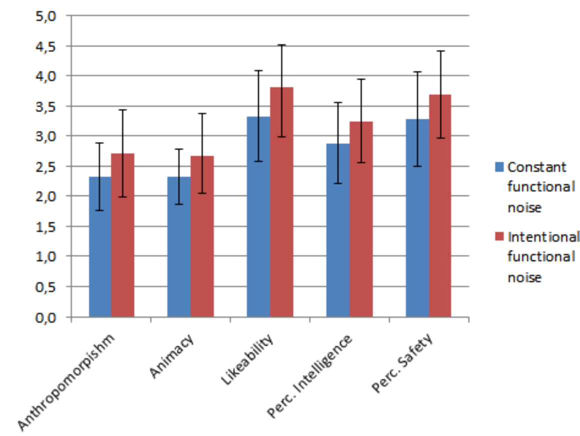

Figure 2. Mean ratings for the combined sample Godspeed scales.

3. RESULTS AND DISCUSSION

Participants liked the robot more in the functional noise conditions, instead of a constant noise conditions, $F(1,39)=3.844$, $p<0.05$. A main effect was found for functional noise on perceived helpfulness: participants rated the functional noise conditions (M=3.35, sd=1.089), as being significantly more helpful than the constant noise conditions (M=2.70, sd=1.081), $U=135.5$, $p<.05$.

When we combined this dataset with the one in [6], we found a significant main effect of functional noise on helpfulness. Participants found an intentional noise pattern (M=3.35, sd=1.122) significantly more helpful a constant functional noise pattern (M=2.73, sd=.987), $U=546.00$, $Z=-2.546$, $p<0.05$. Furthermore, we found significant (2-tailed) main effects for functional noise on all Godspeed scales: anthropomorphism ($F(1,73)=7.685$, $p<0.01$), animacy ($F(1,75)=7.474$, $p<0.01$), likeability ($F(1,75)=9.336$, $p<0.01$), perceived intelligence ($U=520.00$, $Z=0.10$, $p<0.01$) and perceived safety ($U=607.50$, $Z=0.059$, $p<0.05$). For the above scales the intentional noise conditions were rated more positively than the constant noise conditions as can be seen in Figure 2.

No significant effects were found between size of the robots. Both short and tall robots were simple-looking robotic devices without moveable arms. It could be that a robot with a more anthropomorphic, or sophisticated shape, yields different results.

We are aware that we have introduced limitations towards the validity of our work. Previous work in HRI has found that full-frontal robot approaches are not necessarily the most comfortable. The experiment procedure perhaps made participants unnaturally well aware of the approaching robot; participants were focused on the robot from start to finish.

In conclusion, we found that a robot approaching with intentional noise (increasing in volume when the robot accelerated and decreasing in volume when the robot decelerated) was perceived more helpful, and was regarded more positively. Our study shows that functional noise could be a powerful tool to convey a robot's intentions when approaching a user.

4. ACKNOWLEDGMENTS

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Lost in Proxemics: Spatial Behavior for Cross-Cultural HRI

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ABSTRACT
Socio-psychological research hints to the fact that people from different cultures have different preferences with respect to proxemics. Thus, what might be considered normal for one person, could be a violation of a norm for another person. If cultural background influences spatial behaviors, a logical follow-up question would be if a robot should be equipped with different sets of normative motion behaviors for guiding people. In this paper, we provide an overview of research into cultural differences in proxemics and human-robot social norms. We will address culture not at a national level (i.e. Dutch vs. German national culture), but instead at a clustered, supranational level based upon work by [13]. We conclude with foreseen challenges and solutions for analyzing the appropriateness of HRI behaviors in the context of different cultures.

Categories and Subject Descriptors
J.4 [**Computer Applications**]: Social and Behavioral Sciences

General Terms
Human Factors

Keywords
Human-Robot Interaction, Cultural Differences, Public Space, Proxemics.

1. INTRODUCTION
The phrase "as robots start entering our life" might be an understatement, especially in this field of research. It is not so much a question of if, but more when, and how social robots will enter our daily lives. Over a decade ago, Fong et al. [10] provided an overview of the then-current state of robotics, and distinguished six major application areas. In this paper we focus on culture-aware robotics within the service application field, and specifically short-term public interaction robots.

As part of the EU FP7-project Spencer[1], we intend to elicit and evaluate socially normative motion behaviors for a robot which navigates through a crowded environment. The crowded environment is an international airport, where the robot will guide delayed, culturally diverse, passengers from their intercontinental flight to their connecting continental (European) flight. We do not attempt to trivialize the underlying technical challenges to navigate such an environment in an effective and safe way, but we will focus on the aspect of cultural normative behavior.

Research has pointed to evidence suggesting that people explain machine behavior in terms of human behavior. People anthropomorphize, or have "the tendency to imbue the real or imagined behavior of nonhuman agents with humanlike characteristics, motivations, intentions, or emotions" [9]. Examples include a preference for a specific (static) robot head, given a certain task [12], or the perception of cameras as eyes.

In this paper, we will first provide a short overview of human social norms in general, and cross-cultural social norms research specifically (Section 2). We will then discuss human-robot social norms (Section 3), and discuss challenges for cross-cultural human-robot interaction (HRI) research (Section 4).

2. ON SOCIAL NORMS
Social norms are unwritten norms, sustained by feelings of embarrassment and guilt when violated [8], the disapproval of other people, and social sanctions [32]. These norms are situational dependent; norms governing appropriate conduct during a soccer game differ from those which govern a funeral [1]. The definition of social norms we use in this paper is "Rules and standards that are understood by members of a group and that guide and/or constrain social behavior without the force of laws" [6].

Examples of research into human adherence to social norms include series of experiments by Cialdini et al. and Keizer et al. [24]. The norm researched was the social norm of littering in public space. The main findings include that a) people tend to litter more in an already-littered environment, b) littering increased when the norm was made salient, and c) that the violation of one norm (a littered environment) makes violation of others norms more likely – the latter also called a cross-inhibition effect. Similar results have been found for other social norms, such as the norm of "being silent in the library" [1].

While above research provides insightful results, these are not necessarily the social norms that are automatically relevant or applicable for the Spencer project. A norm that ís relevant, is the norm concerning the adherence to one's personal space. Personal space is one of the four proxemics zones defined by Hall [14], and refers to the semi-circular shaped protective bubble people keep around themselves that cannot be invaded without causing some sort of discomfort. In his book, *the Hidden Dimension* [14], Hall indicated the size of one's personal space to be around 45 cm., this being applicable to Northern Americans, and indicating this size to be different for, for instance, Chinese people.

2.1 Personal space is dependent on culture
Several experiments showed that people with different cultural backgrounds have a different sized personal space zone. One

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[1] http://www.spencer.eu

example dimension to explain cultural differences is the dimension, or maybe division, of cultures into "contact" and "noncontact" cultures. Based upon observations, Hall [14] noted that people from noncontact cultures (Northern European, Northern American countries) maintain a larger personal space compared with their counterparts from contact cultures (Southern European, Southern American, Arab countries).

In one of the experiments, 105 students from three different ethnical groups (Japanese, American and Venezuelan) had a (seated) five-minute conversation with a same-sex, same-nationality confederate [34]. Either in their native language, or in English. They found, when speaking English, participants from the non-contact culture (Japan) sat further apart from each other compared to the contact culture (Venezuela). Within the ethnical groups male participants sat further apart than female participants. Furthermore, when speaking their native language, contact culture participants sat closer together.

Other experiments looking at cross-cultural proxemics distances include the work by Little [27], who used the placement of dolls to infer at which distance people from either the U.S., Sweden, Scotland, Italy and Greece would place people in 19 different social situations, and found similar differences between countries.

Likewise, Høgh-Olesen [19] looked at proxemic differences between cultures, but also at similarities. Based upon the work of Pike [31], he differentiated between two terms; proxethics and proxemics. Proxethics refers to the behaviors and dynamics which are shared by humans – thus being universal. In contrast, proxemics looks at the differences [19]. Høgh-Olesen found six cross-cultural proxethics conventions within six cultures (Greenland, Finland, Denmark, Italy, India and Cameroon). For instance, people leave more room between two strangers compared with one stranger, and the personal space is smaller in social spaces (a café) as compared with non-social spaces (library).

With the knowledge that social norms exist for humans, and these norms can be different for people with different cultural background, a question arises what culture is, and what research has been conducted with regards to cross-cultural human-robot interaction. However, before discussing this in Section 3, we will take a look at the current research in HRI with respect to social norms.

2.2 Human-Robot Social Norms

HRI work related to social norms has mostly been concerned with physical norms, such as approaching someone. Work by Walters [38] focused primarily on the identification of the size of humans' personal space bubble. Takayama & Pantofaru [35] looked at the effect of robot gaze on the approach distance humans keep. They found that when the robot would gaze towards one's legs, men and woman would approach equally close (M=0.28 / 0.30m). However, when the robot gazed towards the participants face, woman maintained a significant larger personal space (M=0.30 m.) compared with men (M=0.24m).

Related to personal space, Dautenhahn et al. [7] looked at the angle of robot approach. In a between-subjects experiment, the majority of participants indicated the robot should bring a remote control from a right-frontal side approach, instead of a full-frontal approach. Koay et al. [25] found comparable results in a longitudinal study, however, over time, participants allowed the PeopleBot to approach equally close from the full-front as from the front-side.

Pandey & Alami (2009) developed and tested a framework for a social robot which (autonomously) conformed to four different social conventions, these being: (1) Maintain right-half portion in a narrow passage, (2, 3) pass and overtake a person from his / her left side. (4) Avoid very close sudden appearance from behind a wall. In a between-subjects experiment (N=8), a 84.7% reduction in unwanted behavior was found [29].

From this we conclude that social norms exist for humans, and that, if equipped with social norms, acceptance and user experience of social robots can be improved.

3. THERE'S CULTURE AND THERE'S CULTURE

Culture is an ambiguous concept. We use the following definition of culture: "a fuzzy set of attitudes, beliefs, and behavioral norms, and basic assumptions and values that are shared by a group of people, and that influence each member's behavior and his/her interpretations of the 'meaning' of other people's behavior" [33]. Triandis divided culture into a subjective and material culture. *Material culture* consists of elements, for instance food, houses and tools. *Subjective culture*, on the other hand refers to the characteristic way in which a specific group perceives its environment [36]. When referring to culture, we are referring to subjective culture.

Usually, when scholars are looking at a culture – and the differences between cultures, the level of analysis is the nation, or sometimes subcultures within a nation. Karahanna et al. [22] defined different levels of cultures, these being supranational, national, and levels within a nation, such as the professional, organizational and the group level.

Over the years, there have been several scholars like Hofstede [18] and Pelto [30] who described differences between national cultures according to different dimensions. In a study by Gelfand et al. [11] participants (N=6823) from over 33 countries were asked to rate the appropriateness of twelve behaviors in fifteen everyday situations, and, whether or not there were clear rules for appropriate behaviors in these situations. It was found that there was a high within-nation agreement about the level of constraint in everyday situations, and a high level of variability between-nations. The nation as unit of analysis appears to have proven to be an useful unit of analysis.

A common belief is that society is becoming more and more individualistic, in part due to IT advances. As Jones [21] puts it: "[…] many researchers find culture to be a dynamic, constantly changing field. Cultures are merging, technology is changing the way we communicate, and globalization is changing the way we trade and interface". Thus, the question arises if cultures as a whole are also becoming more individualistic. Hamamura [15] compared national studies studying individualism-collectivism in the U.S. and Japan over time. In contrast to the common belief they concluded both cultures did not become significantly more individualistic. Similar, Gelfand et al. [11] concluded that social constraint appeared to be more or less stable over time in the United States.

Due to various reasons, some of the 196 countries on this planet will have inhabitants with similar cultural backgrounds. We intend to analyze cultures at the supranational level, here being regional clusters of countries.

3.1 Supranational Level: Clusters of Cultures

According to Gupta et al. [13], three major forces have been used historically to cluster countries, these being (1) geographic

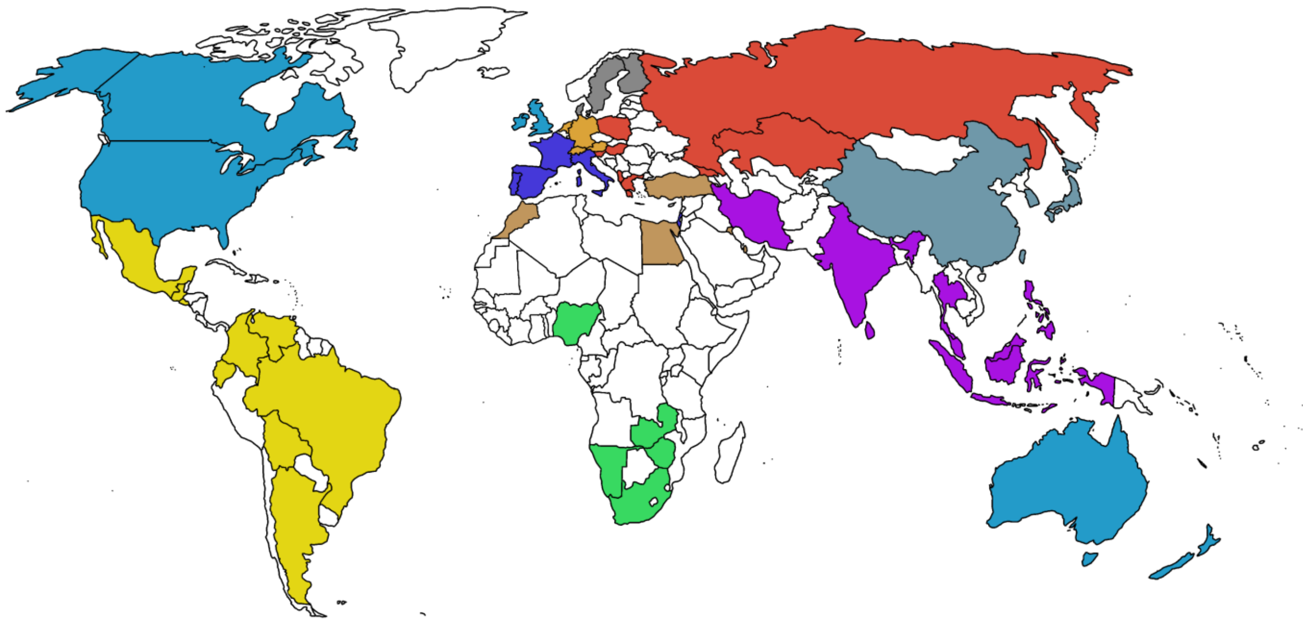

Figure 1. Ten clusters of cultures, figure based upon [13].

Legend: Anglo, Latin Europe, Nordic Europe, Germanic Europe, Eastern Europe, Latin America, Sub-Saharan Africa, Middle East, Southern Asia, Confucian Asia

proximity, (2) mass migration & ethic social capital, and (3) religious and linguistic communality. Societal clustering is a part of the GLOBE project. One of the goals of the authors was to understand similarities and differences among the countries studied within the GLOBE project [20]. As part of this project, 61 nations were clustered into 10 clusters of cultures (see Figure 1, and Appendix I) [13]. Examples include the *Nordic European* cluster containing Finland, Sweden and Denmark, and the *Germanic European* cluster with Austria, Switzerland, the Netherlands and Germany. Appendix I provides the countries contained within each of the ten regional clusters. The remainder of this section will discuss the methodology by which the measures underlying this clustering were developed in more detail.

Among the measures were nine dimensions of culture. These dimensions (*performance orientation, assertiveness, future orientation, humane orientation, institutional collectivism, in-group collectivism, gender egalitarianism, power distance, and uncertainty avoidance)* are the primary measures of interest for us. For each of these scales, questions assessed participants' idea regarding both the practices *(as is)* as well as the values *(should be)* in *organizations* and *society*.

As high wind blows on high hills, there are limitations with the GLOBE project as with any other research paper. Hofstede [17] provides an overview of similarities and differences between the GLOBE study and his own work [16]. One of his major concerns is that the questionnaire items might not have captured what the researchers had in mind, and, that the complete GLOBE questionnaire has not been published. Hofstede is well-known for his work on national value differences while employed by IBM. Five dimensions of national culture were identified based upon results from a survey completed by 117.000 IBM employees. Both GLOBE and Hofstede's IBM studies make sense of culture within an industrial setting. On the other hand, the GLOBE involved managers, whereas the IBM study involved seven categories of employees, of which two were managerial categories [17] of employees. While it can be expected that the GLOBE project will either be loved or hated by scholars, in a way like the IBM study [21], for us the most important fact is that both studies provide empirical evidence that there are differences between cultures.

The next section will provide an overview of cross-cultural research in HRI.

3.2 Human-Robot Cultural differences

Several studies have been conducted in order to explain cultural differences in different situations involving robots. These situations range from a plain, general attitude to robots, to experiments involving human-robot teamwork.

Bartneck et al. [3] distributed a survey among internet users from different countries in which participants were asked to complete the Negative Attitudes towards Robots Scale (NARS) questionnaire. Results indicated cultural background significantly effected attitude towards robots.

In an unpublished experiment by Sau-Lai Lee, reported by Kiesler [24], Chinese participants viewed a video of robot interaction with an experimenter, they were asked whether or not the robot would know certain landmarks. The "cultural background" of the robot was manipulated by having the robot talk either English or Cantonese, and informing participants the robot was created in either China or New York. Based upon the origin of the robot, people had a different mental model of the robot. Lee found two relevant results providing evidence for this. First, people expected the robot to have more knowledge about famous landmarks in both countries, than about not so famous landmarks. The second, perhaps the most important: participants expected the "Chinese" robot to know more about Chinese landmarks than the "American" robot, and vice versa. In a similar way, Trovato et al. [37] found that Egyptian and Japanese participants preferred a robot displaying a similar cultural background. A robot was programmed to greet participants in the English language with either an Arabic or Japanese accent, and performing a greeting gesture also performed by humans in that culture. It was found that Japanese participants preferred the Japanese robot, and Egyptians the Arabic robot.

Wang et al. [39] conducted a 2x2 experiment involving robots, manipulating culture and robot communication style. 320 participants, 80 Chinese dyads and 80 U.S. dyads, interacted with a robot providing advice either implicitly or explicitly. The underlying hypothesis was that since the Chinese typically prefer and implicit communication style, and U.S. people a more explicit, a robot displaying a matching communication style would be seen as a more in-group member and thus more trusted and perceived as more credible. Supporting their hypothesis, Chinese participants preferred the implicit robot whereas U.S. participants preferred the explicit robot. Furthermore, when the robot communicated in the preferred way, participants were more likely to change their decisions in order to align with the robot.

Li et al. [26] also found evidence in a HRI trial that participants from a low-context culture (Germany) had different scores with respect to the evaluation of the interaction than those from high-context cultures (Chinese and Korean).

From the above we expect people from different cultures will have different views on which behaviors are normative for a robot. Previous work with regards to cultural aspects in HRI has been limited mostly to human-robot collaborative teamwork. The work in HRI on proxemics has not yet taken culture into account, which could become a shortcoming when robots are going to interact in public spaces with people having different cultural backgrounds.

4. TOWARDS A METHODOLOGY

In this section, we will describe two major challenges we see for HRI research researching cross-cultural robot behavior. These challenges are:

1) Choosing a research methodology

2) Sampling of cultures of interest

We will describe both challenges, insofar as not discussed before, and offer our ideas to solve this in Section 4.2.

4.1 Overview of methodologies

Different methodologies have been employed in order to gather data from participants from different cultures. In this section, we will first provide an overview of different methods which have been used to find answers with regards to cross-cultural differences, both in human-human, and human-robot interaction. We will then conclude with an experimental setup.

A number of studies manipulated culture by using native students and exchange students in a lab experiment. ([4], [26], [34]). Already in the 80s, Baldassare & Feller [2] hinted that the frequent comparison of U.S. versus exchange students of a culture decreases ecological validity, because a) the students are not observed in their natural culture, b) they have been influenced by North American proxemics patterns for an undisclosed time, and c) they are not a representative sample. Wang et al. [39] collected data at two separate sites; thus using native students in both settings. However, this sample was also not representative because it only included students.

Woods et al. [40] used a method called "video-based human-robot interaction" (VHRI) in which participants viewed videos of a human interacting with a robot. Results between this video-based methodology and a lab experiment with real participants were found to be comparable.

Self-reported measures, such as questionnaires, were also frequently employed. The advantage here being able to use participants from geographically distributed locations. ([3], [11], [5]). All reported studies report having the questionnaires translated and back-translated into the participants' native language.

Two experiments made use of either scaled dolls or silhouettes in order to capture people's impression of appropriate interpersonal distance in different situations ([27], [28]). Like a lab experiment, the use of dolls does require some sort of physical location when collecting data at different sites.

All these methods have advantages and disadvantages. The first method, experiments with an actual embodied robot, would be preferred for HRI since it would provide the most realistic setting. An ideal situation would be an experiment, be it a Wizard-of-Oz experiment with one type of robot, shipped all over the world to various data collection sites. This is an utopian experiment design in a world not constrained by resources like time, money and man-hours. The other methods (VHRI studies and scaled figures) could provide a solution, albeit generalizability of the results to a real-world setting could be questioned. In the next section we propose a hybrid approach to tackle these issues.

4.2 Proposed methodology

At this moment, we are conducting a survey with this setup using stills of 3D people. This survey is currently being distributed to three countries. While data collection has not yet been finished, one of the possible issues we might face is that the results are not generalizable enough because when you approach a group, the formation of the group is going to change as soon as you approach. Therefore, the use of 3D pictures might not be a sufficient methodology to investigate cross-cultural robot spatial behavior.

Based on this insight, we propose a combination of a lab- and video study to increase ecological validity while investigating the following questions:

1) "From which angle should a robot approach a small group of people?"

2) "Do people from different cultures have significant different preferences when a robot approaches a small group of people?"

3) "Do survey-based HRI studies provide reliable results when used in lieu of experiments when evaluating robot spatial behavior?"

In our situation, we have access to two robots of similar design, at two different sites – a site in the Netherlands, and a site in Spain. We propose to run a between-groups field experiment at both locations, thus having two different cultures. In the experiment, we will ask small groups of people (3-5) to stand in a room and discuss a topic. Participants will be informed that after a minute a robot will approach the group and bring the new discussion topic. The robot will approach the group from various angles, and stop at different distances.

At one of these locations, we will make a video recording of the different experiment conditions with actors. In order to test if the behaviors are perceived equally (un-)appropriate in videos compared with the field experiment, we will distribute the video to participants from the same countries as those in the field experiment. If it turns out to be true, the questionnaire can be distributed to participants with cultural backgrounds not investigated in the field experiment.

5. CONCLUSION

Service robots start entering our daily lives. When real social robots do, an important question will be if culturally different motion behaviors are necessary for a robot guiding people with distinct different backgrounds. Previous HRI research focusing on cultural aspects does not provide indisputable results, though we find it likely these results could surface when evaluating motion behaviors with respect to different cultures.

Based upon an overview of previously used methods to evaluate cross-cultural differences we have proposed a mixed-methods method in order to evaluate cross-cultural HRI behavior preferences in a resource-efficient way.

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8. Appendix I

Table 3 provides the ten GLOBE clusters of societies and the respective countries within each cluster.

Table 3. GLOBE clusters. Source [13]

Anglo Cultures England, Australia, South Africa (White sample), Canada, New Zealand, Ireland, United States
Confucian Asia China, Hong Kong, Japan, Singapore, South Korea, Taiwan
Eastern Europe Albania, Georgia, Greece, Hungary, Kazakhstan, Poland, Russia, Slovenia
Germanic Europe Austria, Germany, Netherlands, Switzerland (German speaking)
Latin America Argentina, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Mexico, Venezuela.
Latin Europe France, Israel, Italy, Portugal, Spain, Switzerland (French speaking)
Nordic Europe Finland, Sweden, Denmark
Southern Asia India, Indonesia, Iran, Malaysia, Philippines, Thailand
Sub-Sahara Africa Namibia, Nigeria, South Africa (Black sample), Zambia, Zimbabwe
Middle East Egypt, Kuwait, Morocco, Qatar, Turkey

The Sweet Spot for Human Robot Interaction:

Cultural Differences in how an Engagement-Seeking Robot should Approach a Small Family

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ABSTRACT

The sociologist Hall coined the term proxemics to indicate the studies of man's use of space. Social psychological research found these interpersonal distances to be culturally dependent. We set out to extend the state of the art on human-robot proxemics by investigating whether preferences for how a robot should approach a small group is culturally dependent. In this paper, we present our first study in this, a set of measures and preliminary results of an online survey (N=181) which was distributed to people in three countries; China, the U.S. and Argentina. Our results show that participants prefer a robot which stays out of people's intimate space zone just like a human would be expected to do. The cultural differences found were partly in line with our expectations: Chinese participants showed high-contact responses and believed closer approaches were appropriate compared with their U.S. counterparts. Argentinian participants more closely resembled the rating of the U.S. participants.

Author Keywords

Cross-cultural, human-robot interaction, cross-cultural survey, proximity, social computing, social robotics, social interaction, human computer interaction, online survey.

ACM Classification Keywords

J.4 [**Computer Applications**]: Social and Behavioral Sciences

INTRODUCTION

In our daily life everything and everyone occupies an amount space, simply by "being there". When moving through space, people keep a certain distance between each other, and this distance depends on factors like culture, familiarity and personality, as well as the context of the situation.

Hall coined the term proxemics. According to Hall [5], one's body is surrounded by ellipse-shaped bubbles. Each of these bubbles is appropriate for different social interactions. One of these zones, the personal space zone, acts as a virtual buffer zone around our body. Hall puts it as *"a small protective sphere or bubble that an organism maintains between itself and others"*. When this buffer zone is invaded, people compensate for this intimate contact, by non-verbal or verbal compensating behaviors such as stepping away, or limiting eye contact. Literature has found that while every human adheres to personal space, and to others' personal space, the size of this bubble is among others dependent on culture.

People keep a certain distance towards each other, but small groups of people also organize themselves in patterns; such as circles, or lines. When such a pattern is stable, it can be called a formation. Kendon [9] introduced the term F-formation to refer to a specific formation which occurs *whenever two or more people sustain a spatial and orientational relationship in which the space between them is one to which they have equal, direct and exclusive access.*

Research in the field of Human-Robot Interaction (HRI) provided support for the Media Equation theory, which holds that people treat computers and other media as if they were either real people or real places [12]. A most relevant example is a study by Hüttenrauch et al. [8], which found that most people place themselves in Hall's personal zone (between 0.45 and 1.2 meters distance) when interacting with a robot.

While a large body of research in HRI has research the concept of proxemics (and general approach behavior), this research has been limited in that it has mostly focused on approaching single persons – usually from Western countries - in a controlled lab setting. We intend to extend this state of the art by looking at small groups of people. Specifically, we will try to identify the "*sweet spot*" for robots approaching small groups of people. This is the optimal approach and placement position for a robot which is seeking to gain the attention of a small group of people. We are particularly interested in finding out whether this 'sweet spot' differs across culture, either in distance to the group or in placement position. To do so, we have conducted an online survey which we distributed to three different cultural regions in the world through a crowdsourcing platform. This survey research is a first study to investigate whether differences exist and which will inform further studies where people will be exposed to actual robots in laboratory and in-the-wild settings.

In this paper we will report on the methodology we used and we will provide preliminary results.

RELATED WORK

This section will discuss two major themes which have been mentioned in the introduction; namely cross-cultural proxemics and group formations. We will conclude this section with our hypotheses, which provide the basis for the experimental method.

Proxemics

In his book, *the Hidden Dimension*, Hall [5] defined four interpersonal distances zones. These zones are called the *intimate, personal, social* and *public* space zones (Table 1). These four zones are a simplification of an earlier model, which contained eight zones. Each of the four zones contains a close and a far phase, which again amounts to a total of eight. However, since practically all research refers to four zones, we will do the same.

Zone	Range	Situation
Intimate	0-0.45m	Lover or close friend
Personal	0.45-1.2m	Conversation between friends
Social	1.2-3.6m	Conversation
Public	3.6m+	Public speech

Table 1: Proxemics zones as defined by Hall [5].

As stated in the introduction, research has found that the proxemics zones depend on multiple factors, among which culture.

Sussman & Rosenfeld [16] conducted a study in which 105 students from three different ethnical groups (Japanese, American and Venezuelan) had a (seated) five-minute conversation with a same-sex, same-nationality confederate. They found that, when they were speaking English, participants from the low-contact culture (Japan) sat further apart from each other compared to participants from a high-contact culture (Venezuelan). Within their respective cultural groups, male participants sat further apart than female participants. Furthermore, when speaking in their native language, participants from high-contact culture sat closer together.

Little [10] used the placement of dolls to infer at which distance people from either the U.S., Sweden, Scotland, Italy and Greece would place people in 19 different social situations. He found that people from North European cultures placed dolls significantly further apart compared with their Mediterranean counterparts. This could be explained by Hall's explanation of high contact- and low contact cultures. Based upon observations, Hall noted that people from low-contact cultures maintain a larger personal space compared with their counterparts from high-contact cultures. Northern European cultures are considered being low-contact, whereas Southern European, Southern American and Arab [4, 5] cultures on the other hand are considered high-contact cultures. From this, it appears that human personal spaces zones are dependent on cultural background. These differences may not manifest itself at the nation level. Social psychology is not the only field that investigated proxemic zones, also in the field of Human-Robot Interaction (HRI) some studies have been conducted.

In the field of HRI, research on proxemics found that people appear to respect a robot's personal space zone [8, 20] and maintain a distance from a robot that would be considered respectful when approaching a fellow human. When a robot approaches a human, the comfortable approach distance has been found to be roughly 57 cm [19], which is comparable with distances between people when they have a conversation (see Table 1). Furthermore, behaviors such as a robot's gaze can influence the distance people put between themselves and a robot [18], in a similar way as people do. Work on proxemics in HRI also found people show similar compensating behaviors as they would do when a human would invade their personal space [15]. Up to now, HRI research has not yet taken culture into account in the same way as researchers such as Little [10] and Sussman & Rosenfeld [16] have.

People organize themselves spatially not only by interpersonal distance, but also in terms of their spatial arrangement when being part of small groups. For instance, when shared attention (toward an object) is required. Kendon [9] introduced the concept of *F-Formations*. According to Kendon, activity is always located in a space. This space can be called the 'transaction segment'. When two or more people form a group, they arrange the spatial formation of the group in such a way that the individual transaction segments overlap; thus creating a joint transactional space, also called the O-space. People stand around the O-space in an F-formation. The O-space is enclosed by the P-space, in which the persons making up the formation are located. The R-space is the space located beyond the P-space. There are different arrangements of F-formations. A circular formation is most common in a free-standing conversations. Other formations include the vis-à-vis, L-shape and circular formations.

Rehm et al. [13] report the "six most occurring formations", and divide these six in open and closed formations. People in open formations are said to allow others to join the conversation; while this is not the case with closed

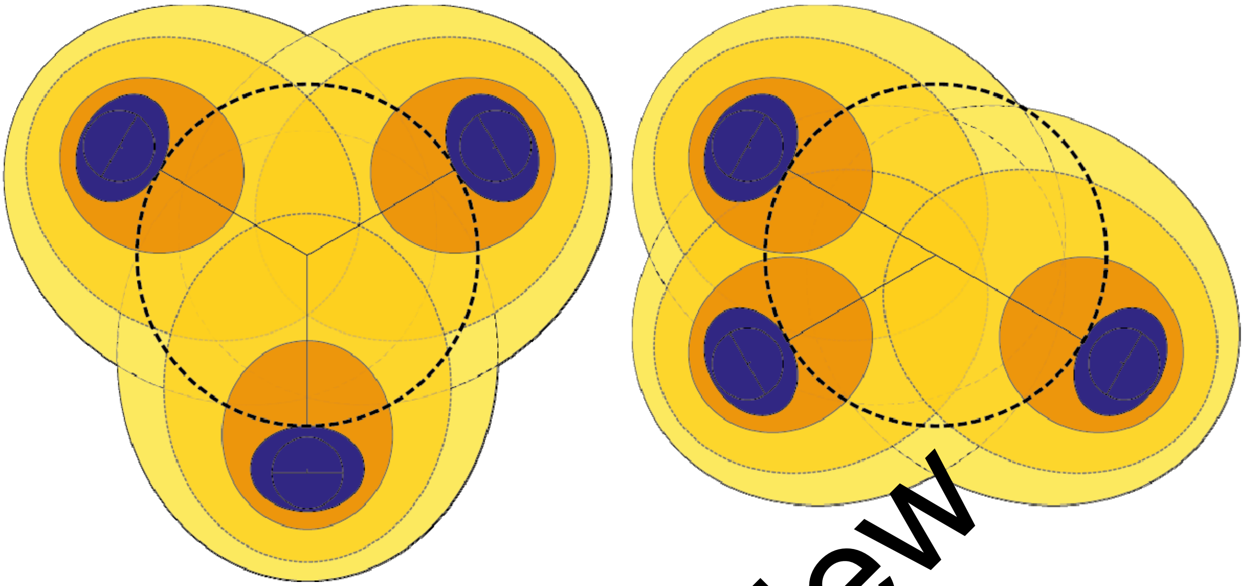

Figure 1: Circular F-Formation with congruent (left) and incongruent (right) angles.

formations. In an experiment with virtual characters, Rehm et al. [13] found that participants were more likely to join an open formation (84% of the trials) than a closed formation. All participants positioned themselves at a social distance, half in the close-social, and half in the far-social distance. However, it was found that two Arabic participants positioned themselves in the close-social space, which is consistent with findings in cross-cultural research in that Arabic people generally stand closer to each other.

When Proxemic Zones Collide…

Work on personal space zones has focused on the personal space of single people, and while numerous works call these zones "elliptical", only one distance is reported, which is the distance to the front. The diameter of the different zones can be estimated, but has not been researched extensively up till now.

Figure 1 contains two different F-formations: a circular formation with congruent angles, and a more open formation with incongruent angles. We have placed three figures along a circle having a diameter of 122cm (or 4 feet). The circles around the participants represent our hypothesized proxemics zones, these being the intimate zone-, close personal and far personal space zone respectively. A group is a dynamic entity, therefore the members will re-arrange themselves as soon as another actor (be it a robot or a human) joins the group. Apart from this, one initial position where an actor places itself to join a group can be more preferred compared with another. We would like to introduce this optimal approach position as the *sweet spot*. This *sweet spot* is a combination of the position, an actor chooses with respect to the group members in between which it approaches, and the distance it keeps from those actors.

Based upon the proxemics theory, we hypothesize that participants will find the approach of a robot which stays out of their intimate zone more appropriate. Our first hypothesis is therefore:

> H1: Participants will rate an approach as more comfortable when the robot stays out of every group member's intimate space zone.

Since groups are not heterogeneous, we often have preferences to join a group at a particular position where there is a person we know, or that seems otherwise appropriate. We are interested in small groups such as families (father, mother and child). It may for instance, be seen as more appropriate to approach a group in between the mother and father as compared to in between the child and one of the parents, essentially cutting off a child from one of the parents.

> H2: Participants will rate a robot approach as less appropriate when a robot approaches in between a child and parent, as compared with approaching in between both parents.

Given that different cultures exist, and that research by Rehm et al. [13] found that participants from high-contact cultures stand closer to a group of people compared with people from low-contact cultures, we hypothesize a similar cultural dependent preference will exist when a robot approaches.

H3: Participants from a high-contact culture (China, Argentina) are more comfortable with a close approach by a robot than participants from a low-contact culture (United States).

METHODOLOGY

We conducted a 3 (nationality) x 3 (position in the group) x 6 (distance from the group) online study. A survey-based questionnaire was distributed through a crowdsourcing platform (crowdflower.com) to a targeted population. Participants were shown images of small families of 3D people and a robot (See Figure 2). These groups were composed of three people: a man, a woman and a child. Participants were asked to indicate how appropriate they believed the position of the robot was after the robot had approached. The position of the robot was manipulated two-fold within-subjects (see next section), the nationality of the participants was a between-subjects variable. A questionnaire was used to measure the dependent variables.

For the groups, a circular formation with congruent angles was chosen. We are aware of the fact that people will more often stand in non-congruent angle formations and we will reflect on this in the discussion section.

Figure 2 Example top-down still as shown to participants

The diameter of the O-space was set to 1[illegible]2 cm, which correspondents to Hall's social space. The height of the participants was based upon average international height[1]. The male was scaled to 178 cm, the female to 152 cm, and the child to 140 cm. The height of the robot was scaled to 140 cm, as can been seen in Figure 3.

Figure 3 The fictional family was scaled to average international dimensions

Independent variables

Two variables were manipulated within-subjects: approach position of the robot (the position between which family members the robot approached, Figure 4), and the approach distance. We refer to the combinations of position and angle as scenes.

For each of the three different approach positions, the robot was placed at six different distances, measured from the center of the circle. These distances were 20, 40, 60, 80, 100 and 120 centimeter. As a control method, participants were exposed to each scene **twice**. A final scene where the robot was positioned at the center was also included. Thus: participants were asked to rate (2*18 +1=) **37** scenes.

Circles 1 and 2 (20 and 40 cm.) are within participants' intimate zone, circles 3 and 4 (60 and 80 cm.) in the personal zone, and circles 5 and 6 (100 and 120 cm.) lie in the social zone, which is outside the yellow area in Figure 4.

Dependent variable

The dependent variables were measured using a 113-item questionnaire, measuring a total of 6 constructs. The questionnaire was divided into three consecutive blocks: appropriateness-rating of the robot-group scenes, cultural- and personality background questions, and general demographic questions.

In the first block, participants were asked to rate the 37 'robot approaches a family' scenes which have been described in the previous section. To avoid order-effects, all scenes were randomized. Participants were provided with the instruction: "*The robot approached the family and has come to a halt between particular family members at a particular distance. Now it will interact with them*", and asked to indicate on a 7-point Likert scale whether or not

[1] http://dined.nl//ergonomics/

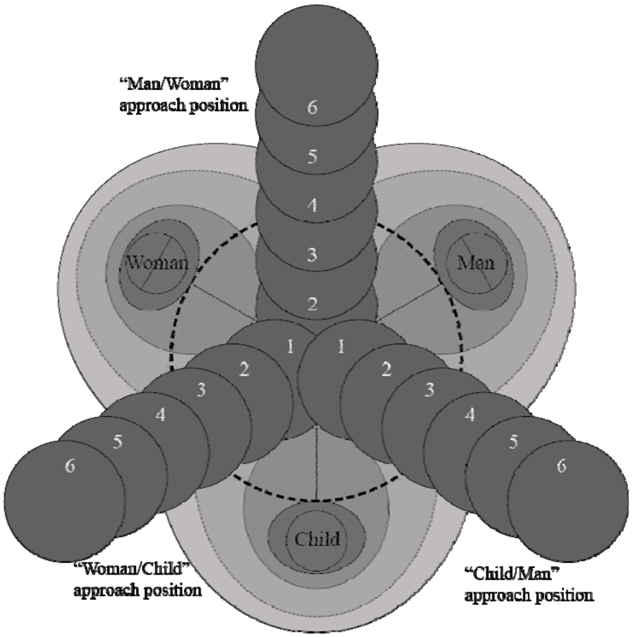

Figure 4: F-Formation used. Dark grey indicates possible location of the robot. Grey: intimate zone, light grey: personal space zone. Participants standing in a circle with a diameter of 122 cm.

the position of the robot was considered appropriate. Another four items were included in this block to measure how participants themselves would approach the family. Two items were included to check the approach position- and distance manipulation. A final item was included in which we asked participants if they could indicate where they thought the family they had seen in the situations originated from.

The second block of the questionnaire consisted of a series of validated scales measuring four dependent variables. Participants' general attitude towards robot was measured by the *Negative Attitude Towards Robots* scale, a 14-item 7-point Likert scale. One way to explain cultural differences is by measuring *individual vs. group self-representations*. This was operationalized using 7 items, by Brewer & Chen [1], and analyzed in a similar way as Wang et al. [22]. An indication of whether participants were members of a high-contact, or low-contact culture was assessed by measuring *closeness*. Five items from the IPROX (iconic proximity) questionnaire were used [7]. The final construct in this block was personality. We measured the Big Five personality traits using the 20-item Mini-IPIP scale [2].

The final block of questions included demographic questions like gender, age, nationality, and level of education. Social-demographic questions like nationality of ancestors, marital status and children were also included.

Participants

Participants were recruited from three different countries: China, Argentina and the United States. People from these three countries are generally considered culturally different. Not only because they are geographically on different continents, but also because various studies have shown there to be cultural differences [3, 4, 14] in for instance societal values.

For each country, participants were recruited through the Crowdflower platform[2], which allows for specification of the target country. The initial aim was to recruit 100 participants from each country. After data collection, 244 participants had completed the questionnaire; each participant was paid $1 for completion of the survey. Responses were limited to 1 per IP address. After applying the exclusion criteria (see data analysis), the total sample contained 181 participants, as specified in Table 2.

Data analysis

Participants who failed to correctly answer the two manipulation checks were excluded from the sample. A second control method was to analyzing the robot-scene questions, which were 18 situations rated twice by each participant, on a 7-point Likert scale. Participants who rated four or more situations with a difference of 3 or more points were also excluded from the survey. In total 63 participants (26%) were excluded and as such the sample consisted of 155 participants (Table 2). Internal reliability of all scales was assessed by calculating Chronbach's Alpha (α), and deemed acceptable, see Table 3.

	N	Mean age (sd)	Male / Female
U.S.	86	43.27 (12.25)	26 / 60
China	29	30.48 (8.93)	19 / 10
Argentina	66	33.06 (10.90)	48 / 18
Total	181	37.50 (12.54)	93 / 88

Table 2 Distribution of participants

Measure	# items	α
NARS – subscale 1	6	0.693
NARS – subscale 2	5	0.611
NARS – subscale 3	3	0.685
IPIP Big Five – Extraversion	4	0.728
IPIP Big Five – Agreeableness	4	0.687
IPIP Big Five – Consciousness	4	0.652
IPIP Big Five – Neuroticism	4	0.614
IPIP Big Five – Intelligence	4	0.750
Personal Closeness (IPROX)	5	0.834

Table 3 Dependent measures internal reliability (α)

[2] http://www.crowdflower.com

Experiment procedure

Participants were recruited through the Crowdflower platform. In the instructions, participants were informed that they were to complete an academic survey on an external website[3], after which they had to input a completion code.

The survey consisted of an introduction which contained detailed instructions as well as a picture of the family (Figure 3), with the instructions that "In the picture […] you see a stereotypical family: a father, a mother and a child". The survey consisted of three blocks, as explained in the "dependent variable" section. At the end of the survey, participants were given the opportunity to state final comments, or answer any question they might have. At this point participants were also provided with the completion code required to get reimbursed for their time.

RESULTS

Participants prefer a robot that stays out of our intimate space zone

In H1 we hypothesized that participants would rate a scene as more appropriate when the robot was positioned out of every group member's intimate space zone. As can be read in Section 3.1 (Independent variables), circles 1, 2, and the middle circle are considered to be in the intimate space zone. For the purpose of analysis, ratings for circles 1 and 2 (intimate space zone) were averaged as well as the ratings of circles 3, 4, 5 and 6 (outside intimate space zone).

Participants rated the robot positions in the intimate space zone as significantly less appropriate (M=3.14, sd=1.[illegible]5) compared with those positions where the robot was positioned outside the intimate space zone (M=4.[illegible]1, sd=.99), $T(180) = -13.97$, $p<.001$, $r=0.721$. We therefore **accept H1**: a robot which stays out of the intimate space zone of each of the group members is considered to be more appropriate.

Appropriateness of a robots approach is not always affected by its position relative to the family members.

A factorial repeated-measures ANOVA with two independent variables (distance and position) was conducted. Mauchly's test indicated that the assumption of sphericity had been violated for the main effects of distance, $X^2(14) = 617.11$, $p<0.001$, and angle, $X^2(2) = 79.19$, $p<0.001$. Sphericity had also been violated for the interaction effect, $X^2(54)=194.14$, $p<0.001$. Degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .42$ and $\varepsilon = .74$ for the main effects, and $\varepsilon=.80$ for the interaction effect).

There was a significant main effects of the approach distance ($F(2.107,375.069)=61.84$, $p<0.001$), and angle on the appropriateness of the robot's position ($F(1.47, 261.626)=3.785$, $p<0.05$). Post-hoc contrasts revealed a significant difference of appropriateness between the "Woman/Child" and "Man/Child" approaches: the appropriateness of the "Woman/Child" approach was significantly higher (M=4.187, SE=.093) compared with the "Man/Child" approaches (M=3.936,SE=.086), $F(1,178) = 17.041$, $p<.001$. The appropriateness of the "Man/Woman" approaches was in between both (M=4.097, SE=.088). We therefore only **partially accept H2**, in which we hypothesized that participants would rate a robot approach as less appropriate when a robot approached in between a child and parent, as compared with approaching in between both parents. Instead, participants indeed found an approach between parent and child less appropriate but only for the position between father and child. The most appropriate approach position was generally thought to be in between the mother and the child.

Influence of cultural background on appropriateness

Our third hypothesis was that participants from (what are seen as) high-contact cultures (such as China and Argentina) would rate a close approach as more comfortable than participants from a low-contact culture (United States). To check whether our prediction regarding low-contact and high-contact cultures was true, we compared the national group's ratings on closeness. There was a significant difference between the ratings, $F(2) = 15[illegible]28$, $p<0.001$. As can be seen in Figure 5, participants from the United States scored significantly higher on the closeness measure, which indicated they put more distance between themselves and other people. This effect was vice-versa for Chinese people, as expected. The U.S. participants scored low on closeness, while the Chinese scored high and the Argentinian participants scored high on closeness but not as much as the Chinese participants. Therefore, we feel we can assume that the national groups included in this sample can indeed be considered to have different cultural backgrounds concerning the low-high contact dimension.

There was a significant three-way interaction effect between the nationality of the participant, distance, and position of the robot on appropriateness of the scene, $F(16.06, 1429.379)=1.557$, $p<0.05$. This is explained mostly by a significant two-way interaction effect between the distance of the robot, and the nationality of the participant, $F(4.214, 375.069)=6.101$, $p<0.001$. This effect can be seen in Table 4 and Figure 6. The Table and Figure show that the U.S. and Argentinian participants show similar appropriateness scores for the approach distances, but, that approaching in between the "Man/Woman" was considered more appropriate by the U.S. participants for the further distances, whereas the Argentinian believed the "Woman/Child" position was more appropriate.

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[3] http://www.surveymonkey.com

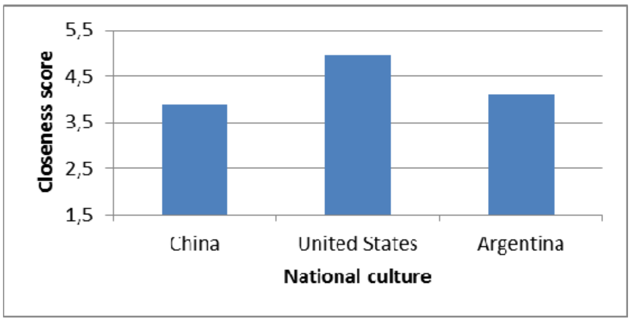


Figure 5 Participants from what are considered low-contact cultures scored indeed significantly higher on the "closeness" construct (scale: 1: high contact, 6: low contact).

The Chinese participants scored less on the extremes, and a notable difference was that the closer approaches (within the intimate zone) were actually considered to be quite appropriate. Like the U.S. and Argentinian participants, the Chinese also had a clear preference for a further approach (80-100 cm), though this difference was much less pronounced for the Chinese participants.

We therefore **partially accept H3**. We believed that participants from high-contact cultures (such as China and Argentina) would rate a close approach as more comfortable than participants from low-contact culture. Chinese participants gave high-context responses, and a closer approach was seen as more appropriate. However, we expected similar results for Argentinians, which we did not found.

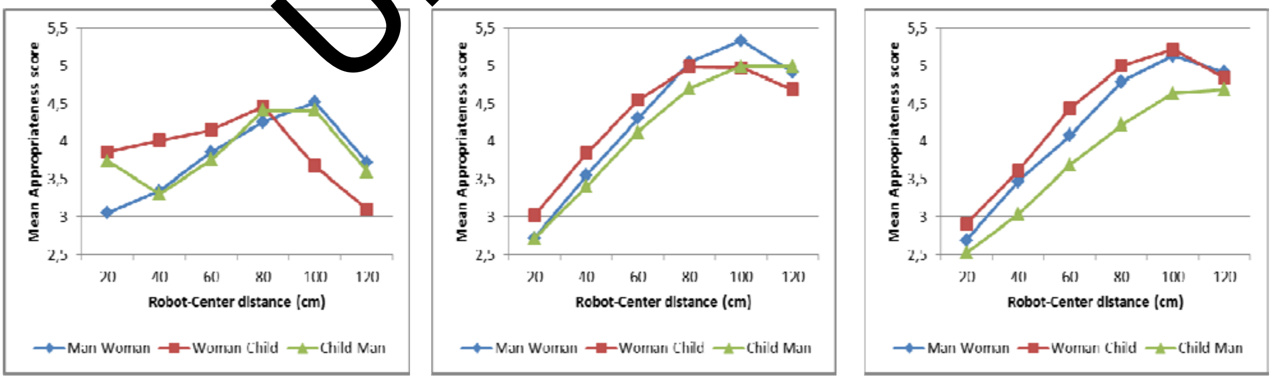
DISCUSSION

In this paper we presented the methodology and preliminary results of a novel approach to investigate cross-cultural HRI proxemics preferences. In this discussion section we will discuss both the methodology, and the results as found. We will end with directions for future research.

We based our second hypothesis on the notion that not all groups are heterogeneous, and the "best" robot approach might very well be influenced by the relationship of the family members. We hypothesized that participants would

	China			United States			Argentina		
20	3.052	3.862	3.741	2.721	3.[illegible]23	2.721	2.697	2.909	2.530
40	3.345	4.017	3.310	3.552	3.84[illegible]	3.407	3.477	3.614	3.038
60	3.862	4.155	3.759	4.308	4.552	4.128	4.083	4.439	3.689
80	4.259	4.466	4.414	[illegible].04[illegible]	4.988	4.709	4.795	5.000	4.220
100	4.517	3.672	4.414	5.[illegible]37	4.977	4.994	5.136	5.220	4.644
120	3.724	3.103	3.603	4.[illegible]13	4.692	4.994	4.917	4.841	4.689

Table 4 Mean appropriateness ratings for the Chinese, U.S. and Argentinian sample. Appropriateness on a scale from 1 to 7.



China United States Argentina

Figure 6 Mean appropriateness ratings for the Chinese, U.S. and Argentinian sample. Appropriateness on a scale from 1 to 7.

find approaches in between the parents more appropriate compared with the approaches where a child is cut off from one of the parents. The reason for the unexpected findingthat approaches between mother and child were found quite appropriate could be quite pragmatic, which we had not considered. By approaching in between the mother and child, which was found to be the most appropriate by participants, the robot directly faced the father of the family. It could be that a robot's frontal approach to a male is seen as more appropriate. Even though previous work by Walters et al. [21] did not confirm this notion, this warrants further investigation into differences in gender preferences.

Figure 6 show similarities in the appropriateness ratings of the U.S. and Argentinian samples respectively, despite the fact that Argentinian's closeness scores indicate a more high-contact culture. Therefore we expected they would find the robot approaching closer appropriate. Perhaps, despite our best efforts, the Argentinian sample was not "representative enough" of the general South American population. Another explanation could be that the Argentinian participants experienced the family in the pictures as U.S. or other national background and adapted their scores to what they felt was appropriate to approach them. Further analysis of our data could provide future insights in this. A final explanation could be that our preference for closeness measure did not completely capture the subtleties of high-low contact cultural backgrounds.

To analyze cross-cultural differences in proxemics, we used an online questionnaire as this would allow us to distribute the survey to geographically dispersed samples. The survey contained static images, and while the results do support most of our hypothesis, we are somewhat concerned with the ecological validity of our research. Groups are dynamic entities. The formation of the group changes when a new member joins the group, and our images might very well not have been able to capture these subtle dynamics. For future work we propose to examine this work in a study where groups of people are approached by a robot– primarily to see if the results found with this survey are replicable when such an experiment would be conducted in a lab setting.

Participants viewed the robot-group scenes from above. This may – unintentionally – have caused a limitation as participants might not have been able to take the height of the actors into account. In a similar way, the scenes with 3D figures may not have been life-like and people may have perceived them as being not truly representative of real humans.

A third limitation of the experimental design might be with respect to the chosen F-formation. As we explained in the methodology section, we chose for a closed circular formation with congruent angles (Figure 1). It could very well be that another formation, for instance with incongruent angles, yields different results. Either because of the position of the group members, or simply because there is more room for a robot to approach when the angles are not congruent.

Our future work will focus on replicating a similar experimental setup in either a physical lab or field setting in order to account for some of the limitations that arose in this experiment. Furthermore, we have not yet analysed the relation between personality and the appropriateness of robot scenes. Previous work in HRI has shown that a high score on extraversion leads to more tolerance to uncomfortable robot approaches [17]. It could very well be that personality also influences ratings of appropriateness. In a similar way *attitude towards robots* and *individual vs. group self-representations* could influence the results in subtle ways, which we have not yet analyzed.

CONCLUSION

In this paper we have presented the preliminary results of a survey which we distributed to three countries (China, the U.S. and Argentina). We were interested in finding out whether or not people from different nationalities have different proxemics expectations from a robot which approaches a small family.

Our results show that while participants found a robot more appropriate when it stayed out of the intimate space zone, there are cultural differences which surface when comparing China with the other two countries. Unexpectedly, the Argentinian ratings were more close to the U.S. ratings even though both Argentina and China were considered to be high-contact cultures, and both scored as such on our closeness measure.

In our future work we will look into more detail to the interplay between personality and culture, as well as to the limitations caused by the methodological choices.

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