Motions of robots matter!

the social effects of idle- and meaningful motions

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Motions of robots matter! The social effects of idle- and meaningful motions.

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ABSTRACT

Humans always move, even when “doing” nothing (for example, when breathing). This is not necessarily true for robots, and the question emerges whether there is a social function to these so-called (human) “idle motions”. Since humanoid robots share time and space with people, it is important to understand how these idle motions may influence human-robot interaction, and how they may impact human perceptions of robots. Various theoretical approaches have tried to explain the social responses of humans in virtual environments: According to the threshold model of social influence (Blascovich, 2002) people respond socially on the basis of social verification. If applied to human-robot interaction this model would predict that people increase their social responses depending on the social verification of the robot. On other hand, the media equation hypothesis (Reeves & Nass, 1996) holds that people will automatically respond socially when interacting with artificial agents. In our study a simple joint task was used to expose our participants to different levels of social verification. Low social verification was portrayed using idle motions and high social verification was portrayed using meaningful motions. Our results indicate that in line with the threshold model of social influence, social responses increase with a high level of social verification. We discuss to what extent the results support theories of social influence.

Keywords: deictic gestures, idle motion, idle behavior, social influence, media equation, social robotics, non-verbal communication, threshold model of social influence.
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INTRODUCTION

Creating the “illusion of life” with inanimate objects has been an endeavor humankind has been pursuing for centuries, and at the beginning of last century this endeavor gave birth to animations. With further advancements in technology one can argue that in the field of animation we have successfully created believable characters that seem ‘life-like’, as is illustrated in current movie- and gaming industries. Arguably, significant progress in creating this “illusion of life” can be made with the help of animated robots that have the ability to share our time, space and lives.

Researchers have been fascinated by the possibility of interaction between a robot and its environment, and one of the concerns of the relatively new field of human robot interaction (HRI) is bringing robots to ‘life’. As a result, HRI research has begun to investigate the social characteristics of robots, since, humans tend to interact with machines in the same way that they interact with humans (Reeves & Nass, 1996). This underlying assumption has led to the development and research of robotic systems that have interaction capabilities more similar to human-human interactions (Mutlu, Shiwa, Kanda, Ishiguro, & Hagita, 2009; Yamazaki, Yamazaki, Kuno, Burdelski, & Kuzuoka, 2008; Sidner, Kidd, Lee, & Lesh, 2004).

These robotic systems are mostly referred to as social robots, and are seen as possible companions, assistants, or pets, in addition to the more traditional role of servants. These robots facilitate interaction, and communicative functionality in a manner that helps overcome the difficulties inexperienced users face when interacting with new technologies.

The communicative functionality is, however, largely dependent on the appearance of—and attributions to—the robot (Salem, Eyssel, Rohlfing, Kopp, & Joublin, 2013).

Because of this dependency, social robots are created with human morphology in mind, having one head, two arms, and two legs. Applying human morphology to robots has been argued to enhance their interaction with humans (Breazeal, 2004; Duffy, 2003). When we interact or communicate we do this using multiple channels, including verbal channels of communication (e.g. spoken, written and signed language) and non-verbal channels of communication (e.g. gaze, gestures, postures, facial expressions etc.). Non-verbal channels seem to be less under our conscious control, and are thus perceived as more accurate in communicating certain meanings e.g., facial expressions for bad tasting food.

An important class of non-verbal communication consists of gestures, commonly referred to as body language. Gestures can be subdivided into two types of gestures, a communicative gesture (meaningful gesture) and a non-communicative gesture (transition gesture) (Kahol, Tripathi,
Panchanathan, & Rikakis, 2003). Meaningful gestures are frequently used in human-human interaction and add additional information to the interaction that is not expressed by verbal communication alone (Kendon, 1986). It is estimated that 90% of all gestures occur during a spoken utterance (McNeill, 1992). There are four different kinds of gestures that only occur during speech: Iconic, deictic, beats and metaphorics. Iconic gestures illustrate shape and size e.g., drawing the outline of a moving box with your hands. Deictic gestures indicate spatial information e.g., to indicate positions and locations of an item in a room. Beats emphasize words e.g., a brief up and down waving motion when uttering “all right”. Metaphorics explain a concept e.g., making the peace sign with a hand. With the exception of beats gestures, these examples imply that most meaningful gestures consist of visible bodily movements that communicate a particular message.

Various studies that have examined these meaningful gestures have been conducted in the field of HRI. It is assumed that a robot portrays these gestures in a more effective manner than is the case for an artificial agent in HCI (human computer interaction). The main reason why robots portray these gestures more effectively is that people and robots share the same physical space. This further emphasizes the important difference in physical affordances a robot is equipped with, allowing for multimodal communication channels. Gaze has been demonstrated to influence how a participant perceives a robot during a conversation—by communicating attention or engagement between the participant and the robot—and has mainly been researched in a persuasion context (Chidambaram, Chiang, & Multu, 2012; Ham, Bokhorst, Cuijpers, van der Pol, & Cabibihan, 2011). Other non-verbal meaningful gestures, like deictic hand/arm gestures, have been demonstrated to increase the persuasion of robots (Torta, van Heumen, Cuijpers, & Juola, 2012) and anthropomorphism (Salem, Eyssel, Rohlfing, Kopp, & Joublin, 2011) in a positive way. Also, head gestures are an integral part of human-human interaction, and research indicates a link between head movements (e.g. head nods) and listener attention (Sidner, Lee, Morency, & Forlines, 2006; Kuno, Sadazuka, Kawashima, Yamazaki, & Kuzuoka, 2007).

There is, however, a dearth of research regarding deictic head motions and their effect on robot-human interaction. For example: Does this motion increase the level of anthropomorphism? Furthermore, within the field of HRI, gestures are deemed to play an important role on the establishment and maintenance of long-term relationships between humans and robots. This makes it important to further investigate to what extent people ascribe social responses to these meaningful gestures. For this study, we will refer to these meaningful gesture interactions between robot and human as “meaningful motions”.
The influential role of meaningful motions in human-human interaction suggests that a robot’s capacity to portray motion is likely to be an important communication channel, and may distinguish robots from other inanimate intelligent artifacts. However these motions occur mainly during a spoken utterance (McNeill, 1992), and during human-robot interaction there are also numerous speechless and motionless situations. Typically, a robot stops moving during these idle periods and the robot appears inanimate and lifeless. In contrast, a human body never stops communicating because our bodies never stop moving (Jung, Kanda, & Kim, 2013). Research performed by Yamaoka and colleagues (Yamaoka, Kanda, Ishiguro, & Hagita, 2005), states that it is essential for robots to portray ‘life-like’ behavior when engaging in communication with humans. Idle interactions have been suggested to presents a basic level of the “illusion of life”, which helps people accept that the humanoid robot is a social entity (Jung, Kanda, & Kim, 2013). At present most of us are familiar with video game and movie animations and the interaction modalities that these characters use to portray an illusion life. In the context of animations, idle motions do not directly contribute to the characters’ expressions (Jung, Kanda, & Kim, 2013), but they aid in showing the existence of life (e.g., breathing motions when idle). It seems reasonable to assume that adding idle motions to robots (i.e., posture shifts) creates a more ‘life-like’ perception.

At present writing, there is no research in the field of HRI that investigates whether idle motions make a robot appear more ‘life-like’. In the field of HCI (human-computer interaction) there is considerable research about making virtual avatars seem more ‘life-like’ (Abe & Popović, 2006; Kopp & Wachsmuth, 2000; Terzopoulos, 1999), but few studies focus on idle motions. Studies that do concern themselves with idle motions generally focus on motion generators and are limited to their implications in human interactions.

A study by Cafaro and colleagues (Cafaro, Gaito, & Vilhjálmsson, 2009) focuses on idle gaze. Idle gaze is a human-human interaction were people look randomly at their surroundings, especially when there is no interaction taking place. Cafaro and colleagues developed a demo that reportedly results in believable gaze portrayals; however, the study lacks further verification with participants. Similarly, Egges and colleagues developed an idle motion engine that combines balance-shifting motions with small posture variations (Egges, Molet, & Magnenat-Thalmann, 2004). They argue that posture sway—implemented as a stop/frozen animation—is the motion most used in computer animation to counter no-planned-action situations (Egges, Molet, & Magnenat-Thalmann, 2004). The main reason humans execute this posture swaying motion is because our center of gravity is high but the supporting surface
of our feet is small; this requires humans to have good posture control to maintain balance (Manninen & Ekblom, 1984). According to research by Knapp, Hall & Horgan (2013), humans also change balance as a sign of fatigue, and these motions are also linked to other non-verbal signs to determine the degree of attention or involvement. Conclusions of the study by Egges and colleagues (2004), however, are limited to the researchers’ interpretations of the motions and lack further verification with participants.

An idle motion that is considered a signature movement and indicator for lifelike motion is breathing. This idle motion is used a lot in gaming and movie animations, (Zordan, Celly, Chiu, & DiLorenzo, 2004). However, at current writing there are no studies available that further investigate this movement in relation to HCI and HRI.

Seeing that the few studies that do focus on idle motions are within the field of HCI, we should mention that there are important differences between the fields of HCI and HRI. One of the main differences is that social robots share the same physical space and time as humans, which results in several implications. For example, with pointing tasks (deictic gestures) robots have appropriate consistency when referring to 3D space, in contrast, digital agents pointing to real-life objects can lead to inconsistencies between the 3D virtual space and “real” 3D space (Shinozawa, Naya, Yamato, & Kogure, 2005). Furthermore, human communication is influenced by the situation and communication environment. When the communication partner (robot) is located in the same environment, then humans recognize and interpret communication context faster (Shinozawa, Naya, Yamato, & Kogure, 2005). Additionally, since a robot shares our space it is important that, just like humans, robots should incorporate idle interactions that indicate the robot as being ‘alive’ (Lee & Kim, 2006), e.g. a standby interaction indicating that the robot is enabled. For this study we will refer to these interactions as idle motions.

In sum this emphasizes the need for idle interactions, or idle motions, during human robot interactions. But as was already indicated, research in this topic is limited, and it is unclear to what extent people ascribe social traits to various idle motions portrayed by social robots. Furthermore, it is unclear if idle motions add meaning or expressiveness to the interaction with a robot, e.g., do they only contribute towards the illusion of life or also contribute in a social manner? Breazeal (2003) provides four subclasses of social robots defined by the ability of the robot to adhere to ascribed social models for complex environments and scenarios. Her subclasses suggest that the more socially intelligent a robot’s observable behavior is perceived to be, the more people will be inclined to interact with the robot as they would with other socially intelligent entities. This implies that given a high level of social intelligence a robot could be perceived to mimic human-human interaction. Social intelligence,
appearance and attributions of social robots are all mediated by anthropomorphism, which is the attribution of human qualities to non-living objects (Epley, Waytz, & Cacioppo, 2007; Breazeal, 2003). Anthropomorphism is a mechanism through which social interactions with robots and humans can be facilitated (Duffy, 2003), and the effect of anthropomorphism is increased when a robot portrays non-verbal communication (Salem, Eyssel, Rohlfing, Kopp, & Joublin, 2013).

There are several theories within the field of HRI that provide different explanations of people’s social responses towards social robots (Von der Pütten, Krämer, & Gratch, 2009; Epley, Waytz, & Cacioppo, 2007; Blascovich, 2002; Nass & Moon, 2000; Reeves & Nass, 1996). Arguably, the most sophisticated models explaining the social responses of humans to social robots are the media equation hypothesis (Reeves & Nass, 1996) and the threshold model of social influence (Blascovich, 2002). These theories are argued to have the highest potential in contributing to our understanding of human-robot interaction (Von der Pütten, Krämer, Gratch, & Kang, 2010). We describe these theories in further detail below, suggesting a framework to further investigate interactions using idle motions and meaningful motions.

Threshold Model of Social Influence

A theory that combines social response and meaningful interaction is suggested by Blascovich (Blascovich, 2002) named the threshold model of social influence. The important factor in the threshold model of social influence is the so-called “social verification” which is “the extent to which participants experience interactions with others in ways that verify that they are engaging in semantically meaningful communication” (i.e., significant symbolic interaction) (Blascovich, 2002, p. 26). On the basis of social verification Blascovich (2002) assumes that people react socially to humans or artificial agents. Blascovich (2002) suggested that in human-human interactions two interpersonal factors are used to verify that the humans are engaged in a meaningful interaction: agency and behavioral realism. Behavioral realism refers to the extent to which, in our case, robots behave as people expect others to behave (behaves...
realistically). Thus behavioral realism is the portrayal of social cues, which people use to make inferences about social presence in a robot (Fogg, 2002). Agency refers to the extent to which a robot is perceived as representing a real person. As can be seen in figure 1, social verification is an interaction of behavioral realism and agency. When agency is high behavioral realism is of less importance, but when agency is low, behavioral realism may be needed for participants to overcome the social influence threshold and interact with a robot in a social way. Some studies that manipulated agency did not uncover any effects: participants had the same evaluations for different levels of agency (Midden & Ham, 2012; Von der Pütten, Krämer, Gratch, & Kang, 2010). In the same study performed by Von der Pütten and colleagues (2010) behavioral realism was manipulated, and results were in line with Blascovich (2002): higher levels of behavioral realism (i.e., social cues) led to more social behavior. However the findings presented by Von der Pütten and colleagues (2010) left room for false positives, since only three out twenty dependent measures showed a significant effect (type I error). As of current writing there is still no supporting evidence of this theory.

The Media Equation Hypothesis

Research performed by Reeves and Nas (Reeves & Nass, 1996) has indicated that people respond socially to computers, much like how they respond socially to other humans. The research that first reported this effect demonstrated that people give significantly more positive responses when completing an evaluation about a computer if the evaluation takes place on the same computer they recently interacted with, versus a different computer in the same room (Nass, Moon, & Carney, 1999). The media equation hypothesis (Reeves & Nass, 1996) further states that as long as there are some behaviors that suggest a social presence, humans automatically respond socially when interacting with artificial agents. They found that participants rated the artificial agents significantly more positively e.g., the computer is seen as friendlier, more helpful, and more intelligent (Reeves & Nass, 1996). Reeves and Nas ascribe this effect to a conservative error people are prone to make: when in doubt treat it as human, any medium that is close enough will receive human treatment (Reeves & Nass, 1996).

“When our brains automatically respond socially and naturally because of the characteristics of media or the situations in which they are used, there is often little to remind us that the experience is unreal. Absent of significant warning that we have been fooled, our brains hold sway and we accept media as real people and places” (Reeves & Nass, 1996, p. 12). Nas and Moon (2000) attributed the social responses to mindlessness, meaning that when humans are interacting with artificial agents we are in a mindless-state in which we only react to social cues and ignore the fact that we are interacting with
a machine. This suggests that that people do not need much of a cue to respond socially according the media equation hypothesis.

Because of the media equation hypothesis and its generality, meaning that it applies to everyone and all media (De Angeli, Gerbino, Nodari, & Petrelli, 1999), it is unclear what types of cues people require for the effect to occur. Research conducted by Tourangeau and colleagues (Tourangeau, Couper, & Steiger, 2003) failed to demonstrate socially biased reports when the online survey was accompanied by a researcher’s picture, compared to an online survey without the picture. Research by Bartneck and colleagues (Bartneck, Rosalia, Menges, & Deckers, 2005) demonstrated that humans have less concerns about abusing robots than about abusing humans, indicating further limitations of ambiguous social cues assumed by the media equation hypothesis.

Reeves and Nass (1996) do not agree that different social cues increase social responses, “social and natural responses come from people, not from media themselves” (Reeves & Nass, 1996, p. 252). Contrastingly, the threshold model of social influence (Blascovich, 2002) proposes that with social verification, which implies semantically meaningful interactions, people’s social responses increase.

The Current Study

In order to further explore the social effects of movements on the social interaction between robots and humans we compare the idle- and meaningful motions. In addition to elucidating the potential role of robot motions in shaping human’s perceptions of robots, we also hope to compare competing models of social effects in human-robot interaction: the media equation hypothesis (Reeves & Nass, 1996) and the threshold model of social influence (Blascovich, 2002). As described earlier, the media equation hypothesis suggests that as long as there is a certain cue present people will react socially (Reeves & Nass, 1996). The media equation theory does not support that different social cues increase the social responses to varying degrees (Nass & Moon, 2000), thus in line with the media equation hypothesis we expect to find the same level of social responses when comparing meaningful motions and idle motion.

In our experiment meaningful motions portray intentional behavior (e.g., deictic gesture), whereas idle motions portray unintentional behavior (e.g., idle gaze). Thus, according to the threshold model of social influence, meaningful motions serve as semantically meaningful communication with the robot, and are perceived to have higher behavioral realism than idle motions. Therefore, in line with the threshold model of social influence we expect that meaningful motions will increase social verification, meaning that participants should interact more socially with the robot, compared to interactions after
idle motions. Agency is not manipulated since previous research deemed it ineffective in invoking social responses by humans (Midden & Ham, 2012; Von Der Pütten, Krämer, & Gratch, 2009).

We furthermore argue that meaningful motions are perceived as more socially intelligent which has been argued to be effective in invoking social responses (Von Der Pütten, Krämer, & Gratch, 2009), and increasing anthropomorphism (Epley, Waytz, & Cacioppo, 2007; Breazeal, 2003). Thus, by portraying meaningful motions the robot shall be perceived as more socially competent. We furthermore argue that with meaningful motion, the perceived life-likeness of the robot also increases, thus, meaningful motions shall be perceived as more life-like.

With this study we also want to verify if there are any differences between different motions in responses and how life-like the motions are, e.g., comparing the idle motion of breathing to the idle motion of posture sway. This is important since at current writing it is unclear how idle motions and certain meaningful motions, like deictic head gestures, are being perceived by people. No-motion will be used as a baseline and we expect that movements will make the robot appear more life-like than no-motion (control condition). Furthermore, we are interested in emotion ratings by participants since emotions add expression and are linked to a more believable and natural interactions (Canamero & Fredslund, 2000) and it is unclear if idle- or certain meaningful motions are ascribed any emotion.

Summarizing, comparing idle motions and meaningful motions will indicate if social verification is an important factor. Based on expectations described above we hypothesize that if peoples social responses increase for meaningful motions compared to idle motions, this will support the threshold model of social influence. If social responses are equal for both idle- and meaningful motions, the result will support the media equation hypothesis. Moreover, we believe that motion will be perceived as more life-like and receive higher social responses compared to a no-motion baseline, and that meaningful motion will be perceived as more life-like and social compared to idle motion.
METHOD

We conducted an experiment where the Nao robot (Alderbaran Robotics, France) helped participants unpack a cardboard moving box that contained 16 items. There were two main conditions: In one condition the Nao robot displayed the so-called idle motions, in the other condition the robot displayed the meaningful motions. Within the two main conditions there was a baseline no-motion condition and three motion conditions.

Participants

Seventy-three participants took part in the experiment, of which 41 were male and 31 were female (mean age 25.55, SD = 7.012, range 18 to 54). Participants were recruited through the participant database of the Human-Technology Interaction department of the Eindhoven University of Technology, through word-of-mouth, and through the social network Facebook. Participants were randomly assigned to one of the two experimental conditions. Forty participants had prior experience with robots, including the Nao robot. Participants received a compensation of 5 euros for participating in the experiment, or 7 euros if they were not affiliated with Eindhoven University of Technology.

Design

The experiment was conducted using a mixed design. We used two different motion types as a between-subjects factor, which, differed in terms of social verification: (1) Meaningful motion and (2) Idle motion. The Meaningful motion condition portrayed semantically meaningful communication (high social verification). The Idle motion condition portrayed interactions that are argued to only aid in the “illusion of life” (low social verification). In both groups a no-motion condition was used as a baseline. For each of the motion types there were three different movements that were implemented on the robot. This allowed us to study whether effects of social verification resulted from motion per se or from specific movement characteristics. The three different meaningful motions tested during the experiment were: (1) Deictic arm gestures, indicating spatial information moving the robots arms. (2) Deictic head gestures, indicating spatial information moving the robots head. (3) Eye-contact/gaze, creating a mutual facial gaze interaction with the robot indicating attention. The three different idle motions tested during the experiment were (1) Posture Shift/sway, creating the impression the robot adjusts its body posture, (2) Random head movements, creating the impression that the robot is gazing randomly at its direct surroundings, and (3) Breathing motion, creating the impression that the robot
is breathing. Each participant experienced three movement conditions (either idle or meaningful) and the baseline condition in four blocks. The baseline was always presented first, the three movement conditions were counterbalanced across subjects. Each block required the unpacking and correctly placing of four items from the moving box, after which participants were asked to fill in a questionnaire. Each block consisted of four trials resulting in a total of 16 trials per participant.

Experimental Setup

Participants interacted with the humanoid Nao robot (see Figure 2) that is produced by the French company Aldebaran Robotics for research purposes. The Nao is a 58-cm tall humanoid robot, which has 25 degrees of freedom, two cameras, an inertial measurement unit, touch sensors and four microphones all enabling him to detect and interact with its surroundings. We programmed the Nao robot using Aldebaran Robotics Choregraphe, which enabled us to manipulate the degrees of freedom into the required motions and record these for further manipulations. To ensure that there was minimal variability in the experimental procedure, the robot was partially controlled using a Wizard-Of-Oz technique. This was achieved using programming language Python, creating a script with which we could successfully control the robot during the experiment. Furthermore, the python script was used to combine the movements of the Nao with speech, thus having the ability the sync certain movements with utterances. For each of the within-subject conditions there were predetermined utterances that would instruct the participant. These utterances were randomized for each within-subject condition and were triggered once the participant stood in front of the robot. Once triggered the Nao robot would generate the required utterance and movement according the Python script. The Nao robots speech was identical across conditions and was generated using the text-to-speech function provided by Aldebaran Robotics. The items that were located in the cardboard moving box, and had to be unpacked, were carefully chosen to avoid any confusion or bias that could be introduced by placing the items in certain locations. For example, the vase was asked to be placed on a table instead of in a closet. Specifically the 16 items comprised a white vase, green and yellow cup,
instruction manual, white bowl, clock, candles, photo frame, telephone, fruit bowl, two glasses, power adapter, headphones, stereo cable and a remote control. Furthermore, the utterances of the items included the color of the item if deemed too ambiguous. The questionnaire, which was conducted after completing each of the within-subject conditions, was programmed using Macromedia’s Authorware software. This enabled us to automate the questionnaire process, randomize the questions and gather the data in an appropriate digital format for further analysis.

The experiment took place in the Uselab of Eindhoven University of Technology. The Uselab creates a believable living room setting in which the Nao robot would serve as a household assistant. The overview below (see Figure 3) shows where the robot was located within the room and the location of the other appliances that were used during the experimental procedure.

![Figure 3](image)

**Fig. 3.** A top down view of the UseLab. On the right side the different items are listed that were used during the experiment. Furthermore the minimum distance label can be seen between the Nao robot and participant.

The interaction with the Nao robot was filmed using 3 cameras located at positions depicted in Figure 3. The experimenter observed and controlled the interaction between the Nao robot and the participant from the operating room located behind the see-through mirrors.
Motions

The between-subject conditions differed from each other by the different motions the robots performed. All the motions, apart from the eye contact, were created using the Choregraphe software designed for the Nao robot. While designing these motion, we applied the Principles of Animation (Johnston & Thomas, 1995) to the Nao robot, which acted as a guideline to create an illusion of life. That these principles could be applied to robots has already been suggested (Ribeiro & Paiva, 2012; van Breemen, 2004). Motions included in the experiment were chosen primarily because of technical constraints imposed by the characteristics of the Nao robot, e.g., the robot lacks the degrees of freedom to portray facial expressions.

During the design phase of the experiment it became clear that the Nao robot did not have all the required degrees of freedom to realistically portray a breathing motion. A real breathing motion has a downward motion, combined with a chest expanding motion (Zordan, Celly, Chiu, & DiLorenzo, 2004). To mimic this motion, the Nao robot made a slight swaying motion with its head, its shoulder joints made a slight angular shift and its hip joints also swayed slightly. The frequency of the breathing motion was static (i.e., the time interval was not varied across its duration), and after running pilot tests, the motion was deemed realistic enough for the participants to distinguish it as a breathing motion. The Nao robot portrayed idle gaze by adjusting both the head pitch and head yaw degrees of freedom. A total of 8 pre-recorded head motions were executed at a random time interval (between 15-22 seconds). The posture sway motions portrayed by the Nao robot required manipulations of the head, arm and leg/hip joint degrees of freedom. This is because posture sway in human idle motion affects all the joints. A total of 8 randomized pre-recorded motions were executed at random on a certain time interval (between 20-30 seconds).

Pilot studies indicated that the frequency of the motion seemed natural; the participants did not describe the robot as seeming nervous or as exhibiting behavior outside of posture shifts. During the experiment, we verified whether the idle motions were perceived correctly by having the participant describe which motion the robot portrayed. Out of 37 participants that witnessed the idle motions, 86.5% perceived posture shift/sways correctly, 78.4% perceived idle gaze correctly and 83.8% perceived the breathing motion correctly.

The meaningful motion eye-contact/gaze was realized using an existing model provided by our department. This model enabled the Nao robot to use a face tracking algorithm in combination with the camera located in the head of the Nao robot. The face tracking algorithm is coupled with the
degrees of freedom of the head, which enables the Nao robot to create a continuous gaze effect. During this interaction type the Nao robot is making sure the participant is looking at its eyes, thus creating a mutual facial gaze interaction. Initial “eye-contact” could cause issues considering participants are of different heights and the camera height of the robot is static. The Nao robot would request the participant to position their face in front of the robot until facial recognition was established. This was controlled by the experimenter in the operating room. After this the participant was requested by the Nao robot to stand up again, and the Nao robot indicated to the participant that it had successfully established face tracking upon which the experiment continued.

The deictic arm and head gestures acted in a complementary way, but the speech and gesture did not manifest the same information. This means that the gesture was carried out to convey additional meaning when this meaning was lacking in the speech. The Nao robot said “Please take the power adapter, and place it in the closet” and the robot would point or nod accordingly towards the moving box with the power adapter and the closet in which the power adapter should be placed. The closet could either be located on the right or left. This ensured a meaningful semantic and pragmatic relationship between the gesture and speech. Since both conditions had 4 items each that required being unpacked, the Nao robot had 4 deictic arm gestures and 4 deistic head gestures. Care was taken so that the interaction adhered to the before-mentioned design factors (Johnston & Thomas, 1995); timing was especially of importance to create a natural interaction. Out of 36 participants in the meaningful motion condition, 91.7% perceived the deictic point gesture correctly, 83.4% perceived the deictic head gesture correctly and 86.2% perceived the gaze motion correctly. The no-motion condition, which acted as a baseline throughout the experiment, was perceived correctly by 86.5% out of 73 participants.

Verbal Utterance
The experiment makes use of the text-to-speech system provided by Aldebaran Robotics, and it was suggested in previous research that this system could cause issues recognizing the pronunciations of words. It was important that the verbal instructions should were clear enough to ensure that the robot’s pronunciations did not create any confusion during the task. Specifically in the meaningful condition it was important that the deictic gestures that accompanied speech were supplementary, thus the verbal utterance could be self-sufficient in solving the task.

To ensure this was the case the verbal utterances were divided in so called “chunks” of speech-gesture production. A “chunk” is defined by pairs of an intonation phrase and a co-expressive gesture phase (Kopp & Wachsmuth, Synthesizing multimodal utterances for conversational agents, 2004). Each
instruction given by the Nao robot could consist of two chunks, which were based on the following syntax:

<P lease take the [object]<and place it [position+location].>
An example would be: Please take the remote control, and place it in the closet.

In the meaningful condition the two syntax components had a separate deictic gesture assigned to them. For example, the Nao robot would pronounce “Please take the remote control” while pointing at the moving box, followed by pronouncing “and place it in the closet,” accompanied by a pointing gesture towards the closet. This was all done in a fluent manner that felt natural to our human interpretation. For a complete overview of the verbal utterances, see Appendix A.

Questionnaire

The measure that we incorporated to gain a deeper understanding of how commutative robots impact and shape user experience and evaluation of human-robot interaction is based on the 5-point scale Godspeed questionnaire (Bartneck, Kulić, Croft, & Zoghbi, 2009). With the Godspeed questionnaire we can assess whether people perceive the robot as a lifelike, friendly, social, and intelligent. The Godspeed questionnaire measures a total of 5 dimensions: anthropomorphism, animacy, likeability, perceived intelligence and perceived safety over a total of 24 questions. These dimensions and other attitude measurements have been used to verify the media equation hypothesis (Goldstein, Alsiö, & Werdenhoff, 2002; Johnson, Gardner, & Wiles, 2004; Chiasson & Gutwin, 2005). We excluded perceived safety from the questionnaire since this was not relevant to our study, and replaced this dimension with the emotion dimension (4 questions, see Appendix B), which allowed us to measure the rated emotional responsiveness. Another new dimension was introduced, named social intelligence (4 questions, see Appendix B), which enabled us to measure the social competence and social skills of the Nao robot (Dautenhahn, 1998; Dautenhahn, 1995). The dimension was created with the assistance of research conducted by Martinez-Miranda & Aldae (2005). With the addition of the new dimensions participants had to answer 29 questions in total on a 5-point scale, -2 to 2, where -2 was seen as the most negative choice and 2 the most positive e.g., -2 representing Dead to 2 representing Alive. The dependent variables consisted out of perceived anthropomorphism, perceived animacy, perceived likeability, perceived social intelligence, perceived emotion and perceived intelligence. An open question was included as a confirmation check that participants did perceive the portrayed motions correctly. For a full description of the questionnaire administered, see Appendix B + C.
Procedure
On arrival at the lab, the experimenter asked the participant if he or she had any experience with the Nao. The participants received further explanation of the experiment procedures by the experimenter and were asked to fill out the informed consent forms. After this they were given the opportunity to ask for further clarifications. When there were no further questions the experimenter started the experiment, from the control room. The robot first introduced himself and provided a short explanation of the experiment. First the baseline condition with no movements was presented, in which the robot directed the participant with verbal utterances required for unpacking the box. The utterance consisted of two parts: the first part indicated the item (e.g., Please take the white vase) and the second part indicated the location and position where the item should be placed (e.g., and place it on the table). As was instructed beforehand, the participant was required to stand in front of the Nao robot to signal that they were ready for the next item. The participant was given the impression that the robot was detecting them, and was not aware that the experimenter actually triggered the Nao robot’s subsequent behavior. After placing four items in the correct location the Nao robot instructed the participant to take a seat in the chair, and fill in the questionnaire provided on the laptop. After completing the questionnaire, the participant stood in front of the Nao robot again to continue the next experimental block. This was repeated four times for a total of sixteen items, until all the within-subject conditions were completed. Upon completion the robot thanked the participant and bid them farewell. In total the participants interacted approximately ten minutes with the Nao robot. After completing the last questionnaire the participants were debriefed about the purpose of the experiment and then thanked and paid. The experiment lasted about thirty minutes.

Data analysis
A multivariate ANOVA analysis was used to test for the effects of our manipulations on the dimensions of the questionnaire. The Likert scale scores were the dependent variables and both manipulations (idle motions and meaningful motions) the independent variables. To check the internal consistencies of the dependent measures a reliability analysis (Cronbach’s α) was conducted. The Cronbach’s alpha rating exceeds 0.7 for all the dimensions of the questionnaire, indicating that the items are considered to have a good consistency (see Table 1).
| Questionnaire Dimension | Items | Cronbach’s α |
|-------------------------|-------|--------------|
| Anthropomorphism        | 5     | 0.88         |
| Animacy                 | 5     | 0.86         |
| Likability              | 5     | 0.93         |
| Perceived Intelligence  | 5     | 0.86         |
| Social Intelligence     | 4     | 0.82         |
| Emotion                 | 4     | 0.72         |

Data analysis was performed using IBM SPSS Statistics 20 (IBM Corporation, 2013) and Microsoft Excel 2013 (Microsoft Corporation). The statistical analysis was conducted with the significance level set to $p = 0.05$ with a confidence interval of 95%. We had to exclude the data of 10 participants regarding the eye-contact/gaze within condition (meaningful motion) because of technical difficulties which caused the robot to lose eye-contact.
RESULTS

Results of our experiment will be presented in four subsections. In the first subsection of the results we analyze if there are any effects between the idle motion and meaningful motion condition. The second subsection of the results reports the effects of the motion conditions compared to the baseline no-motion condition, and examines if participants had any preferences in motions that were portrayed by the Nao. To determine if there were any preferences in motion (i.e., breathing vs idle gaze) the analysis was conducted with a Bonferonni post-hoc. We used a Bonferonni post-hoc correction since it is assumed to be more accurate than a Tukey post-hoc correction with a small set of planned comparisons (Field, 2013). In the last subsection of the results demographics and other confounding and control variables are presented. For the purpose of clarity, the dependent variables anthropomorphism, animacy, likability, perceived intelligence, social intelligence and emotion will be referred to as *questionnaire dimensions*.

Social verification

A comparison was made between idle- and meaningful motion conditions in order to verify our hypotheses regarding the *media equation hypothesis* and *threshold model of social influence*. A conventional MANOVA analysis was performed with the *questionnaire dimensions* as dependent variables. Social verification (idle, meaningful) and motion (motion, no-motion) were the factors. We hypothesized a main effect of social verification, and an interaction effect of motion on social verification. A MANOVA analysis revealed no significant effect of social verification, $p = 0.15$, and no significant interaction effect of motion on social verification, $p = 0.32$.

However, this analysis still includes the subject differences of the baseline no-motion condition, which introduces “baseline variance” and makes the analysis less sensitive. By subtracting the baseline no-motion condition ratings on the motion ratings we control for these differences between subjects (see Figure 4). Further analysis of social verification was performed with the subtraction of the baseline no-motion condition.
A MANOVA analysis with the questionnaire dimensions as dependent variable and social verification as factor reveals a statistically significant main effect of social verification, $F(6, 202) = 4.38$, $p < .01$, $\eta_p^2 = 0.12$. Participants rate the Likeability dimension higher ($F(1, 209) = 7.17$, $p < 0.01$, $\eta_p^2 = 0.03$) for conditions which portrayed meaningful motions ($M = 0.28$, $SD = 0.85$) than for idle motions ($M = -0.02$, $SD = 0.79$). Perceived Intelligence is higher ($F(1, 209) = 13.64$, $p < 0.01$, $\eta_p^2 = 0.06$) for conditions which portrayed meaningful motions ($M = 0.37$, $SD = 0.78$) than for idle motions ($M = -0.03$, $SD = 0.79$). Likewise, social intelligence is higher ($F(1, 209) = 10.11$, $p < 0.01$, $\eta_p^2 = 0.05$) for conditions which portrayed meaningful motions ($M = 0.54$, $SD = 0.65$) than for idle motions ($M = 0.22$, $SD = 0.81$) and, finally, emotion is higher ($F(1, 209) = 4.76$, $p = 0.02$, $\eta_p^2 = 0.02$) for conditions which portrayed meaningful motions ($M = 0.61$, $SD = 0.74$) than for idle motions ($M = 0.37$, $SD = 0.83$).

The anthropomorphism dimension was not significantly different between both motion conditions, $p = 0.76$, neither the animacy dimension was rated significantly different between both motion conditions, $p = 0.74$. 

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Fig. 4 Results of the six dimensions of the extended Godspeed questionnaire comparing the meaningful and idle motion conditions after subtracting the baseline. The errors bars show the standard error for the mean at +/- 1 SE.
Effect of motion

We investigated whether participants who experienced the idle motion condition rated the robot significantly higher in social responses compared to the no-motion baseline condition (see Figure 5). For the purpose, we conducted a MANOVA analysis with questionnaire dimensions as dependent variable and idle motion (idle motion, no-motion) as a factor. For the idle motion condition a statistically significant main effect of motion was found, $F(6, 134) = 8.911, p < 0.01, \eta^2_p = 0.29$. Participants rated the anthropomorphism dimension significantly higher ($F(1, 141) = 4.48, p = 0.01, \eta^2_p = 0.09$) for conditions which portrayed motion ($M = 0.11, SD = 0.95$) than for the baseline condition without motion ($M = -0.55, SD = 0.96$). Emotion is significantly higher ($F(1, 141) = 5.41, p = 0.02, \eta^2_p = 0.04$) for conditions which portrayed motion ($M = 0.61, SD = 0.83$) than for the baseline condition without motion ($M = 0.24, SD = 0.84$), and animacy was rated significantly higher ($F(1, 141) = 5.45, p < 0.01, \eta^2_p = 0.14$) by participants for the idle motion condition ($M = 0.45, SD = 0.84$) than for the baseline condition without motion ($M = -0.36, SD = 0.97$).

The other Godspeed questionnaire dimensions did not differ significantly compared to the baseline no-motion condition (likeability: $p = 0.88$; perceived intelligence: $p = 0.83$; social intelligence: $p = 0.16$).

![Figure 5](image_url)

Fig. 5 Results of the six dimensions of the extended Godspeed questionnaire comparing the baseline no-motion condition against the idle motion condition. The errors bars show the standard error for the mean at +/- 1 SE.

For the meaningful motion condition we wanted to know whether meaningful motions have higher social responses than the baseline no-motion condition, and whether meaningful motions are perceived as more intelligent, and more socially intelligent compared to baseline. For this purpose, we
conducted a MANOVA analysis with *questionnaire dimensions* as dependent variable and meaningful motion (meaningful motion, no-motion) as a factor. For the meaningful motion condition a statistically significant main effect of motion was found, $F (6, 134) = 7.65, p < 0.01, \eta^2_p = 0.26$.

![Figure 6](image)

**Fig. 6** Results of the six dimensions of the extended Godspeed questionnaire comparing the baseline no-motion condition against the meaningful motion condition. The error bars show the standard error for the mean at +/- 1

Participants rated the social response dimensions anthropomorphism, perceived intelligence, social intelligence and emotion significantly higher for the meaningful motion condition, but there was no significant difference for likeability (see Figure 6 & Table 2).
Furthermore, we wanted to know if meaningful motions were perceived as more life-like than the baseline no-motion condition. As can be seen in table 2, participants rated animacy significantly higher for the meaningful motions compared to the baseline no-motion condition.

We specifically designed the experiment with various different idle and meaningful motions. By doing so we can distinguish whether certain idle- or meaningful motions were perceived as more effective on the questionnaire dimensions. A MANOVA analysis was conducted with the questionnaire dimensions as dependent variable and the different motions (idle or meaningful) as factor. This analysis was conducted with the subtracted baseline no-motion condition since we were only interested in motion effects.

For idle motions there was no significant main effect of the different idle motions on any dimension of the questionnaire, $p = 0.9$.

For meaningful motions there was no significant main effect of different meaningful motions, $p = 0.48$. However there is a significant difference for social intelligence $F(1, 105) = 4.84$, $p = 0.01$, $\eta^2_p = 0.09$, and a trend for perceived intelligence $F(1, 105) = 2.74$, $p = 0.07$, $\eta^2_p = 0.05$. 

### Table 2 Overview of the results of the ANOVA testing the within-subject effect of meaningful motions compared to the baseline condition.

| Questionnaire Dimension | Baseline no-motion condition | Meaningful motion condition | Effects of the Meaningful motions of the Robot |
|-------------------------|-------------------------------|-----------------------------|---------------------------------------------|
|                         | $M$  | $SD$ | $SE$ | $M$  | $SD$ | $SE$ | $df$ | $F$  | $p$  | $\eta^2_p$ |
| Anthropomorphism        | -0.59 | 0.74 | 0.12 | 0.03 | 0.93 | 0.09 | 1    | 13.25 | 0.01 | 0.09     |
| Animacy                 | -0.51 | 0.87 | 0.15 | 0.33 | 0.82 | 0.08 | 1    | 27.44 | 0.01 | 0.17     |
| Likability              | 0.71  | 0.88 | 0.15 | 1.0  | 0.85 | 0.08 | 1    | 2.89  | 0.09 | 0.02     |
| Perceived Intelligence  | 0.23  | 0.89 | 0.15 | 0.6  | 0.78 | 0.08 | 1    | 5.82  | 0.02 | 0.04     |
| Social Intelligence     | 0.17  | 0.89 | 0.15 | 0.72 | 0.65 | 0.06 | 1    | 15.42 | 0.01 | 0.1      |
| Emotion                 | -0.03 | 0.7  | 0.12 | 0.58 | 0.74 | 0.07 | 1    | 18.45 | 0.01 | 0.12     |
Results of the six dimensions of the extended Godspeed questionnaire for the three meaningful motion conditions. The errors bars show the standard error for the mean at +/- 1 SE.

Post hoc comparisons using the Bonferroni correction ($\alpha = 0.013$) indicated that the mean score for the deictic arm gesture condition on social intelligence ($M = 0.98, SD = 0.56$) was significantly different, $p = 0.02$, than the eye-contact/gaze condition ($M = 0.54, SD = 0.72$). The deictic head gesture condition ($M = 0.63, SD = 0.57$) was marginally significantly different $p = 0.06$ from deictic arm gesture (see Figure 7).

**Confounding variables**

Participant’s prior experiences with the Nao robot were compared across conditions using a chi-square goodness of fit test. There was no significant association of previous experience with the Nao robot $\chi^2 (1) = 1.66, p = 0.20$. Comparing technological affinity, there was a significant association across conditions $\chi^2 (1) = 41.71, p < 0.01$. However, further analysis checking for correlations of technological affinity on the questionnaire dimensions did not suggest any significant results.

Gender effects were analyzed using an MANOVA analysis with questionnaire dimension as dependent variable and with gender as covariate. There were a total of 41 males and 32 females that participated in the experiment. For the idle motion and meaningful condition a statistically significant main effect of gender was found on social verification, $F (6, 201) = 2.38, p = 0.03, \eta^2_p = 0.06$. Perceived...
intelligence was rated significantly higher ($F(1, 209) = 4.48, p = 0.04, \eta_p^2 = 0.02$) by female participants ($M = 0.32, SD = 0.85$) than by male participants ($M = 0.05, SD = 0.76$).

During the experiment participants repeatedly mentioned, on their own initiative, that they had the impression that the robot started to move more fluently. To avoid possible order effects the motions portrayed during the experiment were counter balanced, so it should not have affected our previous analyses. The order effects are shown in Figure 8. The line chart (see Figure 8) shows a possible effect of trial number, or order, on the anthropomorphism, animacy and emotion dimension for both motion conditions.

![Line charts of the extended Godspeed questionnaires dimensions comparing the trial number (order) effects.](image)

Fig. 8 Line charts of the extended Godspeed questionnaires dimensions comparing the trial number (order) effects.

To determine if there were any significant effects of the order in which the motions were portrayed a MANOVA analysis was performed with questionnaire dimensions as dependent variable and trial order as a factor. For the motion conditions no statistically significant main effect of trial order was found, $p = 0.8$. However, participants did rate the anthropomorphism dimension significantly higher ($F(2, 209) = 5.61, p < 0.01, \eta_p^2 = 0.05$) for motions in the fourth trial ($M = 0.92, SD = 0.94$) than for motions in the second trial ($M = 0.41, SD = 0.85$) and rated the animacy dimension marginally significantly higher ($F(2, 209) = 2.93, p = 0.6, \eta_p^2 = 0.03$) for motions in the fourth trial ($M = 1.01, SD = 0.84$) than for motions in the second trial ($M = 0.68, SD = 0.77$). The emotion dimension was not significant, $p = 0.24$. 
DISCUSSION

The current study compares two models that provide different explanations of people’s social responses towards social robots. The results of this study support the threshold model of social influence. By comparing these models, we also gained further insights regarding idle motions (for which research was lacking), and meaningful motions (for which we found effects comparing three different meaningful motions). In the next sections, we discuss the findings, point out the limitations, draw conclusions from the current research, and suggest possible implications for further research in the field of human robot interaction.

Social verification

We expected that participants’ social responses would be higher for the meaningful motions compared to the idle motions. Results indicated that participants rated the Nao robot significantly more positively in the meaningful motion condition i.e., the robot was seen as friendlier, more intelligent, empathic and helpful compared to the idle motion condition. We can thus conclude that we found support for the threshold model of social influence.

Previous research by Von der Pütten and colleagues (2010) only investigated no-motion versus motion as a manipulation of social verification. However in our study we investigated the effects of two motions that have different characteristics, and by doing so determined the effects of an intermediate level of social verification on social responses. We assume that by approaching the social verification manipulation in a more subtle way, and actually finding effects, our results can be perceived as more substantial evidence of social verification.

Furthermore, we expected that a robot portraying meaningful motions would be perceived as more socially competent compared to a robot portraying idle motions. Our results indicate that participants’ perceived the robot higher in social intelligence and perceived intelligence when the robot portrayed meaningful motions compared to idle motions. Thus, the robot portraying meaningful motions is perceived as more socially competent and skilled. This also confirms that when the robot portrayed meaningful motions the participants perceived the interaction as semantically meaningful i.e., significant symbolic interaction. Epley and colleagues (2007) stated that social intelligence increases the level of anthropomorhism, however we did not find a significant difference between anthropomorphism ratings between idle- and meaningful motion. It is possible that the friendly appearance of the Nao robot already influences human-traits ascribed to the robot to a high degree,
so that our manipulation of movement type had no further influence. Another possible explanation is a limitation introduced by technical constraints e.g., the robot movements were not subtle enough to portray the nuanced movement variations that humans produce.

Studies by Bartneck and colleagues (Bartneck, Kanda, Mubin, & Al Mahmud, 2009; Bartneck, Van Der Hoek, Mubin, & Al Mahmud, 2007) indicated that perceived intelligence of the robot had a strong positive effect on its animacy. In line with their research, we assumed that with meaningful motions (thus higher perceived intelligence) the robot would be perceived as more life-like compared to idle motions. However, our results did not indicate any significant difference in animacy between the motion conditions. A possible explanation can be obtained from the research by Bartneck and colleagues (2007). Their results suggested that robots with more humanlike morphology have a weaker correlation between animacy and perceived intelligence. They explained their findings by suggesting that robots with more similar morphology to humans (such as having arms) presented a possible danger for participants and thus had an impact on their affective state (Bartneck, Van Der Hoek, Mubin, & Al Mahmud, 2007). In line with their suggestion, it is possible that robot movements in the meaningful condition of deictic arm and head gestures, influenced the affective state of our participants. Even more so, through eye-contact/gaze motion, our robot communicated attention (Chidambaram, Chiang, & Multu, 2012), thus participants could have felt intimidated e.g., having the impression of being watched. We do, however, lack further evidence to support these claims.

Summarizing, our results indicate that people increase in social responses with a high level of social verification, thus indicating that different motion characteristics are relevant to further develop a social interaction between robots and humans. This is a remarkable result since this effect has to our knowledge not been previously uncovered with the use of robots. However, we could not confirm that meaningful motion is perceived as more life-like compared to idle motion.

Effect of motion
Since there is virtually no research on idle motions with robots we aimed to investigate how humans perceive different idle motions portrayed by a robot. We could not determine any differences between idle motions themselves, but comparing idle motions to a no-motion condition did result in some findings. Our results indicated that participants perceived the robot portraying idle motions as more human-like, alive and empathic compared to the robot with no motion. These results are in line with research by Gazzola and colleagues (Gazzola, Rizzolatti, Wicker, & Keysers, 2007) were they compared brain responses to human and robot actions. They concluded that humans automatically ascribe
human traits to a robot when the robot portrays human behavior. Our result thus demonstrates that robots portraying idle motion can take advantage of brain mechanisms humans developed to understand other humans, resulting in human like responses towards the robot.

As a result, the robot portraying idle motions was also perceived by participants as more empathic, or emotionally expressive compared to the no-motion robot. It was assumed that idle motions do not add to the expression of a character (Jung, Kanda, & Kim, 2013). However, our research demonstrates that by having robots portraying idle motions, people will attribute intentions to the robot. In fact, participants sometimes remarked in the answers to the open question (which acted as a motion manipulation check), that the robot seemed bored or nervous during the idle motion portrayals. We interpret this as further indication that participants successfully anthropomorphized the robot portraying idle motions. However the indication that idle motions are being ascribed a certain level of intention does not confound our assumption that idle motions are low in social verification (semantically meaningful). This is because the idle motions were not perceived as being additive to the task, i.e., participants did not perceive the robot portraying idle motions as more intelligent or more socially capable than the robot portraying no motion. We can thus assume that the perceived intentionality resulting from idle motions did not introduce confounds regarding our results of social verification, which maintains that interactions need to be semantically meaningful.

Overall, people ascribed human qualities to a robot that portrays idle motions. Concluding from our experiment it does not seem to matter which idle motions are portrayed by a robot: as long as the robot makes slight random motions, humans will perceive the robot as more human-like and alive.

Similar to the idle motion condition, participants in the meaningful motion condition rated the robot as more humanlike, alive and emotionally expressive when the robot portrayed meaningful motions compared to no motion. In line with results discussed in the social verification section, the robot portraying meaningful motions was perceived by participants as more socially competent and intelligent. We can thus confirm that the meaningful motions are indeed contributing in a semantically meaningful manner to the interaction.

The most interesting difference was found in comparison of the three meaningful motions. Here, results indicated that deictic arm gestures were perceived as more socially intelligent than the eye-contact/gaze motion. Presumably this is because the deictic arm gestures are more noticeable as moving gestures that are additive to the task, compared to the other two meaningful motions. It must also be noted that the eye-contact/gaze condition had some technical difficulties; namely, there were
recognition difficulties introduced by the movements participants made during the placement of items. The speed with which the robot can process the participant’s position was not sufficient, causing the robot to lose track of the participant’s location. This technical limitation could lower the ‘believability’ of the robots interaction, since it can be perceived as unnatural when the robot is not fluent in eye-contact/gaze portrayal during an interaction. A possible solution is to have the head position go to its initial position, only then start until a participants face has been recognized, thus establishing face tracking again.

Although the results were not significant, figure 7 suggests a trend in favor of deictic arm gestures, compared to deictic head gestures. Apart from the reason described above, a possible explanation for such difference could be that several participants were exchange students from India. After the experiment these participants indicated that they did not ascribe spatial information to deictic head gestures. We did find that the results changed a bit after controlling for participants from India, though not to a significant extent. This does however indicate that in the design stage of social robots it is important to take into account cultural differences in interaction.

In summary, for both idle- and meaningful motion conditions we can confirm our hypothesis that motion is perceived as more life-like to no motion. Furthermore, we can confirm that motions are perceived higher in social responses compared to a no-motion baseline. Participants perceived the robot as more human-like, intelligent helpful and empathic. This further questions the generality in social cues assumed by the media equation hypothesis, which predicts similar social responses for the motion and no-motion condition.

Confounding
While conducting the experiment we received verbal feedback from the participants, on their own initiative. They had the impression that the robot started to move more “fluidly” and seemed more “alive” as the experiment progressed. This got us interested in verifying whether there were any order effects, mainly because we counterbalanced the motions to prevent any of these effects. Results showed a significant effect of order on the anthropomorphism dimension for both the idle- and meaningful motion condition. Participants rated the second motion trial significantly lower in anthropomorphism compared to the fourth motion trial. At first we suspected that participants ” became adjusted to” or “appreciated” the robot interaction more over time and as a result started to ascribe more human traits to the robot. However, after more careful consideration we assume that this effect is a result of our experimental design. Participants first underwent the no-motion baseline
condition and received the first questionnaire, which was similar for the motion conditions that follow. Because of this order, it is very likely that participants were more compliant with our manipulation after they had interacted with the first motion condition, and thus assumed that the robot was designed to become more “alive” throughout the experiment.

We further investigated effects of gender on the perception of the robot interactions. Our results indicated that there is a significant difference between males and females. Females rated the social intelligence dimension significantly higher than males, the other questionnaire dimensions were not significant. A possible reason could be that females are more perceptive of social cues and thus rate social intelligence as higher than males.

Prior experience with the Nao robot was equally distributed among conditions, thus we assume that participants’ prior experience with the Nao robot did not confound social verification between the conditions. Technological affinity was not equally distributed among conditions, however further analysis did not determine any significant correlations between technological affinity and the questionnaire dimensions. We can thus assume that technological affinity did not confound any of the results. Furthermore there were no significant effects of age, and there were too many young participants to conduct internally valid analysis.

**Limitations and future work**

There were several limitations to the present experiment. The first limitation of our study is that we did not manipulate the agency of the robot but only behavioral realism. This prevents us from further verifying the *threshold model of social influence*, since social verification is an interaction effect of the factors of agency and behavioral realism. As a future experiment it would be interesting to manipulate the agency factor using a robot, e.g., a high agency level induced by a human controlling the robot during real-time interaction, and a low agency level induced using a preprogrammed robot.

The second limitation of our study is related to the task participants had to perform. Participants were given the impression that the robot was intelligent and capable in assisting them during the box-moving task. Human curiosity prevailed and some participants attempted to find the limitations of the robot’s interaction e.g., placing items in the wrong location to see how the robot would respond. We did control for this by having the robot repeat the instruction. However repeating the same utterance or motion in exactly the same manner can be perceived as a static, machinelike interaction. This could have influenced the ratings of the robot by participants in a negative way. This underlines the importance for future studies to investigate adaptive social behavior of robots, and their ability to
respond dynamically to interactions with a human. This would also remove the need for the Wizard-Of-Oz technique for controlling the robot, which in our experience can be a source of delay in the robot’s responses. However this is a very complex issue to solve, and requires significant advances in fields like artificial intelligence.

A third limitation is that even though the Nao robot is a very advanced robot, there are constraints on the Nao robot’s ability to fluently portray motions. It is difficult to portray some motions in a manner that is perceived as human-like, especially more subtle idle motions. However, we are convinced that with technological advances these limitations can be resolved. Furthermore, given that we found effects with the limited degrees of freedom and capabilities of these robots, it can be assumed that with more technically advanced robots, our results can be replicated and even examined with greater detail.

A fourth limitation is that the findings limit themselves to mainly students interacting with a Nao robot over a short period of time; it could be that longitudinal experiments would result in different findings. We therefore recommend that a longitudinal study be performed using similar measures as in the present study to investigate whether long term responses to robots require more advanced manipulations.

A possible improvement to our study could be achieved by having the instruction part of the experiment performed exclusively by the robot. The experimenter always greeted the participants in a kind manner with a hand shake, followed by the experimenter giving the instructions. It can be assumed that certain participants were more compliant in their responses of the questionnaire by giving answer they thought the experimenter wanted to hear. This is a common issue with self-reported measures, and it remains unclear to what extent this influenced our data. It is thus important that future research also includes physiological responses, performance or behavioral measures.

Since robots share our physical space and time, it will become increasingly important to investigate how their physical presence influences our perceptions. Research has indicated that we are more engaged with real embodied people than with those that are not in a shared space (Schmitt, Gilovich, Goore, & Jospeh, 1986). It would be interesting to investigate how the same robot interaction is perceived when the robot shares physical space with a participant compared to an un-embodied robot presented on a screen; this could further confirm the assumption that robots are more effective in portraying communication because of their shared physical space and affordances, compared to their digital (e.g., animated) counterparts.
Conclusions

With the current research we compared social responses to robots displaying idle or meaningful motions to induce the illusion that these robots are social beings. We compared two different theories about social reactions between humans and robots. There is still much uncertainty surrounding these competing models, so our contributions are highly relevant within the field of HRI. Our results indicate that people indeed respond socially even with the use of simple social cues (e.g., voice, portrayed motions). Furthermore, with the addition of meaningful motions, people’s social responses increase.

Furthermore, we gained some insights to what characteristics influence social verification by comparing two types of robot motion. We can conclude by adding only idle or meaningful motions a robot does indeed seem more alive. However an important point, which has implications for the design of social robotics, is that there was a clear difference in the effectiveness of meaningful motions. This indicates that “just adding” motions or behavior is not a fruitful avenue for designing more engaging and believable social robots. Every additional motion can create side effects and it is therefore important to investigate the possible effects of different motions and behaviors during a design process before applying them to a social robot. This confirms the opinion of many researchers in the field of HRI that the development of social robotics is a delicate endeavor.

Moreover, we systematically investigated idle motions. One could argue against the use of idle motions, since the other interactions portraying meaningful motions seem to have the same or—for some measures—a better effect. However we think that without idle motions, a robot loses opportunities to initiate interactions with humans. For example, in scenarios with social robots acting as companions or assistants, idle motions will give the owner an indication that the robot is enabled and available for communication.

We can conclude, however, that humans have a high susceptibility to agents that portray simple social cues, and by adding meaningful motions these effects seem to increase. This inspires the question: To what extent can real human interactions be replaced by social robots or other forms of social agents. Davy Levy (Levy, 2007) goes as far as to state that even intimate relationships could be achieved between man and machine because of our tendency to react socially towards machines. He suggests that when technology has reached the point of creating intimate relationships this will have far reaching social implications. This might be true (and time will surely tell) but we are convinced that the benefits social robots can provide will outweigh the negative implications made possible by increasingly natural human-robot interactions.
All in all, with this study we gained new insights regarding the social interaction between humans and robots. We argue that the social robot is an important stepping stone in robot research to further investigate concepts of artificial intelligence and artificial consciousness, and we hope that with this research we made some contribution to humankind’s endeavor to create “the illusion of life”.
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APPENDICES
Appendix A
Verbal Utterances

Listed below are the verbal utterances used during the experiment, and are split into the within condition they were used for. The order of the utterances was randomized within the condition.

**Baseline no-motion condition** (same between conditions)

| Utterance                                                                 |
|---------------------------------------------------------------------------|
| "Please take the white vase, and place it on the table."                  |
| "Please take the glass, and place it in the closet."                     |
| "Please take the remote control, and place it in the closet."           |
| "Please take the photo frame, and place it on the table."               |

**Idle motion Idle gaze**

| Utterance                                                                 |
|---------------------------------------------------------------------------|
| "Please take the clock, and place it on the table."                      |
| "Please take the candle, and place it on the table."                    |
| "Please take the telephone, and place it on the table."                 |
| "Please take the power adapter, and place it in the closet."           |

**Idle motion posture sway/shift**

| Utterance                                                                 |
|---------------------------------------------------------------------------|
| "Please take the instruction manual, and place it on the table."         |
| "Please take the fruit bowl, and place it on the table."                 |
| "Please take the white bowl, and place it in the closet."                |
| "Please take the glass, and place it in the closet."                    |

**Idle motion breathing**

| Utterance                                                                 |
|---------------------------------------------------------------------------|
| "Please take the green cup, and place it on the table."                  |
| "Please take the headphones, and place it in the closet."                |
| "Please take the book, and place it in the closet."                     |
| "Please take the yellow cup, and place it in the closet."               |
Meaningful motion deictic head gesture

"Please take the clock, and place it on the table."

"Please take the candle, and place it on the table."

"Please take the telephone, and place it on the table."

"Please take the power adapter, and place it in the closet."

Meaningful motion deictic point gesture

"Please take the instruction manual, and place it on the table."

"Please take the fruit bowl, and place it on the table."

"Please take the white bowl, and place it in the closet."

"Please take the glass, and place it in the closet."

Meaningful motion eye-contact/gaze

"Please take the green cup, and place it on the table."

"Please take the headphones, and place it in the closet."

"Please take the book, and place it in the closet."

"Please take the yellow cup, and place it in the closet."
Appendix B
Extended Godspeed Questionnaire

Participants were asked to please rate the traits presented below, on a scale from -2 (lowest) to 2 (highest, in regards to the extent that these describe the behavior of the robot Marvin during the trial. The extended Godspeed questionnaire dimensions have been added for clarity.

**Anthropomorphism:** The extent to which the robot is rated ‘human-like’.

| Trait           | -2 | -1 | 0  | 1  | 2  | Natural  |
|-----------------|----|----|----|----|----|----------|
| Fake            | -2 | -1 | 0  | 1  | 2  | Natural  |
| Machinelike     | -2 | -1 | 0  | 1  | 2  | Humanlike|
| Unconscious     | -2 | -1 | 0  | 1  | 2  | Conscious|
| Artificial      | -2 | -1 | 0  | 1  | 2  | Lifelike |
| Moving rigidly  | -2 | -1 | 0  | 1  | 2  | Moving elegantly |

**Animacy:** The extent to which the robot is rated ‘alive’.

| Trait         | -2 | -1 | 0  | 1  | 2  | Alive  |
|---------------|----|----|----|----|----|--------|
| Dead          | -2 | -1 | 0  | 1  | 2  | Alive  |
| Stagnant      | -2 | -1 | 0  | 1  | 2  | Lively |
| Mechanical    | -2 | -1 | 0  | 1  | 2  | Organic|
| Inert         | -2 | -1 | 0  | 1  | 2  | Interactive |
| Apathetic     | -2 | -1 | 0  | 1  | 2  | Responsive |

**Likability:** Impression participants have based on visual and vocal behavior of the robot.

| Trait            | -2 | -1 | 0  | 1  | 2  | Like  |
|------------------|----|----|----|----|----|------|
| Dislike          | -2 | -1 | 0  | 1  | 2  | Like  |
| Unfriendly       | -2 | -1 | 0  | 1  | 2  | Friendly|
| Unkind           | -2 | -1 | 0  | 1  | 2  | Kind |
| Unpleasant       | -2 | -1 | 0  | 1  | 2  | Pleasant |
| Awful            | -2 | -1 | 0  | 1  | 2  | Nice |
### Perceived Intelligence: How competent the robot is perceived as.

| Perceived Intelligence | Incompetent | Ignorant | Irresponsible | Unintelligent | Irrational |
|------------------------|-------------|----------|--------------|---------------|------------|
|                        | -2          | -1       | 0            | 1             | 2          |
| Competent              |             |          |              |               |            |
| Knowledgeable          |             |          |              |               |            |
| Responsible            |             |          |              |               |            |
| Intelligent            |             |          |              |               |            |
| Rational               |             |          |              |               |            |

### Social Intelligence: The extent to which the robot is rated socially competent and socially skilled.

| Social Intelligence    | Uncooperative | Unsupportive | Unpersuasive | Situation unaware |
|------------------------|---------------|--------------|--------------|------------------|
|                        | -2            | -1           | 0            | 1                |
| Cooperative            |               |              |              | 2                |
| Supportive             |               |              |              |                  |
| Persuasive             |               |              |              |                  |
| Situation aware        |               |              |              |                  |

### Emotion: The extent to which the robot is rated emotionally responsive.

| Emotion         | Apathetic | Insensitive | Emotionally unstable | Passive |
|-----------------|-----------|------------|----------------------|---------|
|                 | -2        | -1         | 0                    | 1       |
| Empathetic      |           |            |                      | 2       |
| Compassionate   |           |            |                      |         |
| Emotionally stable |         |            |                      |         |
| Active/Energetic|           |            |                      |         |
Appendix C
Open question & Demographics

Participants were asked the open question at the beginning of each questionnaire trial. The demographics were only asked at the end of the fourth trial.

Open question

What movement did the robot portray? : 

Demographics

On average, how many hours a day do you spend interacting with devices such as PC’s, laptops, tablets and smart phones

( <1 hour / 1-5 hours / 5-10 hours / >10 hours )

Do you have any personal experience with robots (including e.g., robotic toys like Furby and robotic appliances like vacuum cleaners)?

( Yes / No )

Gender: Male [ ] Female [ ]

Age: _ _ _