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Abstract Robots with an Attitude: Applying Interpersonal Relation Models to Human-Robot Interaction

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Abstract— **This paper explores new possibilities for social interaction between a human user and a robot with an abstract shape. The social interaction takes place by simulating behaviors such as submissiveness and dominance and analyzing the corresponding human reactions. We used an object that has no resemblance with human features in its shape or expression mode, in order to exclude the effect of these features on the human behavior. An intelligent walk-in closet was made to behave either dominantly or submissively using lighting effects. The behaviors of the closet were rated by participants using the Bem Sex Role Inventory in a pilot study, resulting in the selection of one submissive and one dominant lighting behavior for the closet. Participants' personality was measured using the Social Dominance Orientation questionnaire. These data were then compared to measurements of user satisfaction and feelings of dominance, arousal, and valence after scenario completion. A surprising effect was revealed as participants with a dominant personality reported feeling submissive to a dominant system, while in comparison, persons with a submissive personality felt more dominant in the same condition. Furthermore, it was found that a submissive system was generally more preferred by users. We draw a careful conclusion that people interact differently with systems that show human-like attitudes, than they would in response to similar attitude expressed by other person. These findings need to be investigated further with dominant/submissive nonverbal behaviors that are then simulated on a humanoid robot.**

I. Introduction

Robots at present are better equipped to communicate through movement than through spoken language. Even when the research on human spoken language emulation and understanding considerably improves, the contribution of the nonverbal cues in human to robot communication will convey irreplaceable information and affect the human to robot interaction.

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There has been a long, ongoing discussion of what social robots should look like, and if they need to resemble humans [1-4]. The ability of a robot to interact with humans, independently of its physical shape, is embedded in the ability to sense the context and the behavioral cues of their users and adapt to them in order to guarantee a seamless and optimal user experience [5]. In this sense, the current paper describes a study involving a robot not in its traditional, humanoid shape, but a much more abstract object which can sense the human state and react with behaviors that are perceived and named with human emotions and mental states.

Digital and electronic systems are often personified by means of ascribing human attributes to them; for example, a personality trait (e.g. a system can be described as “friendly” or “smart”) or a behavior (e.g. a system can be described as behaving erratically or being autonomous) [6]. Under the tendency to personify digital systems lies the assumption that such systems may, to a certain extent, function and communicate more efficiently with humans by acting like humans would. As previously shown by Heider and Simmel [7], and further explored for embodied objects in [8, 9], behaving shapes and objects are attributed with human emotions and personality. We would like to find out how this perception would influence human behavior, if the behaving object and the human are involved in a reciprocal interaction. We use a walk-in closet as behaving object. Since the closet can behave autonomously, but can also interpret the human behavior, and react accordingly [10], we rightfully name it as robot. In this particular study the closet does not analyze the human behavior automatically as it was done in [9-12]. This choice was made, since we aim to offer insights into whether, and to which extend, humans react to the behaviors of abstract or anthropomorphic robots in the same way that they would react to those of other individuals. In this setting, an automatic interpretation of human reaction is not bringing additional insights. However, having developed a feasible framework for automatic analysis of human movement [9-11], the current experiment will add to the design of natural nonverbal human-robot interaction.

We use the Interpersonal Behavior Circle (IBC) theory by Leary [13] to make the behavior of the closet realistic with respect to the interpersonal interaction scenarios. The IBC framework consists out of two axes: dominance-submission on the vertical axis and hate-love (affinity) on the horizontal axis. The theory states that if social interaction participant A behaves in a certain manner, this automatically provokes a complementary (opposite as described in IBC) attitude with the interacting participant B.

This paper is organized as follows: the next section discusses the model of interpersonal interaction that forms the basis for this study. Section III discusses the design of an intelligent walk-in closet with different lighting behaviors that are perceived either as submissive or dominant. This closet was used as our abstract robot entity for the purposes of the experiments featured in this paper. Section IV discusses a pilot user test that evaluates the effect of the designed behaviors on people, which we use in Section V to analyze the effect of the chosen dominant and submissive behaviors on individuals with different personalities. Section VI reports the results from the study, followed by a discussion in Section VII.

II. Models of Interpersonal Relationships Confined by the Abstract Robot Platform.

Assigning complex humanlike behaviors to very abstract robots is a challenging task that aims to bring a better understanding of our perception and reaction to emotions and mental attitudes. In particular, we isolate the effect of the behavior and exclude the influence of the shape on the perception of emotions and mental attitudes, as previously done in several experiments [7, 9]. Exchange of movement with dynamic lighting behavior can, to a certain extent, simulate perceived motion, but still this motion does not resemble human motion. In addition, lighting has been thoroughly researched as part of the ambient experience, especially in settings such as retail stores where the focus lies on how it affects consumer experience and behavior. Many of the studies performed in this direction are based on the theoretical model presented by Mehrabian-Russell, which states that there is a relationship between approach-avoidance behaviors and the arousal state elicited by changes in the lighting [14]. Furthermore, Summers and Hebert [15] have shown that light intensity influences the shopping behavior of consumers in a retail store. It was found, for instance, that increasing the contrast of illuminated products in a shop compared to the background luminance had a positive effect on the amount of items bought.

In order to predict the approach-avoidance behavior of a user in reaction to an ambient intelligent environment, the dominance-submissive axis of the interpersonal circumplex was used as a theoretical foundation [13, 16]. The interpersonal circumplex displays several variables measuring interpersonal relations as points in a circumference linked by axis. Each axis links two diametrically opposed variables, and variables situated opposite to each other are negatively related [13]. Carson [16] states that the behavior of a person tends to induce a complementary behavior from their counterpart. More specifically in the case of this study is that *dominant* behavior elicits *submissive* responses and vice versa. Markey [17] studied and validated this theory, based on the observational ratings of 158 participants interacting in different dyadic social situations. Tiedens and Fragale [18] studied complementarity (vs. mimicry) of dominant and submissive nonverbal behaviors by exposing participants to a confederate who displayed either a dominant or submissive posture and concluded that, generally, people tend to take a complementary posture. Additionally, when participants in this study took a complementary posture, they were more inclined to like the interaction partner than people who mimicked the confederate's posture. However, the law of attraction states that people prefer to interact with others with whom they share the same personality [19, 20]. The law of attraction was also found to be true when people interact with dominant or submissive systems [21]. This would suggest that dominant individuals prefer to be in the company of other persons with a dominant personality, and the same can be said for other personality traits, such as submissiveness. It appears that, although people in general prefer to interact with others similar in personality characteristics, when confronted to a strong dominant or submissive individual a complementary behavior is elicited.

III. Design of Lighting Behaviors on the Walk-in Closet Platform

To explore the interactions between a human and an everyday object that expresses behavior, the smart walk-in closet developed at the Eindhoven University of Technology [10] was used. The closet is equipped with sensors and a lighting system capable of responding to a user's movement by changing the way in which the light "behaves". The closet consists of a series of shelves attached to a wall (Figure 1). Each shelf holds two stacks of clothing, which can be illuminated by a series of 14 dimmable shelf lights and four ceiling spots.

The sensors that were implemented in the closet consist of 14 infra-red sensors that detect movement activity nearby each shelf and 48 pressure-sensors on the floor in front of the closet. These are used to detect the location of the user. All sensors are connected to a computer running MaxMSP, in which the different lighting behaviors were programmed.

To test whether individuals react to an ambient intelligent environment in a similar way as they would be expected to react to another individual, we situated them in the context of the walk-in-closet and asked them to perform different scenarios. In each case, the closet would adopt a different style of lighting behavior. We confirmed the closet's intended dominant or submissive behaviors during a pilot study where participants were asked to evaluate a set of five different lighting behaviors. In the main study, the reaction of the participants to the closet behavior was analyzed under the two frequent assumptions of interpersonal theory for predicting behavior during the social interactions, as discussed earlier.

It was expected that the congruent condition (similar personality-lighting condition) would result in a higher self-reported liking of the system compared to the incongruent condition. With respect to the behavioral reaction towards the walk-in closet, it was expected that participants would report themselves as feeling more submissive in reaction to the dominant lighting state and more dominant when the lighting state was showing submissive behavior.

Fig. 1. Overview of the walk-in closet's design with ceiling spots to lighten the overall environment, and shelf lights that are used to express the system's behavior. Pressure sensors under the carpet track the user's general location, whereas infrared sensors are able to recognize hand movements nearby each shelf.

Most previous research in the field of lighting design and its influence on human behavior addresses static lighting conditions [22, 23]. Behaviors are in essence not static but a sequence of actions. In terms of lighting patterns, a behavior may be simulated through the illusion of motion achieved by flashing lights in rapid succession (ideally below 200ms). This is known as apparent motion [22]. In this experiment, we used apparent motion to simulate behaviors.

The lights in the closet were manipulated along the following dimensions: brightness, intermittence, speed of the lights reaching a certain brightness-state, and reactions to sensors. The design of the lighting behaviors were based on the use of cues that visualize the message of social inequality as found by Schwartz, Tesser & Powell [24]. According to these authors, dominant and submissive cues are analogous to being in the foreground compared to being in the background with regard to space and time.

Spatially, this opposition refers to objects (or characters) in the foreground in a representation being regarded as more visible in contrast to objects in the background. Temporally, this opposition refers to objects preceding in time as being interpreted as more relevant than those relegated to a second or following role. In the lighting behaviors we designed, the spatial opposition foreground-background equates to brighter-dimmer, and the temporal opposition equates to a light that is guiding, in contrast to a light that follows.

A neutral control condition was designed so that all lights in the closet were activated in a static state on medium settings. For the other lighting behaviors, the four ceiling spots were kept activated at all times in a static state on medium settings. The following section discusses which lighting behaviors were selected for the main study, during a pilot evaluation.

IV. Pilot Study: Selection of Lighting Behaviors

Initially, five different lighting behaviors were designed for the closet. To limit the number of comparisons and confirm our designs of *dominant* and *submissive* lighting behaviors, a pilot study was conducted where participants rated the behaviors using the dominance-loaded masculinity scale subset of the Bem Sex Role Inventory (BSRI) [25] and adjusted it to evaluate the system. This scale was used to measure the dominance of the abstract robotic system.

A. Lighting Behaviors: Neutral, Dominant, and Submissive

In the neutral condition, all lights in the closet were activated in a static state on medium settings. For the other four lighting behaviors, the four ceiling spots were kept activated at all times in a static state on medium settings. The closet's lighting behaviors consisted only of manipulations of the shelf lights.

The first submissive lighting condition only activates shelf lights when the user is located nearby this specific shelf. The closer the user is to the shelf, the brighter that shelf will be illuminated. This has the effect of the closet following the user's actions (figure 2). The second submissive lighting condition only follows the user's movement in one dimension: all shelf lights are activated at all times, but will be in a dim state when the user is close to the closet, and shine brighter when the user is further away from the wall. This results in a behavior that makes the closet reduce its lighting output and take in less visual space, therefore having the effect of making way for the approaching user.

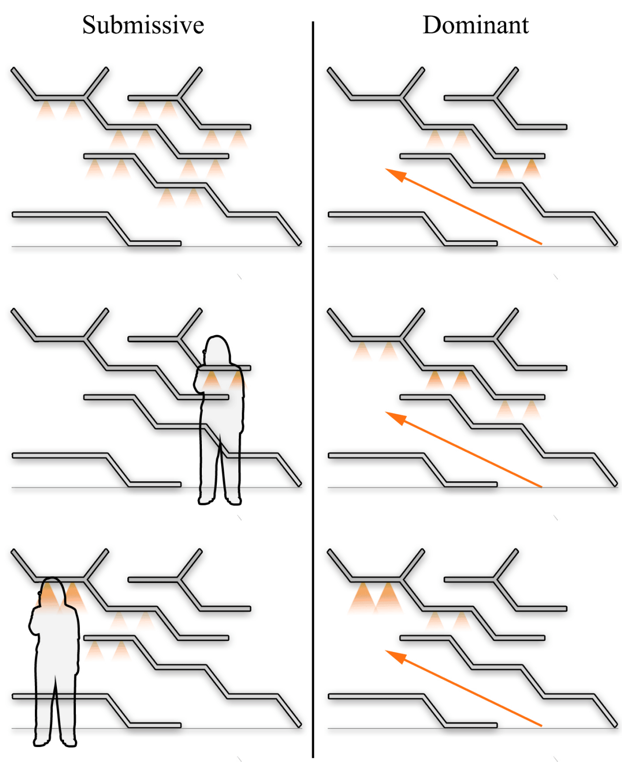

Fig. 2. Schematic overview of the two lighting behaviors selected for the *main* study. The first submissive lighting condition (left) illuminates shelves closest to the user, seeming to follow the user's movements in the closet. The

second dominant lighting condition (right) directs the user towards a specific shelf by using a sequential flickering of lights.

The first dominant lighting behavior is the exact opposite of the last submissive lighting behavior as discussed above. Instead of occupying less visual space when the user comes closer to the system, it will increase in luminance the closer the user approaches. The second dominant lighting condition does not make use of the floor sensors. Instead, it tries to direct the user's attention to a certain shelf flashing on and off a series of lights that move from one shelf to another. Once the flashes have arrived at the desired shelf, the light of this shelf will continue blinking for five more on/off flashes until the same sequence starts again. The system will detect if the user has moved towards this chosen shelf and, if so, will choose a different shelf to direct the user to. This effect results in a lighting behavior that, at all times, tries to direct the user's attention to a different shelf than where they are at the moment (figure 2).

B. *Design of the Scenarios*

Participants were asked to complete a scenario in the walk-in closet. These scenarios were played out in one of the experimental conditions. The introduction of the scenarios is quoted in the text below. Each scenario asked users to complete three tasks: to find a particular item of clothing. The type of clothing was changed per scenario and was also slightly different for female or male participants due to specific types of clothing that are more applicable for one gender.

"*It is a Saturday afternoon and you are shopping for some clothes. You're in no rush so you take all the time you need to try out the new clothing store, since you heard that they also sell clothes now. While walking around you happen to see some shelves that caught your attention. You are looking for the following items, take the one you like most: a short pants, a sweater, a sports polo.*"

C. *Participants and Procedure*

Five participants evaluated the candidate lighting behaviors for the walk-in closet (3 females and 2 males, ages ranged between 24-29). All participants were trainees of the User-System Interaction program at the Eindhoven University of Technology. As with the main study, participants were told that a popular furniture store was planning to start in the retail clothing market, and that we therefore were designing a walk-in closet as a new shopping experience. After completing the study, they were asked if they understood what the study was about. None of the participants were aware that the experiment involved personality (dominance vs. submissiveness) and mostly mentioned goals associated with sales of clothing, and the design of the walk-in closet environment.

Participants were first introduced to the experiment and completed a consent form. They were then asked to complete five scenarios in the walk-in closet.

The first scenario started with the walk-in closet in the neutral condition (static lighting of all shelves). Following this, the order of the experimental lighting conditions was counter-balanced. After each scenario, participants were asked to complete the adjusted BSRI questionnaire to measure how they perceived the interaction with the closet.

D. *Selecting Lighting Behaviors: Results and Discussion*

Four different lighting behaviors of the walk-in closet were evaluated in the pilot study: two of which were designed to be perceived as submissive, and the other two to be perceived as dominant lighting behaviors. A repeated measures ANOVA over the data of the five participants gave no significant results ($F(4, 16) = 1.149$, $P = 0.369$). However, when we visualize the data, a strong indication of an effect can be seen for the second *dominant* lighting behavior (see figure 3).

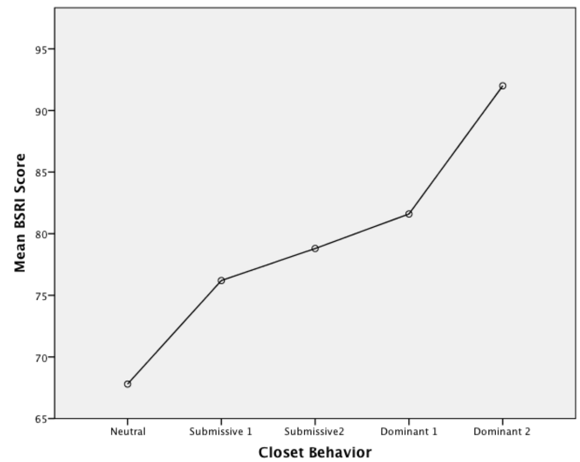

Fig. 3. Pilot study: mean BSRI scores indicating perceived dominance of the system for each lighting behavior (1 – 5: *neutral, submissive 1, submissive 2, dominant 1, dominant 2*). Higher scores indicate the system being perceived as more dominant.

Using post-hoc contrast analysis, it is clear that the second dominant lighting behavior with directed light and flickering effects (condition 5) is perceived by participants to be different from the others in general. This was concluded by comparing each condition individually with the mean results of all conditions ($F(1, 4) = 8.047$, $P = 0.047$). Therefore, this *dominant* lighting behavior was selected for the purposes of our main study. As no clear difference was found comparing the other three non-static behaviors, a choice was made for the first *submissive* behavior that was perceived to be *following* the user's actions. While this design is not statistically distinctive from the other submissive condition, its design is a logical opposite of the selected dominant condition: where the selected dominant lighting effects are *directing* the user's attention towards a pre-selected closet shelf, the selected complementary submissive behavior *follows* the user's action, lighting the shelves that are nearest to the user. Additionally, of the two submissive designs, it is the one that corresponds most with theories on cues of submissive behavior [26].

V. Main Study: Methods

Using the results of the pilot study, the two most convincing lighting behaviors, one *dominant*, and one *submissive*, were selected as experimental conditions for the main study. The behavior of these lighting conditions is illustrated in a sequence of images (figure 2). A full description of these lighting designs is given in the pilot study section of this paper.

A. Participants

A total of 19 participants (nine female and 10 male) were recruited on the Eindhoven University of Technology campus. Their ages ranged from 17 to 33. A small incentive in the form of a five-euro gift voucher was given upon completion of the study.

B. Procedure

Participants were told that we aim to gain insight into new shopping experiences. After completing the initial forms and questionnaires, participants were introduced to one scenario at a time (scenarios in the main study are similar to the ones discussed under the pilot study section). This scenario determines the tasks they had to perform while in the walk-in closet. During scenario completion, participants were exposed to one of the three experimental conditions: the first scenario would always take place in the neutral control condition, whereas the second and the third conditions were counter-balanced across participants in the study to control for carryover effects. Upon completing a scenario, participants were asked to complete the questionnaires. The experiment concluded with a short debriefing.

Measurements

The Social Dominance Orientation (SDO) questionnaire [27] was used to determine to which extent a person has a dominant or submissive personality. Although this scale defines no clear cut-off between personality types, the outcome of the questionnaire provides insight in the dominant or submissive tendency of every participant. Participants' feelings of dominance, arousal and valence were measured using the Self-Assessment Manikin (SAM) [28], scoring ranged from 1 (submissive, not aroused, or sad) to 9 (dominant, aroused, and happy). To measure satisfaction, we administered the User Interface Satisfaction (UIS) inventory [29].

VI. Results

A. Feelings of Dominance

Our hypothesis considers personality to have a moderating effect on user's reactions to the closet's behavior, as according to the theories of interpersonal behavior discussed in the introduction. While personality does seem to play a role, our analysis show contradictory predictions for participants' reactions: those with a submissive personality felt more *dominant* in reaction to the dominant lighting, whereas dominant participants felt more *submissive* in that same condition (figure 4). A simple linear regression reveals this effect: SAM Dominance Score = -.098 * SDO Score + 0.000, R^2=0.306, p = 0.011.

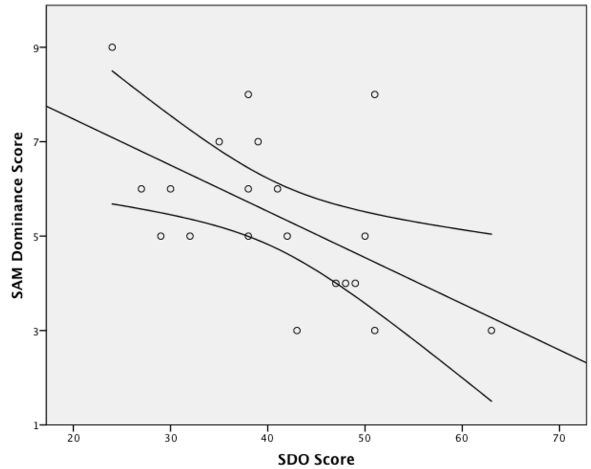

Fig. 4. Feeling of dominance (SAM: higher score = feeling more dominant) as a function of personality (SDO: higher score = more dominant personality). The plot shows the regression line SAM Dominance Score = -.098 * SDO Score + 0.000. Additional lines indicate the 95% confidence interval for the mean. SDO score is a significant predictor for participants' feeling of dominance while interacting with the dominant closet. The peculiar finding here is that more dominant participants felt more submissive, compared to more submissive participants, who felt more dominant. This effect is not found for the closet running either the submissive or neutral lighting behavior.

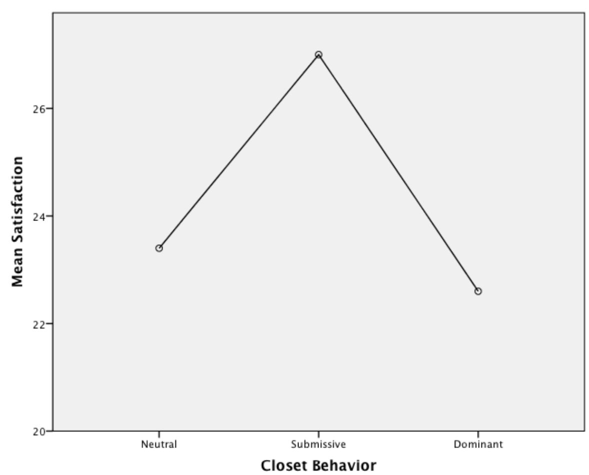

Fig. 5. Satisfaction scores for each lighting condition. Participants preferred the submissive lighting behavior (2) of the walk-in closet.

B. User Preference for a Submissive Closet

The level of satisfaction and arousal was measured per participant for each condition. A repeated measures ANOVA of the user satisfaction data resulted in a main effect which approaches significance ($F(2, 38) = 2.734$, $P = 0.078$). Post-hoc tests of main effects using the Bonferroni correction reveals that participants were more satisfied with the submissive lighting condition than the dominant one ($P = 0.046$). But no statistical difference could be found between satisfaction with the neutral and submissive condition (P = 0.391). Figure 5 displays the

With similar method of analysis, the arousal measurements data resulted in a significant main effect of condition ($F(2, 38) = 3.464$, P = 0.041). Post-hoc pairwise comparisons of main effects using the Bonferroni correction indicate that there is a significant effect when comparing the *dominant* lighting behavior with the *neutral* lighting condition (P = 0.026, see figure 6).

These results reveal that participants in general preferred the closet when it exhibited the submissive, or neutral lighting behavior.

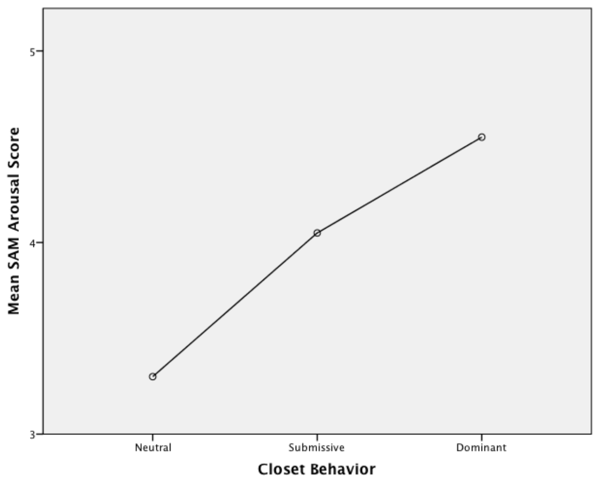

Fig. 6. Arousal scores for the dominant lighting behavior (3) were highest and significant when compared to the neutral condition (1).

VII. Discussion

A. *Feelings of Dominance*

When looking back at Carson's theory for complementary behavior in interpersonal relations, our findings seem paradoxical. When interacting with someone more dominant, one is expected to assume a submissive position and vice versa [10]. This is indeed true when we look at the more *dominant* participants in this study, who felt more submissive when presented with a dominant entity (in the dominant lighting condition). However, the opposite is true for *submissive* participants, who actually felt more dominant as a reaction to the same entity.

While generally people with *submissive* personalities tend to assume a more *submissive* position in human-to-human interaction, the results that we obtained contradict what interpersonal relation theories predict in that they do not seem willing to complement to a system exerting such behavior. The paradox is that our findings for the *dominant* participants do not contradict such theories: in the same condition these participants *do* complement to the dominant system and feel more submissive towards it, thus conforming to behavior as predicted by the aforementioned theories.

Because this is such a contradictory finding, our team has discussed other available explanations for this effect. One issue could be the measurement of feelings of dominance using the SAM, which is mentioned to have a weak independent effect [30]. Naturally, submissive persons are more comfortable *following* others (in this study: the closet entity) and therefore having less of a problem with the dominant lighting behavior, whereas dominant people preferred not to interact with a dominant system. Drawing this conclusion, however, implies that the SAM dominance scale has measured preference or liking instead of feelings of dominance. Moreover, such a conclusion would still contradict the law of attraction [19, 20] which states that people prefer to interact with others that have similar personality traits.

Due to the short period of time and the limited amount of participants we included for the pilot study, the design of the lighting effects of the closet were only partially confirmed. Just the dominant lighting behavior showed a clear difference compared to the other behaviors. Therefore, we should be careful with drawing conclusions concerning reactions to the *personality* of the closet.

More evidence is necessary before we can draw any firm conclusions regarding anthropomorphizing electronic systems and people's experience interacting with them. However, this study shows that designing behaviors for technological systems might not be as easy as borrowing from theories of human communication. Designers should be cautious about assuming such effects until we can clearly indicate that these theories are transferable to the human-system interaction domain. It will be interesting to compare how the anthropomorphism of the system (i.e. using a humanoid robot together with a very abstract system with sensory, motor and decision making skills can influence human response behavior to expressed feelings and attitudes by an artificial system. With this first collection of results, we may have uncovered just the tip of the iceberg of the differences to be found in this area of research.

B. *User Preference for Submissive systems*

Our results also indicate that participants preferred the closet when it exhibited submissive behavior. People did not like the dominant closet and they got more *aroused* over this behavior. One way of looking at this finding is as it is an effect of the user's loss of control. It has been shown before that users generally prefer to have control over systems [31]. In informal post-experimental interviews, many participants reported to find the flickering of lights an unpleasant way of trying to draw one's attention. Because of this last note, it may also be possible that it is the method of drawing one's attention that makes participants dislike the behavior. The use of a different design for the dominant lighting behavior, or a comparison between different dominant lighting behaviors, would be able to provide more insights into the cause of this preference.

In the current study, we were unable to find a statistical difference between the neutral and the submissive lighting condition. As this is an artifact of the selection of lighting effects in the pilot study, we may not yet conclude that submissive lighting behavior is similar to (neutral), constant lighting.

VIII. Conclusions and Future Work

The aim of the present study was to explore if individuals react to the behaviors of an artificial intelligent system in the same way that they would react to other individuals. We based our experiments on the dominance/submissive axis of the interpersonal circumplex, both in terms of evaluating the users' liking of the system and their feelings of dominance or submissiveness in reaction to it [26].

This research reveals effects that are interesting for both research and practical applications that range from the use of robots in social communication to creating an ambience that is pleasurable and inviting for humans to interact with. Our approach of evaluating a closet that shows dominant versus submissive behavior using embedded lighting installations indicate that people prefer a system that displays calm and possibly submissive behavior, over a dominating one.

In addition to this, the results of these studies indicate that personality of the user may have a moderating effect on how they react to a robotic system with either dominant or submissive behavior. What is most interesting about this fact is that reactions to the closet are different than predicted by human-human interaction models of communication. The results as discussed in this paper should make us aware about being cautious when applying human-like behaviors into the design of systems: electronic systems may receive different types of reactions than as expected from theories of interpersonal communication.

The next step to be taken is to collect more evidence of the contradicting effect found for dominant users on dominant behavior of a system. Other systems with dominant behavior designed differently, with different levels of anthropomorphism will have to be evaluated. Moreover, the authors of this paper have started exploring objective ways of measuring the state of participants while exposed to the system. Using Laban Movement Analysis (LMA) [9, 11], we aim to further investigate the qualitative aspects of human reaction, and also to design the expressivity of abstract robotic systems in a more natural way. Expressive behavior is particularly well suited for LMA-based design.

The purpose of this paper is to spark discussion about our unusual findings and inspire new directions of research for designing abstract robotic systems with human-like behaviors. Additionally, the second part of the study reveals users' preference for a calm system.

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